SEL-351-5, -6, -7

Protection System

Instruction Manual

20250909

SEL SCHWEITZER ENGINEERING LABORATORIES

Part Number: PM351-06

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Preface

Manual Overview

The SEL-351-5, -6, -7 Instruction Manual describes common aspects of protection relay application and use. It includes the necessary information to install, set, test, and operate the relay and more detailed information about settings and commands.

An overview of each manual section and topics follows:

Preface. Describes the manual organization and conventions used to present information.

Section 1: Introduction and Specifications. Describes the basic features and functions of the SEL-351, lists the relay specifications.

Section 2: Installation. Describes how to mount and wire the SEL-351, illustrates wiring connections for various applications, describes operation of current board jumpers, and depicts relay front and rear panels.

Section 3: Overcurrent, Harmonic Blocking, Voltage, Synchronism Check, Frequency, and Power Elements. Describes the operation of the instantaneous/definite-time overcurrent elements (phase, neutral ground, residual ground, and negative sequence), time-overcurrent elements (phase, neutral ground, residual ground, and negative sequence), voltage elements (single-phase, phase-to-phase, etc.), synchronism-check elements, frequency elements, power elements (in Firmware Version 7), and voltage sag/swell/interruption elements (in Firmware Version 7).

Section 4: Loss-of-Potential, Load-Encroachment, and Directional Element Logic. Describes the operation of loss-of-potential logic and its effect on directional elements; load-encroachment logic and its application to phase overcurrent elements; voltage-polarized and current-polarized directional elements, including directional control for low-impedance grounded, Petersen Coil-grounded, and ungrounded/high-impedance grounded systems; Best Choice Ground Directional Element logic and automatic settings.

Section 5: Trip and Target Logic. Describes the operation of general trip logic, qualified trip logic, switch-onto-fault trip logic, communications-assisted trip logic, breaker failure, and front-panel target LEDs.

Section 6: Close and Reclose Logic. Describes the close logic operation for automatic reclosures and other close conditions (e.g., manual close initiation via serial port or optoisolated inputs).

Section 7: Inputs, Outputs, Timers, and Other Control Logic. Describes the operation of optoisolated inputs IN101–IN106 and IN201–IN216, local control switches (local bit outputs LB1–LB16), remote control switches (remote bit outputs RB1–RB32), latch control switches (latch bit outputs LT1–LT16), multiple setting groups (six available), programmable timers (timer outputs SV1T–SV16T), output contacts OUT101–OUT107 and ALARM and OUT201–OUT212, and rotating default displays.

Section 8: Breaker Monitor, Metering, and Load Profile Functions. Describes the operation of the breaker monitor, station battery monitor, instantaneous metering, phantom metering for single-phase voltage connections; demand, energy, maximum/minimum, and synchrophasor metering; and load profile reporting (in Firmware Versions 6 and 7).

Section 9: Setting the Relay. Explains how to enter settings and also contains the following setting reference information:

- ➤ Time-overcurrent curves (5 U.S. and 5 IEC curves)
- ➤ Settings Sheets for general relay, SELOGIC control equation, Global, SER, text label, and port settings

The *SEL-351-5, -6, -7 Relay Settings Sheets* can be photocopied and filled out to set the SEL-351.

Section 10: Communications. Describes serial, Ethernet, and USB communications, port connector pinout/terminal functions, communications cables, communications protocols, and ASCII commands.

See **SHO** ***(Show/View Settings)*** on page 10.68 for a list of the *factory default settings* for the SEL-351.

SEL-351-5, -6, -7 Command Summary. Briefly describes the serial port commands that are described in detail in *Section 10: Communications*.

Section 11: Front-Panel Interface. Describes the front-panel operation of pushbuttons and their correspondence to ASCII commands, local control switches (local bit outputs LB1–LB16), and rotating displays.

Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER.

Describes standard 15-, 30-, and 60-cycle event reports, sequential events recorder (SER) report, and voltage sag/swell/interruption (SSI) report (in Firmware Version 7).

Section 13: Testing and Troubleshooting. Describes general testing philosophy, methods, and tools and relay self-tests and troubleshooting.

Appendices.

- ➤ *Appendix A: Firmware, ICD, and Manual Versions*
- ➤ *Appendix B: Firmware Upgrade Instructions for SEL-351 Relays With Ethernet*
- ➤ *Appendix C: PC Software*
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- ➤ *Appendix O: Modbus RTU and TCP Communications*

- *Appendix P: IEC 61850*
- *Appendix Q: Cybersecurity Features*
- *Appendix R: Fault Location and Supplemental Fault Location and Impedance Data*

SEL-351-5, -6, -7 Command Summary. Summarizes the serial port commands that are fully described in *Section 10: Communications*.

Safety Information

Dangers, Warnings, and Cautions

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

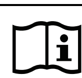
⚠**DANGER**
Indicates an imminently hazardous situation that, if not avoided, **will** result in death or serious injury.

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

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

Safety Symbols

The following symbols are often marked on SEL products.

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

Safety Marks

The following statements apply to this device.

General Safety Marks

⚠WARNING More than one live circuit. See diagram.	⚠AVERTISSEMENT Plus d'un circuit est sous tension. Voir schema.

B300 Relay Code			
Maximum Current [A] Courant Maximal [A]			
120 V		240 V	
Make	Break	Make	Break
30	3	15	1.5

⚠CAUTION There is danger of explosion if the battery is incorrectly replaced. Replace only with Rayovac no. BR2335 or equivalent recommended by manufacturer. See Owner's Manual for safety instructions. The battery used in this device may present a fire or chemical burn hazard if mistreated. Do not recharge, disassemble, heat above 100°C, or incinerate. Dispose of used batteries according to the manufacturer's instructions. Keep battery out of reach of children.	⚠ATTENTION Une pile remplacée incorrectement pose des risques d'explosion. Remplacez seulement avec un Rayovac no BR2335 ou un produit équivalent recommandé par le fabricant. Voir le guide d'utilisateur pour les instructions de sécurité. La pile utilisée dans cet appareil peut présenter un risque d'incendie ou de brûlure chimique si vous en faites mauvais usage. Ne pas recharger, démonter, chauffer à plus de 100°C ou incinérer. Éliminez les vieilles piles suivant les instructions du fabricant. Gardez la pile hors de la portée des enfants.
⚠CAUTION To ensure proper safety and operation, the equipment ratings, installation instructions, and operating instructions must be checked before commissioning or maintenance of the equipment. The integrity of any protective conductor connection must be checked before carrying out any other actions. It is the responsibility of the user to ensure that the equipment is installed, operated, and used for its intended function in the manner specified in this manual. If misused, any safety protection provided by the equipment may be impaired.	⚠ATTENTION Pour assurer la sécurité et le bon fonctionnement, il faut vérifier les classements d'équipement ainsi que les instructions d'installation et d'opération avant la mise en service ou l'entretien de l'équipement. Il faut vérifier l'intégrité de toute connexion de conducteur de protection avant de réaliser d'autres actions. L'utilisateur est responsable d'assurer l'installation, l'opération et l'utilisation de l'équipement pour la fonction prévue et de la manière indiquée dans ce manuel. Une mauvaise utilisation pourrait diminuer toute protection de sécurité fournie par l'équipement.
Connectors for input and supply must have overcurrent protection of 15 A maximum. Provide a 14 AWG copper ground conductor.	Les connecteurs d'entrée et d'alimentation doivent avoir la protection de surintensité de 15 A maximal. Utilisez un conducteur de mise à la terre en cuivre de calibre 14 AWG.
For use in Pollution Degree 2 environment.	Pour l'utilisation dans un environnement de Degré de Pollution 2.
For use on a flat surface of a Type 1 enclosure.	Destiné à l'utilisation sur une surface plane d'un boîtier de Type 1
Terminal Ratings Wire Material Use copper supply wires suitable for 75°C (167°F). Tightening Torque Serial Port 1: 0.6–0.8 Nm (5–7 in-lb) A Terminal Blocks: 0.8 Nm (7 in-lb) B Terminal Blocks: 0.8 Nm (7 in-lb) Z Terminal Blocks: 0.8 Nm (7 in-lb)	Spécifications des bornes Type de filage Utilisez des fils d'alimentation en cuivre appropriés pour 75°C (167°F). Couple de serrage Port Série 1 : 0.,6–0,8 Nm (5–7 livres-pouce) Borniers A : 0,8 Nm (7 livres-pouce) Borniers B : 0,8 Nm (7 livres-pouce) Borniers Z : 0,8 Nm (7 livres-pouce)
AC Voltage Inputs: 250 Vac rms continuous (UL).	Entrées de tension CA : 250 Vca rms continus (UL).

Other Safety Marks (Sheet 1 of 2)

⚠DANGER Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.	⚠DANGER Débrancher tous les raccordements externes avant d'ouvrir cet appareil. Tout contact avec des tensions ou courants internes à l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠DANGER Contact with instrument terminals can cause electrical shock that can result in injury or death.	⚠DANGER Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.

Other Safety Marks (Sheet 2 of 2)

⚠DANGER Removal of relay front panel exposes circuitry which may cause electrical shock that can result in injury or death.	⚠DANGER Le contact avec les bornes de l'instrument peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠WARNING Before working on a CT circuit, first apply a short to the secondary winding of the CT.	⚠AVERTISSEMENT Avant de travailler sur un circuit TC, placez d'abord un court-circuit sur l'enroulement secondaire du TC.
⚠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 accès non-autorisé á l'équipement peut être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accès non-autorisé.
⚠WARNING SEL-351 Relay features such as Synchronism Check do not supervise the auxiliary close pushbutton.	⚠AVERTISSEMENT Les caractéristiques du relais SEL-351 telles que la VERIFICATION DE SYNCHRONISME ne supervisent pas le bouton-poussoir auxiliaire de fermeture.
⚠CAUTION The relay contains devices sensitive to Electrostatic Discharge (ESD). When working on the relay with the front panel removed, work surfaces and personnel must be properly grounded or equipment damage may result.	⚠ATTENTION Le relais contient des pièces sensibles aux décharges électrostatiques. Quand on travaille sur le relais avec les panneaux avant ou du dessus enlevés, toutes les surfaces et le personnel doivent être mis à la terre convenablement pour éviter les dommages à l'équipement.
⚠CAUTION Looking into optical connections, fiber ends, or bulkhead connections can result in hazardous radiation exposure.	⚠ATTENTION Regarder vers les connecteurs optiques, les extrémités des fibres oules connecteurs de cloison peut entraîner une exposition à des rayonnements dangereux.
⚠CAUTION Never apply voltage signals greater than 9 V peak-peak to the low-level test interface (J10) or equipment damage may result.	⚠ATTENTION Au risque de causer des dommages à l'équipement, ne jamais appliquer un signal de tension supérieur à 9 V crête à crête à l'interface de test de bas niveau (J10).
⚠CAUTION On models with auxiliary trip/close pushbuttons, the front-panel breaker LED default labeling matches the rear-panel labeling. If the front-panel breaker LED **CLOSED** and **OPEN** labeling is changed, the front-panel breaker labeling will no longer match the rear-panel breaker labeling.	⚠ATTENTION Sur les modèles avec bouton-poussoirs auxilaires ouverture/fermeture, l'étiquette par défaut du voyant lumineux (LED) du disjoncteur correspond à l'étiquette du panneau arrière. Si l'étiquette du disjoncteur du panneau avant **FERMÉ** et **OUVERT** est changée, l'étiquette du disjoncteur sur le panneau avant ne correspondra plus à l'étiquette du disjoncteur sur le panneau arrière.

LED Safety Warnings and Precautions:

- Do not look into the end of an optical cable connected to an optical output.
- Do not look into the fiber ports/connectors.
- Do not perform any procedures or adjustments that are not described in this manual.
- During installation, maintenance, or testing of the optical ports only use test equipment classified as Class 1 laser products.
- Incorporated components such as transceivers and laser/LED emitters are not user serviceable. Units must be returned to SEL for repair or replacement.

General Information

Typographic Conventions

There are three ways to communicate with the SEL-351:

- ➤ Using a command line interface on 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 typed at a command line interface on a PC.
<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.
MAIN > METER	Relay front-panel LCD menus and relay responses visible on the PC screen. The > character indicates submenus.
SELOGIC Control Equations	SEL trademarks and registered trademarks contain the appropriate symbol on first reference in a section. In the *SEL-351 Instruction Manual*, certain SEL trademarks appear in small caps. These include SELOGIC control equations.
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-351. 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-351.

Wire Sizes and Insulation

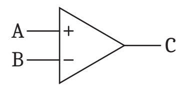
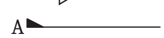
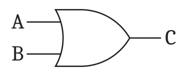
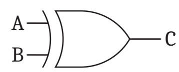
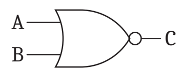
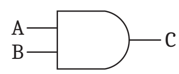
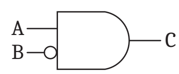
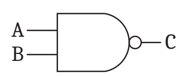
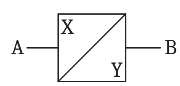
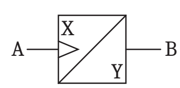
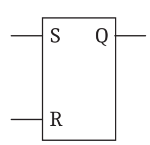
Wire sizes for grounding (earthing), current, voltage, and contact connections are dictated by the terminal blocks and expected load currents. You can use the following table as a guide in selecting wire sizes.

Connection Type	Wire Size		Insulation Voltage
	Minimum	Maximum	
Grounding (Earthing)	18 AWG (0.80 mm^2)	14 AWG (2.10 mm^2)	300 V min
Current	16 AWG (1.30 mm^2)	12 AWG (3.30 mm^2)	300 V min
Potential (Voltage)	18 AWG (0.80 mm^2)	14 AWG (2.10 mm^2)	300 V min

Connection Type	Wire Size		Insulation Voltage
	Minimum	Maximum	
Contact I/O	18 AWG (0.80 mm^2)	14 AWG (2.10 mm^2)	300 V min
Other	18 AWG (0.80 mm^2)	14 AWG (2.10 mm^2)	300 V min

Logic Diagrams

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

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

Trademarks

All brand or product names appearing in this document are the trademark or registered trademark of their respective holders. No SEL trademarks may be used without written permission.

SEL trademarks appearing in this manual are shown in the following table.

ACSELERATOR Analytic Assistant®	MIRRORED BITS®
ACSELERATOR Architect®	SafeLock®
ACSELERATOR QuickSet®	SEL-2407®
ACSELERATOR TEAM®	SELBOOT
Best Choice Ground Directional Element®	SELOGIC®
Compass®	SYNCHROWAVE®

Technical Support

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

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SECTION 1

Introduction and Specifications

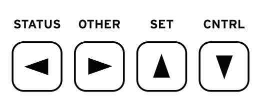
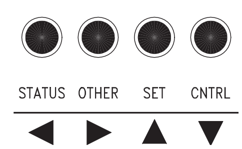
This section includes the following overviews of the SEL-351 Relay:

- *SEL-351 Models* on page 1.1
- *Applications* on page 1.3
- *Specifications* on page 1.4

SEL-351 Models

This instruction manual covers the SEL-351 models with screw terminal blocks introduced in 2009. *Table 1.1* describes distinguishing features of products covered and not covered by this manual. Use any row of the table to distinguish between relays covered and not covered by this manual.

Table 1.1 SEL-351 Models

Distinguishing Feature	**SEL-351 Relays Covered by This Instruction Manual**	**SEL-351 Relays Not Covered by This Instruction Manual**
Product Name	SEL-351 Protection System	SEL-351 Directional Overcurrent Relay, Reclosing Relay, Fault Locator, SELOGIC Control Equations
Model Number[a]	0351*nm* (where *n* = 5, 6, 7 and *m* = 2–9)	0351*nm* (where *n* = 5, 6, 7 and *m* = 0, 1)
Menu Navigation Pushbuttons	Square with arrows inside buttons 	Round with arrows outside buttons 
Ethernet Port(s) on Rear Panel	Yes	No
BNC Connector on Rear Panel	Yes	No
OUT101 and OUT102 Polarity Indicators on Rear Panel	Yes	No

[a] The model numbers used in this table are derived from the SEL-351 ordering information sheets. These numbers should not be used to order an SEL-351. To order an SEL-351, refer to the actual ordering information sheets.

The SEL-351 can be ordered as a horizontal rack mount, horizontal or vertical panel mount, or horizontal projection panel mount (see *Figure 2.2–Figure 2.6*). Standard models come with six optoisolated inputs and eight output contacts. Extra I/O boards can be ordered on any 3U chassis SEL-351 model.

Any SEL-351 model can be ordered with the more sensitive neutral channel (IN) current input options (0.2 A or 0.05 A nominal). *Table 4.4* and accompanying note show the particular ground directional elements available with different options of the neutral channel (IN) current input. The 0.05 A nominal neutral channel (IN) current input option is a legacy nondirectional sensitive earth fault

(SEF) option. The 0.2 A nominal neutral channel (IN) current input option can provide the same SEF function and additional directional options, as detailed in *Table 4.4*.

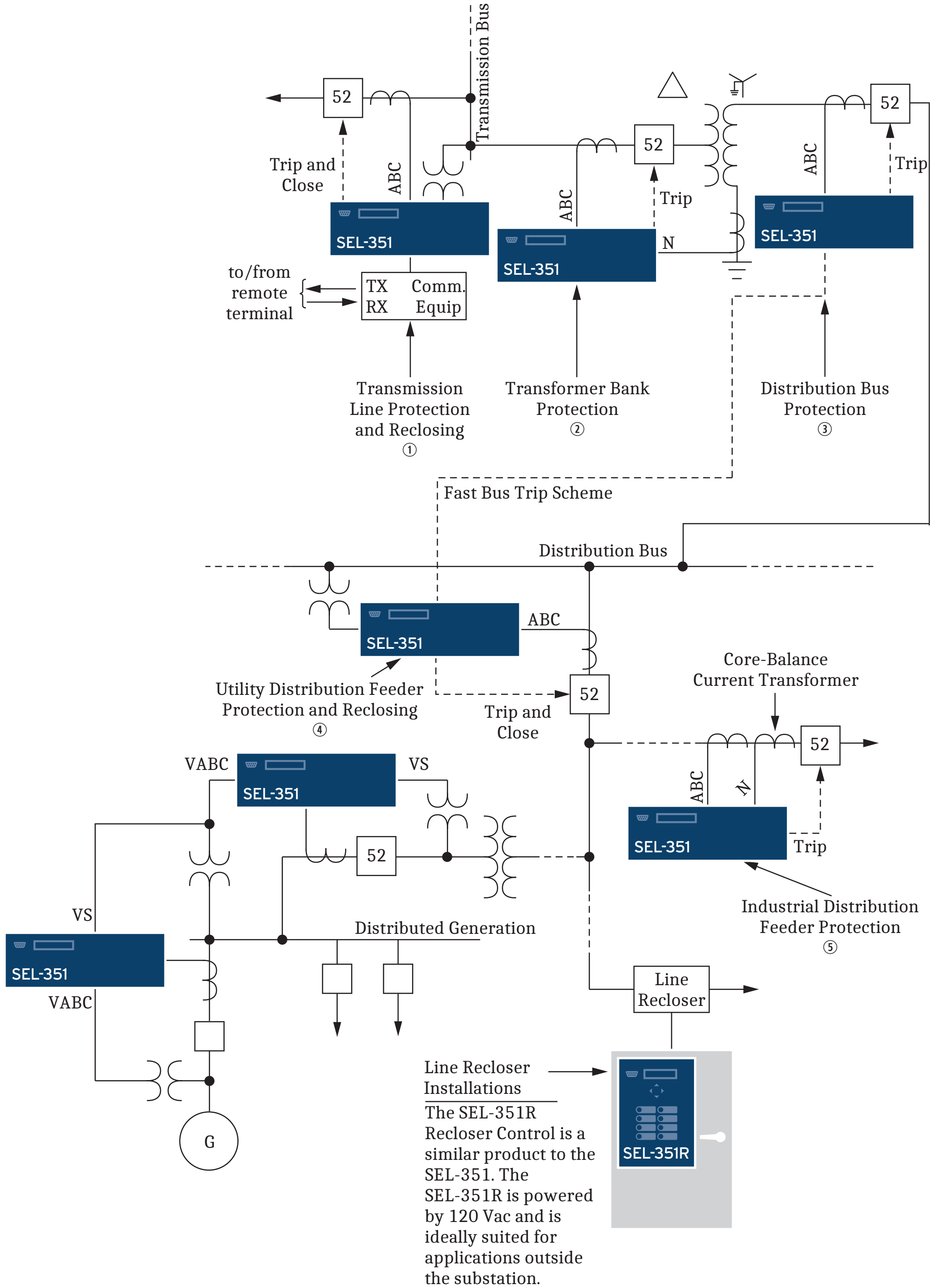
Table 1.2 SEL-351 Firmware Versions

Model Number	Firmware Version	Relay Features
03515	5	Basic features.
03516[a]	6	Standard with MIRRORED BITS communications and load profiling.
03517[b]	7	Includes firmware version 6 features plus power and voltage sag/swell/interruption elements.

[a] 03516 is the same price as 03515.

[b] Lower firmware versions can be upgraded to higher firmware versions. Additional cost applies for firmware version 7.

Applications



① See *Figure 2.17* and *Figure 2.18*. ② See *Figure 2.19* and *Figure 2.20*. ③ See *Figure 2.16*. ④ See *Figure 2.15* and *Figure 2.23*–*Figure 2.27*. ⑤ See *Figure 2.21*.

Figure 1.1 SEL-351 Relays Applied Throughout the Power System

Specifications

Important: Do not use the following information to order an SEL-351. Refer to the actual ordering information sheets.

Compliance

Designed and manufactured under an ISO 9001 certified quality management system
UL Listed to US and Canadian safety standards (File E212775; NRGU, NRGU7)
CE Mark
UKCA Mark
RCM Mark
Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

General

Terminal Connections

Note: Terminals or stranded copper wire. Ring terminals are recommended. Minimum temperature rating of 75ºC.

Tightening Torque

Terminals A01–A28 Terminals B01–B40 (if present):	1.1–1.3 Nm (9–12 in-lb)
Terminals Z01–Z27:	1.1–1.3 Nm (9–12 in-lb)
Serial Port 1 (EIA-485, if present):	0.6–0.8 Nm (5–7 in-lb)

AC Voltage Inputs

Nominal Range	
Line-to-Neutral:	67–120 Vrms
Line-to-Line (open delta):	115–260 Vrms
Continuous:	300 Vrms
Short-Term Overvoltage:	600 Vac for 10 seconds
Burden:	0.03 VA @ 67 V; 0.06 VA @ 120 V; 0.8 VA @ 300 V

AC Current Inputs

IA, IB, IC, and Neutral Channel IN

5 A Nominal:	15 A continuous (20 A continuous at 55°C), 500 A for 1 s, linear to 100 A symmetrical, 1250 A for 1 cycle
Burden:	0.27 VA @ 5 A, 2.51 VA @ 15 A
1 A Nominal:	3 A continuous (4 A continuous at 55°C), 100 A for 1 s, linear to 20 A symmetrical, 250 A for 1 cycle
Burden:	0.13 VA @ 1 A, 1.31 VA @ 3 A

Additional Neutral Channel IN Options

0.2 A Nominal Neutral Channel (IN) Current Input:	15 A continuous, 500 A for 1 second, linear to 6.4 A symmetrical 1250 A for 1 cycle
Burden:	0.00009 VA @ 0.2 A, 0.54 VA @ 15 A
0.05 A Nominal Neutral Channel (IN) Current Input:	15 A continuous, 500 A for 1 second, linear to 6.4 A symmetrical 1250 A for 1 cycle
Burden:	0.000005 VA @ 0.05 A, 0.0054 VA @ 1.5 A

Note: The 0.2 A nominal neutral channel IN option is used for directional control on low-impedance grounded, Petersen Coil grounded, and ungrounded/ high-impedance grounded systems (see *Table 4.3*). The 0.2 A nominal channel can also provide nondirectional sensitive earth fault (SEF) protection.
The 0.05 A nominal neutral channel IN option is a legacy nondirectional SEF option.

Power Supply

High-Voltage Supply

Rated:	125–250 Vdc nominal or 120–230 Vac nominal
Range:	85–350 Vdc or 85–264 Vac
Burden:	<25 W

Medium-Voltage Supply

Rated:	48–125 Vdc nominal or 120 Vac nominal
Range:	38–200 Vdc or 85–140 Vac
Burden:	<25 W

Low-Voltage Supply

Rated:	24–48 Vdc nominal
Range:	18–60 Vdc polarity dependent
Burden:	<25 W

Fuse Ratings

High-Voltage Power Supply Fuse

Rating:	2.5 A
Maximum Rated Voltage:	125 Vdc, 250 Vac
Breaking Capacity:	200 A at 277 Vac/100 A at 125 Vdc
Type:	Time-lag T

Medium-Voltage Power Supply Fuse

Rating:	2.5 A
Maximum Rated Voltage:	125 Vdc, 250 Vac
Breaking Capacity:	200 A at 277 Vac/100 A at 125 Vdc
Type:	Time-lag T

Low-Voltage Power Supply Fuse

Rating:	7 A
Maximum Rated Voltage:	60 Vdc, 250 Vac
Breaking Capacity:	50 A at 250 Vac, p.f. / 50 A at 60 Vdc
Type:	Fast-Acting

Note: Power supply fuses are non-user-replaceable.

Frequency and Rotation

Note: 60/50 Hz system frequency and ABC/ACB phase rotation are user-settable.

Frequency Tracking Range:	40–65 Hz (Zero-crossing detection method, preferred source: VA-N terminals. Backup source(s) VB-N or VC-N, depending on PT configuration.)

Frequency Estimation:	40–70 Hz Below 40 Hz = 40 Hz Above 70 Hz = 70 Hz
Maximum Rate-of-Change:	~20 Hz/s (The relay will not measure faster-changing frequencies, and will revert to nominal frequency if the condition is maintained for more than 0.25 s.)

Output Contacts

Standard

DC Output Ratings

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1 s Rating:	50 A
MOV Protected:	270 Vac/360 Vdc/75 J
Pickup Time:	Less than 5 ms
Dropout Time:	Less than 5 ms, typical

Breaking Capacity (10,000 operations):

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

Cyclic Capacity (2.5 cycle/second):

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

Note: Make per IEEE C37.90-1989.
Note: Breaking and Cyclic Capacity per IEC 60255-0-20:1974.
Note: EA certified relays do not have MOV protected standard output contacts.

AC Output Ratings

Maximum Operational Voltage (U_e) Rating:	240 Vac
Insulation Voltage (U_i) Rating (excluding EN 61010-1):	300 Vac
Utilization Category:	AC-15 (control of electromagnetic loads > 72 VA)
Contact Rating Designation:	B300 (B = 5 A, 300 = rated insulation voltage)
Voltage Protection Across Open Contacts:	270 Vac, 40 J
Rated Operational Current (I_e):	3 A @ 120 Vac 1.5 A @ 240 Vac
Conventional Enclosed Thermal Current (I_{the}) Rating:	5 A
Rated Frequency:	50/60 ±5 Hz
Electrical Durability Make VA Rating:	3600 VA, cos ϕ = 0.3
Electrical Durability Break VA Rating:	360 VA, cos ϕ = 0.3

High-Current Interruption for OUT101, OUT102, and Extra I/O Board

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1 s Rating:	50 A
MOV Protection:	330 Vdc/145 J
Pickup Time:	Less than 5 ms
Dropout Time:	Less than 8 ms, typical

Breaking Capacity (10,000 operations):

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

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

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

Note: Make per IEEE C37.90-1989.
Note: Do not use high-current interrupting output contacts to switch ac control signals. These outputs are polarity dependent.
Note: Breaking and Cyclic Capacity per IEC 60255-0-20:1974.

SafeLock Trip/Close Pushbuttons

Resistive DC or AC Load With Arc Suppression Disabled

Make:	30 A
Carry:	6 A continuous carry
1 s Rating:	50 A
MOV Protection:	250 Vac/330 Vdc/130 J

Breaking Capacity (10,000 operations):

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

Note: Make per IEEE C37.90-1989.

High-Interrupt DC Outputs With Arc Suppression Enabled

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

Breaking Capacity (10,000 operations):

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

Note: Make per IEEE C37.90-1989.

Breaker Open/Closed LEDs

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

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

Optoisolated Input Ratings

When Used With DC Control Signals

250 Vdc:	on for 200–300 Vdc;	off below 150 Vdc
220 Vdc:	on for 176–264 Vdc;	off below 132 Vdc
125 Vdc:	on for 105–150 Vdc;	off below 75 Vdc
110 Vdc:	on for 88–132 Vdc;	off below 66 Vdc
48 Vdc:	on for 38.4–60 Vdc;	off below 28.8 Vdc
24 Vdc:	on for 15–30 Vdc	

When Used With AC Control Signals

250 Vdc:	on for 170.6–300 Vac;	off below 106.0 Vac
220 Vdc:	on for 150.3–264.0 Vac;	off below 93.2 Vac
125 Vdc:	on for 89.6–150.0 Vac;	off below 53.0 Vac
110 Vdc:	on for 75.1–132.0 Vac;	off below 46.6 Vac
48 Vdc:	on for 32.8–60.0 Vac;	off below 20.3 Vac
24 Vdc:	on for 12.8–30.0 Vac	

Note: AC mode is selectable for each input via Global settings IN101D–IN106D and IN201D–IN216D. AC input recognition delay from time of switching: 0.75 cycles maximum pickup, 1.25 cycles maximum dropout.
Note: All optoisolated inputs draw less than 10 mA of current at nominal voltage or ac rms equivalent.

Time-Code Inputs

Relay accepts demodulated IRIG-B time-code input at Port 2, on the rear-panel BNC output, or through the optional SEL-2812-compatible fiber-optic serial port.

Port 2, Pin 4 Input Current: 1.8 mA typical at 4.5 V (2.5 kΩ resistive)

BNC Input Current: 4 mA typical at 4.5 V (750 Ω resistive when input voltage is greater than 2 V)

BNC Input Voltage: 2.2 V minimum

BNC Nominal Input Impedance: ≥1 kΩ

Synchronization Accuracy

Internal Clock: ±1 µs

Synchrophasor Reports (e.g., **MET PM**, **EVE P**, **CEV P**): ±10 µs

All Other Reports: ±5 ms

Simple Network Time Protocol (SNTP) Accuracy

Internal Clock: ±5 ms

Unsychronized Clock Drift

Relay Powered: 2 minutes per year typical

Communications Ports

EIA-232: 1 front, 2 rear

EIA-485: 1 rear with 2100 Vdc of isolation, optional

Fiber-Optic Serial Port: SEL-2812-compatible port, optional

Wavelength: 820 nm

Optical Connector Type: ST

RX Min. Sensitivity: –24 dBm

Table 1.3 Link Budget for Fiber-Optic Serial Ports

Multimode Fiber Size	Link Budget Typical[a] (Minimum[b])	Fiber Loss	Maximum Distance Typical[a] (Minimum[b])
200 µm	20 dB (12 dB)	–10.6 dB/km	1.9 km (1.1 km)
62.5/125 µm	15 dB (8 dB)	–4 dB/km	3.8 km (2.0 km)
50/125 µm	9.6 dB (4.2 dB)	–4 dB/km	2.4 km (1.0 km)

[a] +26 °C
[b] –40 to +85 °C

Per Port Data Rate Selections: 300, 1200, 2400, 4800, 9600, 19200, 38400, 57600

USB: 1 front (Type-B connector, CDC class device)

Ethernet: 2 standard 10/100BASE-T rear ports (RJ45 connector)
1 or 2 100BASE-FX rear ports optional (LC connectors)
Wavelength: 1300 nm
Optical Connector Type: LC connector
Fiber Type: Multimode fiber
Typical TX Power: –15.7 dBm
RX Min. Sensitivity: –30 dBm
Fiber Size: 62.5 µm
Internal Ethernet switch included with second Ethernet port.

Dimensions

Refer to *Figure 2.1*.

Weight

11 lb (5.0 kg)—2U rack unit height relay

15 lb (6.8 kg)—3U rack unit height relay

Operating Temperature

–40° to +185°F (–40° to +85°C)
(LCD contrast impaired for temperatures below –20°C.)
Note: Temperature range is not applicable to UL-compliant installations.

Operating Environment

Insulation Class: 2

Pollution Degree: 2

Overvoltage Category: II

Atmospheric Pressure: 80–110 kPa

Relative Humidity: 5%–95%, noncondensing

Maximum Altitude Without Derating (Consult the Factory for Higher Altitude Derating): 2000 m

Type Tests

Electromagnetic Compatibility Emissions

Emissions: IEC 60255-26:2013, Class A
Canada ICES-001 (A) / NMB-001 (A)

Electromagnetic Compatibility Immunity

Electromagnetic Compatibility: IEC 60255-26:2013

Safety Standards: IEC 60255-27: 2013

Magnetic Field Immunity: IEC 60255-26:2013, Section 7.2.10
Severity Level:
1000 A/m for 3 seconds
100 A/m for 1 minute; 50/60 Hz

Conducted RF Immunity: IEC 61000-4-6:2014
Severity Level: 10 Vrms
IEC 60255-26:2013, Section 7.2.8
10 Vrms

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

Electrostatic Discharge Immunity: IEC 61000-4-2:2008
Severity Level 2, 4, 6, 8 kV contact; 2, 4, 8, 15 kV air
IEC 60255-26:2013, Section 7.2.3
IEEE C37.90.3-2001
Severity Level 2, 4, and 8 kV contact; 4, 8, and 15 kV air

Fast Transient/Burst Immunity: IEC 61000-4-4:2012
Severity Level: 4 kV, 5 kHz
IEC 60255-26:2013, Section 7.2.5

Power Supply Immunity: IEC 61000-4-11:2004/A1:2017
IEC 61000-4-29:2000
IEC 60255-26:2013, Section 7.2.11
IEC 60255-26:2013, Section 7.2.12
IEC 60255-26:2013, Section 7.2.13

Radiated Radio Frequency Immunity: IEC 61000-4-3:2010
Severity Level: 10 V/m
IEC 60255-26:2013, Section 7.2.4
10 V/m
IEEE C37.90.2-2004
Severity Level: 35 V/m

Surge Withstand Capability Immunity:	IEC 6100-4-18:2010 Severity Level: 2.5 kV peak common mode, 1.0 kV peak differential mode IEC 60255-26:2013, Section 7.2.7 2 kV line-to-line 4 kV line-to-earth IEEE C37.90.1-2012 Severity Level: 2.5 kV oscillatory; 4.0 kV fast transient
Surge Immunity:	IEC 60255-26:2013, Section 7.2.7 2 kV line-to-line 4 kV line-to-earth

Environmental

Cold:	IEC 60068-2-1:2007 Severity Level: 16 hours at –40°C IEC 60255-27:2013, Section 10.6.1.2 IEC 60255-27:2013, Section 10.6.1.4 –40°C, 16 hours
Cyclic Temperature With Humidity:	IEC 60068-2-30:2005 Severity Level: +25°C to +55°C, 6 cycles, Relative Humidity: 90% IEC 60255-27:2013, Section 10.6.1.6 25° to 55°C, 95% relative humidity, 6 cycles
Damp Heat, Steady State:	IEC 60068-2-78:2001 Severity Level: +40°C Relative Humidity: 90% IEC 60255-27:2013, Section 10.6.1.5 40°C, 93% relative humidity, 10 days
Dry Heat:	IEC 60068-2-2:2007 Severity Level: 16 hours at +85°C IEC 60255-27:2013, Section 10.6.1.1 IEC 60255-27:2013, Section 10.6.1.3 85°C, 16 hours
Change of Temperature:	IEC 60068-2-14:2009 Severity Level: –40°C to +85°C
Vibration:	IEC 60255-21-1:1988 Severity Level: Class 1 Endurance, Class 2 Response IEC 60255-21-2:1988 Severity Level: Class 1—Shock withstand, Bump, and Class 2—Shock Response IEC 60255-21-3:1993 Severity Level: Class 2 (Quake Response)
Vibration Resistance:	IEC 60255-27:2013, Section 10.6.2.1 Endurance: Class 2 Response: Class 2
Shock Resistance:	IEC 60255-27:2013, Section 10.6.2.2 IEC 60255-27:2013, Section 10.6.2.3 Withstand: Class 1 Response: Class 2 Bump: Class 1
Seismic (Quake Response):	IEC 60255-27:2013, Section 10.6.2.4 Response: Class 2

Safety

Protective Bonding Resistance:	IEC 60255-27:2013
Dielectric:	IEC 60255-27:2013 Severity Level: 2500 Vac on contact inputs, contact outputs, and analog inputs. 3100 Vdc on power supply. Type Tested for one minute. IEEE C37.90-2005 Severity Level: 2500 Vac on contact inputs, contact outputs, and analog inputs. 3100 Vdc on power supply. Type Tested for one minute.
Dielectric (Hi-Pot):	IEC 60255-27:2013, Section 10.6.4.3
Impulse:	IEC 60255-27:2013 Severity Level: 0.5 Joule, 5 kV IEEE C37.90-2005 Severity Level: 0.5 Joule, 5 kV
IP Code:	IEC 60529:1989+AMD1:1999+AMD2:2013 Severity Level: IP30
Product Safety:	C22.2 No. 14 – 95 Canadian Standards Association, Industrial control equipment, industrial products UL 508 Underwriters Laboratories Inc., Standard for safety: Industrial control equipment

Processing Specifications and Oscillography

AC Voltage and Current Inputs

128 samples per power system cycle, 3 dB low-pass filter cut-off frequency of 3 kHz

Digital Filtering

Digital low-pass filter then decimate to 32 samples per cycle followed by one-cycle cosine filter.

Net filtering (analog plus digital) rejects dc and all harmonics greater than the fundamental.

Protection and Control Processing (Processing Interval)

4 times per power system cycle

Oscillography

Length:	15, 30, or 60 cycles
Total Storage:	11 seconds of analog and binary
Sampling Rate:	128 samples per cycle unfiltered 32 and 16 samples per cycle unfiltered and filtered 4 samples per cycle filtered
Trigger:	Programmable with Boolean expression
Format:	ASCII and Compressed ASCII Binary COMTRADE (128 samples per cycle unfiltered)
Time-Stamp Resolution:	1 µs with precise time event (EVE P) reports and Compressed ASCII event (CEV) reports. 1 ms otherwise.
Time-Stamp Accuracy:	See *Time-Code Inputs* on page 1.6.

Sequential Events Recorder

Time-Stamp Resolution:	1 ms
Time-Stamp Accuracy (with respect to time source):	±5 ms

Relay Element Pickup Ranges and Accuracies

Accuracy of cycle-based timers is specified for steady-state frequency.

Instantaneous/Definite-Time Overcurrent Elements

Pickup Range:	0.25–100.00 A, 0.01 A steps (5 A nominal) 1.00–170.00 A, 0.01 A steps (5 A nominal—for phase-to-phase elements) 0.050–100.000 A, 0.010 A steps (5 A nominal—for residual-ground elements) 0.05–20.00 A, 0.01 A steps (1 A nominal) 0.20–34.00 A, 0.01 A steps (1 A nominal—for phase-to-phase elements) 0.010–20.000 A, 0.002 A steps (1 A nominal—for residual-ground elements) 0.005–2.500 A, 0.001 A steps (0.2 A nominal neutral channel (IN) current input) 0.005–1.500 A, 0.001 A steps (0.05 A nominal neutral channel (IN) current input)
Steady-State Pickup Accuracy:	±0.05 A and ±3% of setting (5 A nominal) ±0.01 A and ±3% of setting (1 A nominal) ±0.001 A and ±3% of setting (0.2 A nominal neutral channel (IN) current input) ±0.001 A and ±5% of setting (0.05 A nominal neutral channel (IN) current input)
Transient Overreach:	±5% of pickup
Time Delay:	0.00–16,000.00 cycles, 0.25 cycle steps
Timer Accuracy:	±0.25 cycle and ±0.1% of setting

Note: See pickup and reset time curves in *Figure 3.5* and *Figure 3.6* in the instruction manual.

Breaker Failure Current Detectors and Logic

Pickup Range:	0.5–100.00 A, 0.01 A steps (5 A nominal) 0.1–20.00 A, 0.01 A steps (1 A nominal)
Steady-State Pickup Accuracy:	±0.05 A and ±3% of setting (5 A nominal) ±0.01 A and ±3% of setting (1 A nominal)
Transient Overreach:	±5% of pickup
Reset Time:	≤1 cycle
Pickup Time:	≤1 cycle for currents greater than 2 multiples of pickup
Time Delay:	0.00–16,000.00 cycles, 0.25 cycle steps
Timer Accuracy:	±0.25 cycle and ±0.1% of setting

Time-Overcurrent Elements

Pickup Range:	0.25–16.00 A, 0.01 A steps (5 A nominal) 0.10–16.00 A, 0.01 A steps (5 A nominal—for residual-ground elements) 0.05–3.20 A, 0.01 A steps (1 A nominal) 0.02–3.20 A, 0.01 A steps (1 A nominal—for residual-ground elements) 0.005–0.640 A, 0.001 A steps (0.2 A nominal neutral channel (IN) current input) 0.005–0.160 A, 0.001 A steps (0.05 A nominal neutral channel (IN) current input)
Steady-State Pickup Accuracy:	±0.05 A and ±3% of setting (5 A nominal) ±0.01 A and ±3% of setting (1 A nominal) ±0.005 A and ±3% of setting (0.2 A nominal neutral channel (IN) current input) ±0.001 A and ±5% of setting (0.05 A nominal neutral channel (IN) current input)
Time-Dial Range:	0.50–15.00, 0.01 steps (US) 0.05–1.00, 0.01 steps (IEC) 0.10–2.00, in 0.01 steps (recloser curves)
Curve Timing Accuracy:	±1.50 cycles and ±4% of curve time for current between 2 and 30 multiples of pickup ±1.50 cycles and ±4% of curve time for current less than 1 multiple of pickup ±3.50 cycles and ±4% of curve time for current between 2 and 30 multiples of pickup for 0.05 A nominal neutral channel (IN) current input ±3.50 cycles and ±4% of curve time for current less than 1 multiple of pickup for 0.05 A nominal neutral channel (IN) current input

Second-Harmonic Blocking Elements

Pickup Range:	5–100% of fundamental, 1% steps
Steady-State Pickup Accuracy:	2.5 percentage points
Pickup/Dropout Time:	<1.25 cycles
Time Delay:	0.00–16,000.00 cycles, 0.25 cycle steps
Timer Accuracy:	±0.25 cycle and ±0.1% of setting

Under- and Overvoltage Elements

Pickup Ranges

Wye-Connected (Global setting PTCONN = WYE):	0.00–200.00 V, 0.01 V steps (negative-sequence element) 0.00–300.00 V, 0.01 V or 0.02 V steps (various elements) 0.00–520.00 V, 0.02 V steps (phase-to-phase elements)
Open-Delta Connected (when available, by Global setting PTCONN = DELTA):	0.00–120.00 V, 0.01 V steps (negative-sequence elements) 0.00–170.00 V, 0.01 V steps (positive-sequence element) 0.00–300.00 V, 0.01 V steps (various elements)

Steady-State Pickup Accuracy:	±0.5 V plus ±1% for 12.5–300.00 V (phase and synchronizing elements) ±0.5 V plus ±2% for 12.5–300.00 V (negative-, positive-, and zero-sequence elements, phase-to-phase elements)
Transient Overreach:	±5% of pickup

Synchronism-Check Elements

Slip Frequency Pickup Range:	0.005–1.000 Hz, 0.001 Hz steps
Slip Frequency Pickup Accuracy:	±0.003 Hz
Phase Angle Range:	0–80°, 1° steps
Phase Angle Accuracy:	±4° when |slip frequency| ≤0.4 Hz ±10° when 0.4 Hz < |slip frequency| <1.0 Hz

Under- and Overfrequency Elements

Pickup Range:	40.10–65.00 Hz, 0.01 Hz steps
Steady-State *plus* Transient Overshoot:	±0.01 Hz
Pickup/Dropout Time:	<3.0 cycles
Time Delay:	2.00–16,000.00 cycles, 0.25-cycle steps
Timer Accuracy:	±0.25 cycle and ±0.1% of setting
Undervoltage Frequency Element Block Range:	25.00–300.00 V_{LN} (wye) or V_{LL} (open delta)

Rate-of-Change-of-Frequency Element

Pickup Range:	0.10–15.00 Hz/s, 0.01 Hz/s steps
Dropout:	95% of pickup
Pickup Accuracy:	±100 mHz/s and ±3.33% of pickup
Pickup/Dropout Time:	See *Equation 3.1* in the instruction manual.
Pickup Time Delay:	0.10–60.00 seconds, 0.01 second steps
Dropout Time Delay:	0.00–60.00 seconds, 0.01 second steps
Timer Accuracy:	±6 ms and ±0.1% of setting

Timers

Pickup Ranges:	0.00–999,999.00 cycles, 0.25-cycle steps (reclosing relay and some programmable timers) 0.00–16,000.00 cycles, 0.25-cycle steps (some programmable and other various timers)
Pickup and Dropout Accuracy for all Timers:	±0.25 cycle and ±0.1% of setting

Substation Battery Voltage Monitor

Pickup Range:	20–300 Vdc, 1 Vdc steps
Pickup Accuracy:	±2% of setting ±2 Vdc

Fundamental Metering Accuracy

Accuracies are specified at 20°C, at nominal system frequency, and voltages 67–250 V unless noted otherwise.

V_A, V_B, V_C:	±0.2% (67.0–250 V; wye-connected) ±0.4% typical (250–300 V; wye-connected)
V_{AB}, V_{BC}, V_{CA}:	±0.4% (67.0–250 V; delta-connected) ±0.8% typical (250–300 V; delta-connected)
V_S:	±0.2% (67.0–250 V) ±0.4% typical (250–300 V)
$3V_0$, V_1, V_2 ($3V_0$ not available with delta-connected inputs):	±0.6% (67.0–250 V) ±1.2% typical (250–300 V)
I_A, I_B, I_C:	±4 mA and ±0.1% (1.0–100 A) (5 A nominal) ±6 mA and ±0.1% (0.25–1.0 A) (5 A nominal) ±1 mA and ±0.1% (0.2–20 A) (1 A nominal) ±2 mA and ±0.1% (0.05–0.2 A) (1 A nominal) Temperature coefficient:

$$\frac{0.0002\ \%}{°C^2} \cdot (\_\_°C - 20°C)^2$$

I_N:	±4 mA and ±0.1% (1.0–100 A) (5 A nominal) ±6 mA and ±0.1% (0.25–1.0 A) (5 A nominal) ±1 mA and ±0.1% (0.2–20 A) (1 A nominal) ±2 mA and ±0.1% (0.05–0.2 A) (1 A nominal) ±1.6 mA and ±0.1% (0.005–4.5 A) (0.2 A or 0.05 A nominal channel IN current input)
I_1, $3I_0$, $3I_2$:	±0.05 A and ±3% (0.5–100 A) (5 A nominal) ±0.01 A and ±3% (0.1–20 A) (1 A nominal)

Phase Angle Accuracy

I_A, I_B, I_C:	±0.5° (1.0–100 A) (5 A nominal) ±3° (0.25–1.0 A) (5 A nominal) ±0.5° (0.2–20 A) (1 A nominal) ±5° (0.05–0.2 A) (1 A nominal)
V_A, V_B, V_C, V_S (wye-connected voltages):	±0.5°
V_{AB}, V_{BC}, V_{CA}, V_S (delta-connected voltages):	±1.0°

MW/MVAR
(A, B, C, and three-phase; wye-connected voltages)
MW/MVAR
(three-phase; open-delta connected voltages; balanced conditions)

Accuracy (MW/MVAR)	at load angle
for phase current ≥ 0.2 • I_{NOM}:	
0.35% / –	0° or 180° (unity power factor)
0.40% / 6.00%	±8° or ±172°
0.75% / 1.50%	±30° or ±150°
1.00% / 1.00%	±45° or ±135°
1.50% / 0.75%	±60° or ±120°
6.00% / 0.40%	±82° or ±98°
– / 0.35%	±90° (power factor = 0)

Energy Meter

Accumulators:	Separate IN and OUT accumulators updated once every two seconds, transferred to nonvolatile storage once per day.
ASCII Report Resolution:	0.01 MWh

Accuracy:	The accuracy of the energy meter depends on applied current and power factor as shown in the power metering accuracy table above. The additional error introduced by accumulating power to yield energy is negligible when power changes slowly compared to the processing rate of twice per second.

Synchrophasor Accuracy

Maximum Data Rate in Messages per Second

IEEE C37.118 Protocol:	60 (nominal 60 Hz system) 50 (nominal 50 Hz system)
SEL Fast Message Protocol:	1
IEEE C37.118-2005 Accuracy:	Level 1 at maximum message rate when phasor has the same frequency as phase A voltage, frequency-based phasor compensation is enabled (PHCOMP = Y), and the narrow-bandwidth filter is selected (PMAPP = N). Out-of-band interfering frequency (Fs) test, 10 Hz ≤ Fs ≤ (2 • NFREQ).
Current Range:	(0.1–2) • I_{NOM} (I_{NOM} = 1 A or 5 A)
Frequency Range:	±5 Hz of nominal (50 or 60 Hz)
Voltage Range:	30 V–250 V
Phase Angle Range:	–179.99° to 180°

Harmonic Metering Accuracy

Voltages V_A, V_B, V_C, V_S (Wye or Single-Phase); V_{AB}, V_{BC}, V_S (Delta)

Accuracies valid for THD < 100%, 30 V < fundamental < 200 V sec, 50 Hz or 60 Hz

RMS and Fundamental Magnitude:	±5%
THD Percentage:	±5 percentage points
02 Through 16 Harmonic Percentage:	±5 percentage points

Currents I_A, I_B, I_C, I_N

Accuracies valid for THD < 100%, fundamental voltage < 200 V sec, 50 Hz or 60 Hz

5 A Nominal:	0.25 A < fundamental current < 5 A sec
1 A Nominal:	0.05 A < fundamental current < 1 A sec
0.2 A and 0.05 A Nominal (IN channel only):	0.01 A < fundamental current < 1 A sec
RMS and Fundamental Magnitude:	±5%
THD Percentage:	±5 percentage points
02 Through 16 Harmonic Percentage:	±5 percentage points

Power Element Accuracy

Single-Phase Power Elements

Pickup Setting 0.33–2 VA (5 A nominal), 0.07–0.4 VA (1 A nominal):	±0.05 A • (L-N voltage secondary) and ±10% of setting at unity power factor for power elements and zero power factor for reactive power element (5 A nominal) ±0.01 A • (L-N voltage secondary) and ±10% of setting at unity power factor for power elements and zero power factor for reactive power element (1 A nominal)
Pickup Setting 2–13000 VA (5 A nominal), 0.4–2600 VA (1 A nominal):	±0.025 A • (L-N voltage secondary) and ±5% of setting at unity power factor (5 A nominal) ±0.005 A • (L-N voltage secondary) and ±5% of setting at unity power factor (1 A nominal)

Three-Phase Power Elements

Pickup Setting 1–6 VA (5 A nominal), 0.2–1 VA (1 A nominal):	±0.05 A • (L-L voltage secondary) and ±10% of setting at unity power factor for power elements and zero power factor for reactive power element (5 A nominal) ±0.01 A • (L-L voltage secondary) and ±10% of setting at unity power factor for power elements and zero power factor for reactive power element (1 A nominal)
Pickup Setting 6–39000 VA (5 A nominal), 1–7800 VA (1 A nominal):	±0.025 A • (L-L voltage secondary) and ±5% of setting at unity power factor for power elements and zero power factor for reactive power element (5 A nominal) ±0.005 A • (L-L voltage secondary) and ±5% of setting at unity power factor for power elements and zero power factor for reactive power element (1 A nominal)

The quoted three-phase power element accuracy specifications are applicable as follows:

- Wye-connected voltages (PTCONN = WYE): any condition
- Open-delta connected voltages (PTCONN = DELTA), with properly configured broken-delta 3V0 connection (VSCONN = 3V0): any condition
- Open-delta connected voltages, without broken-delta 3V0 connection (VSCONN = VS): balanced conditions only

SECTION 2

Installation

Overview

Design your rack or panel installation using the mounting and connection information in this section. This section also includes information for configuring the relay to your application.

This section covers the following topics:

Relay Mounting

Rack Mount

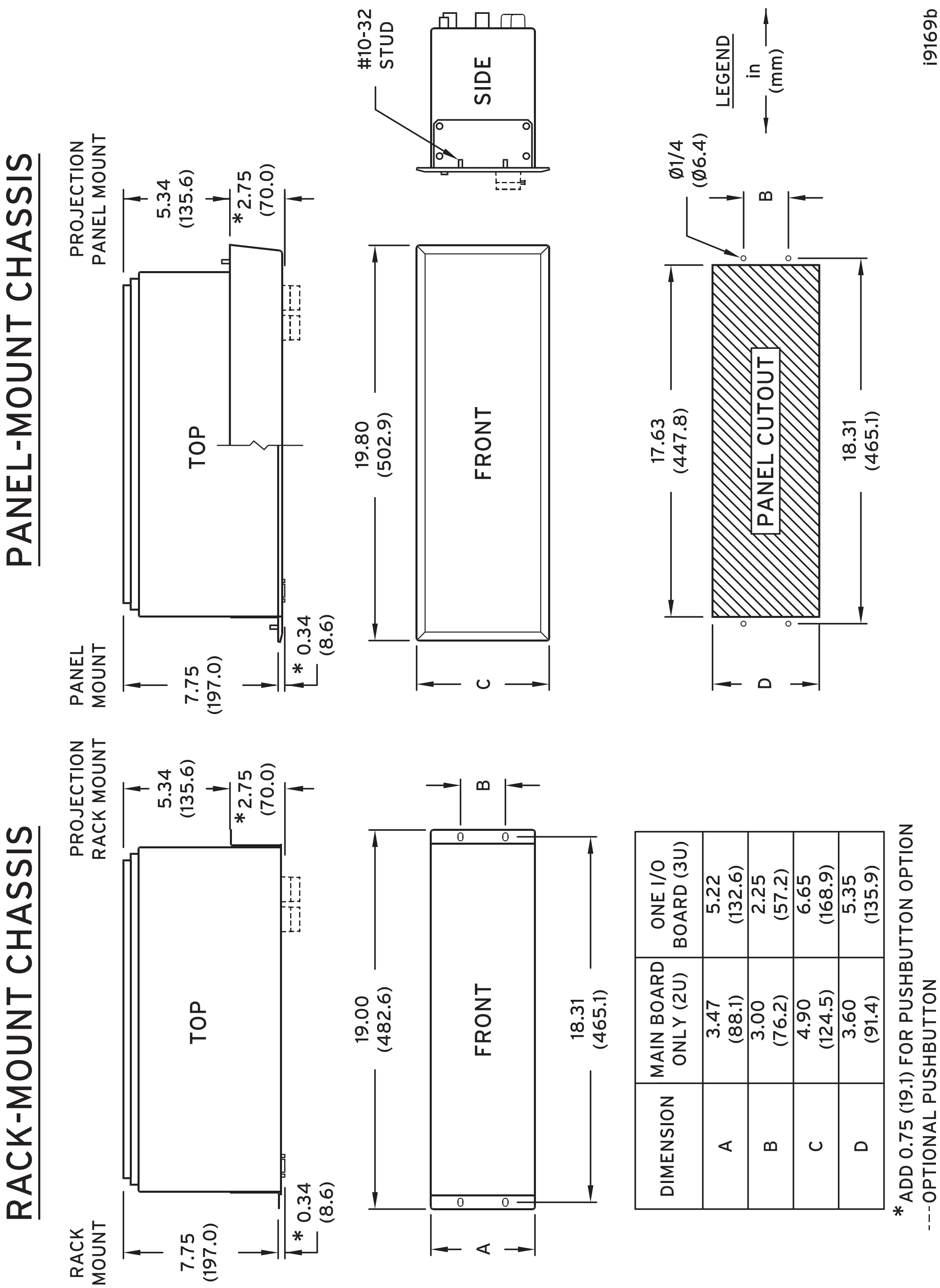
The SEL-351 rack-mount relay bolts easily into a standard 19-inch rack (see *Figure 2.1*). From the front of the relay, insert four rack screws (two on each side) through the holes on the relay mounting flanges.

Reverse the relay mounting flanges to cause the relay to project an additional 2.75 inches (70 mm) from the front of your mounting rack and provide additional space at the rear of the relay for applications where the relay might otherwise be too deep to fit.

Panel Mount

The SEL-351 in a panel-mount relay provides a clean look. Panel-mount relays have sculpted front-panel molding that covers all installation holes. Cut your panel and drill mounting holes according to the dimensions in *Figure 2.1*. Insert the relay into the cutout, aligning four relay mounting studs on the rear of the relay front panel with the drilled holes in your panel, and use nuts to secure the relay to the panel.

The projection panel-mount option covers all installation holes and maintains the sculpted look of the panel-mount option; the relay projects an additional 2.75 inches (70 mm) from the front of your panel. This ordering option increases space at the rear of the relay for applications where the relay would ordinarily be too deep to fit your cabinet.



DIMENSION	MAIN BOARD ONLY (2U)	ONE I/O BOARD (3U)
A	3.47 (88.1)	5.22 (132.6)
B	3.00 (76.2)	2.25 (57.2)
C	4.90 (124.5)	6.65 (168.9)
D	3.60 (91.4)	5.35 (135.9)

Figure 2.1 SEL-351 Dimensions for Rack-Mount and Panel-Mount Models

Front-Panel and Rear-Panel Connection Diagrams

Figure 2.2–Figure 2.6 represent examples of different relay configurations. View the SEL-351 Model Option Tables on our website for model options and additional front- and rear-panel drawings, or contact your local SEL sales representative.

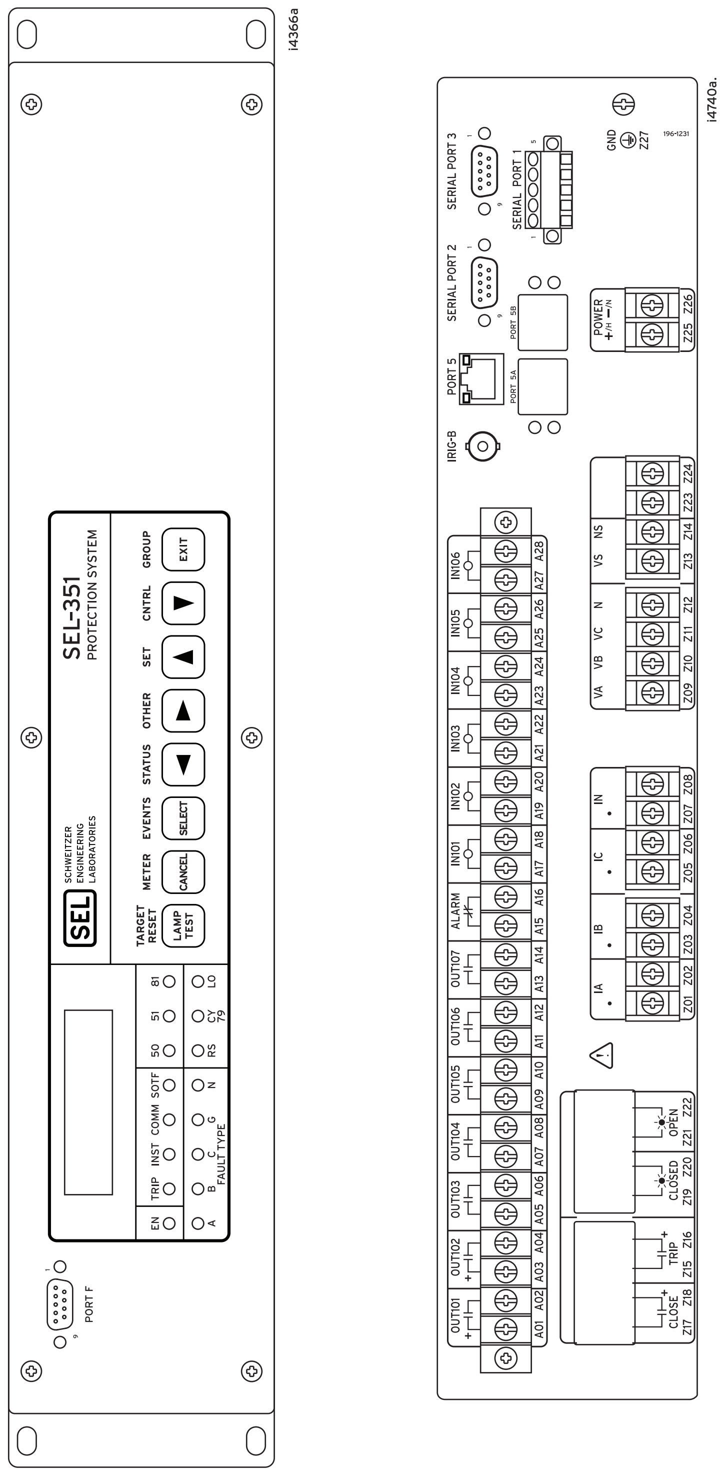


Figure 2.2 SEL-351 Front- and Rear-Panel Drawings; 2U Horizontal Rack-Mount With Optional EIA-485 Port

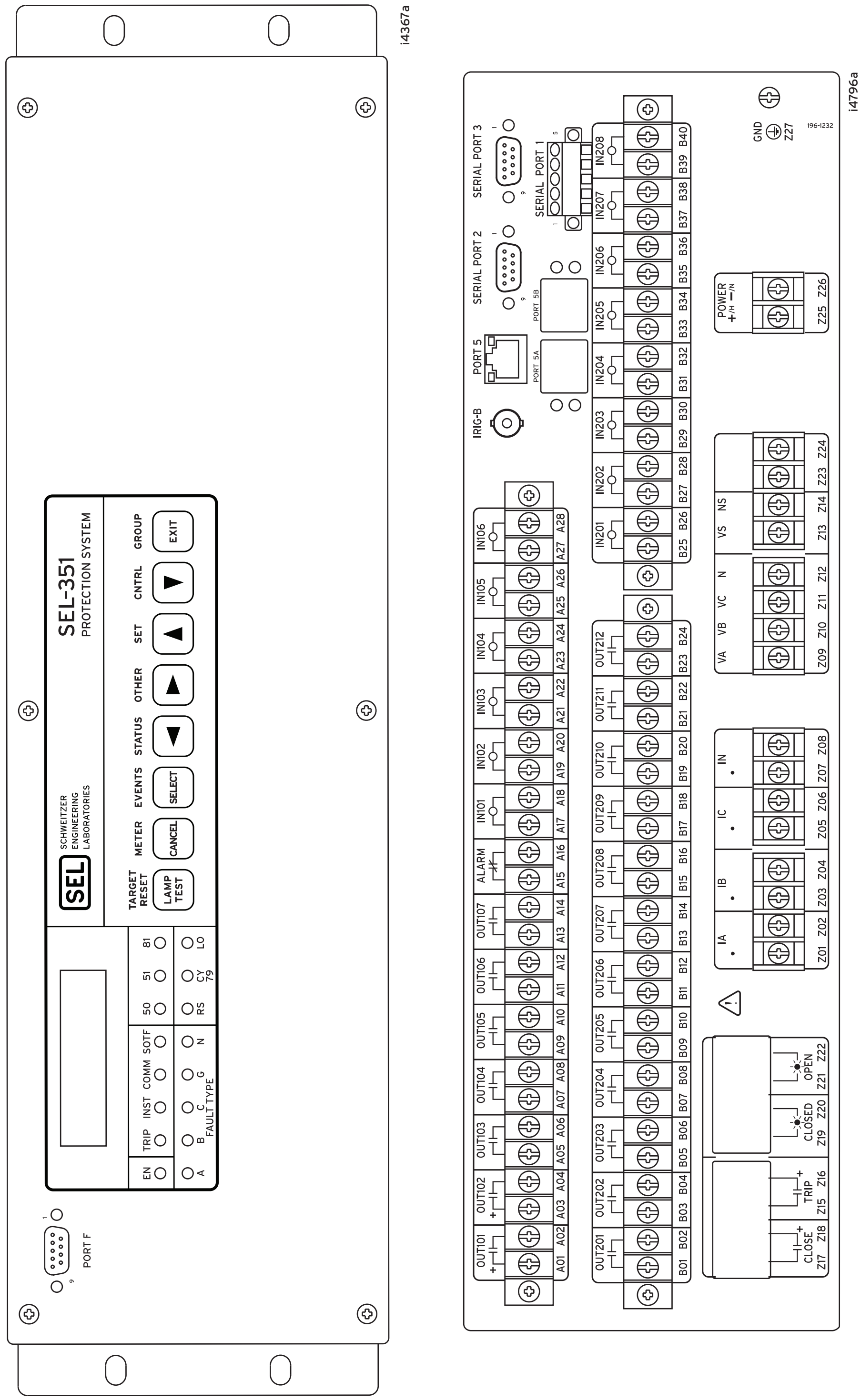


Figure 2.3 SEL-351 Front- and Rear-Panel Drawings; Horizontal Rack-Mount With Optional Extra I/O Board With 12 Standard Outputs and 8 Inputs, and Optional EIA-485 Port

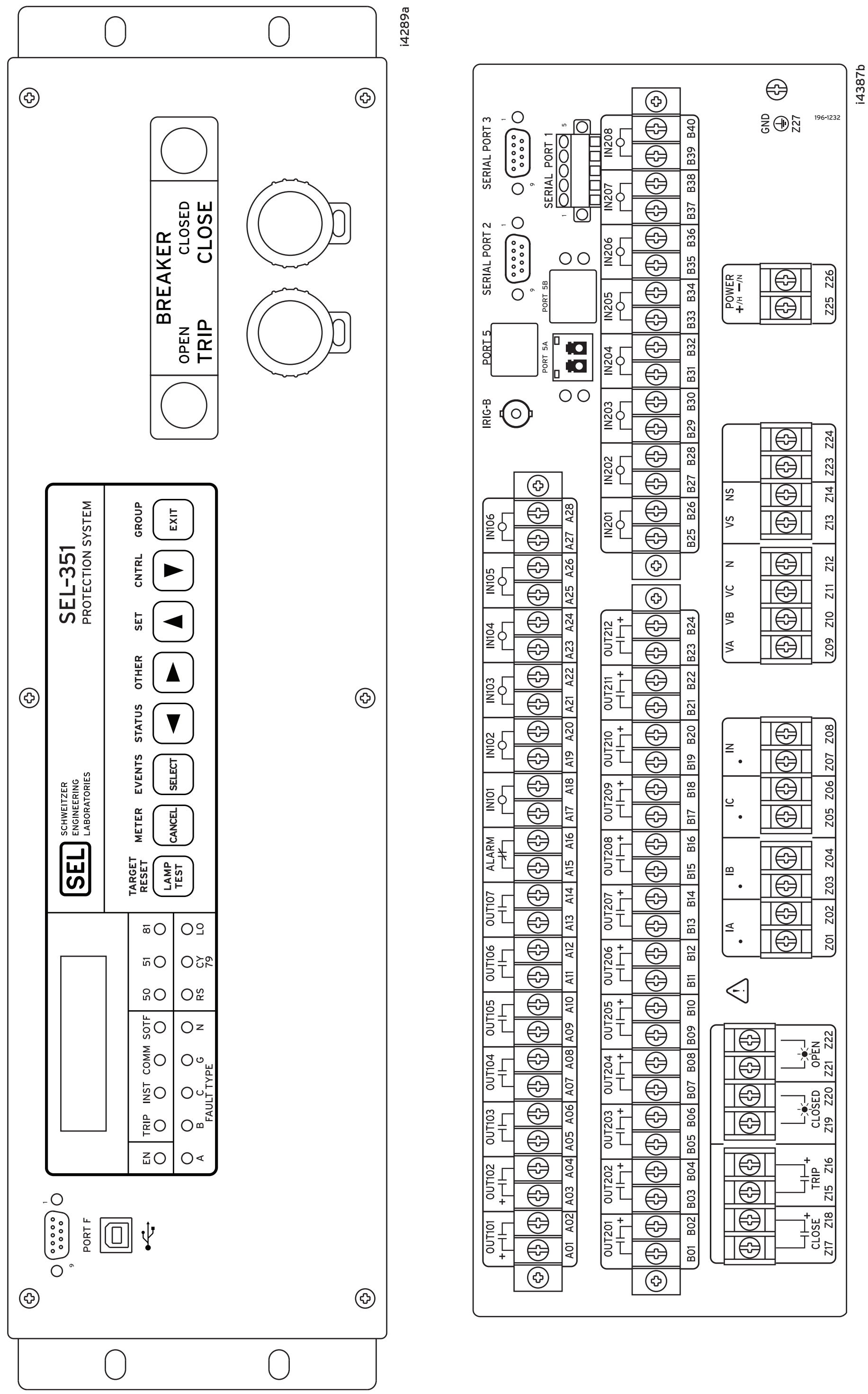


Figure 2.4 SEL-351 Front- and Rear-Panel Drawings; Horizontal Rack-Mount With Optional Front-Panel USB Port and SafeLock Trip/Close Pushbuttons, Optional Extra I/O Board With 12 High-Current Interrupting Outputs and 8 Inputs, and Optional Fiber-Optic Ethernet and EIA-485 Port

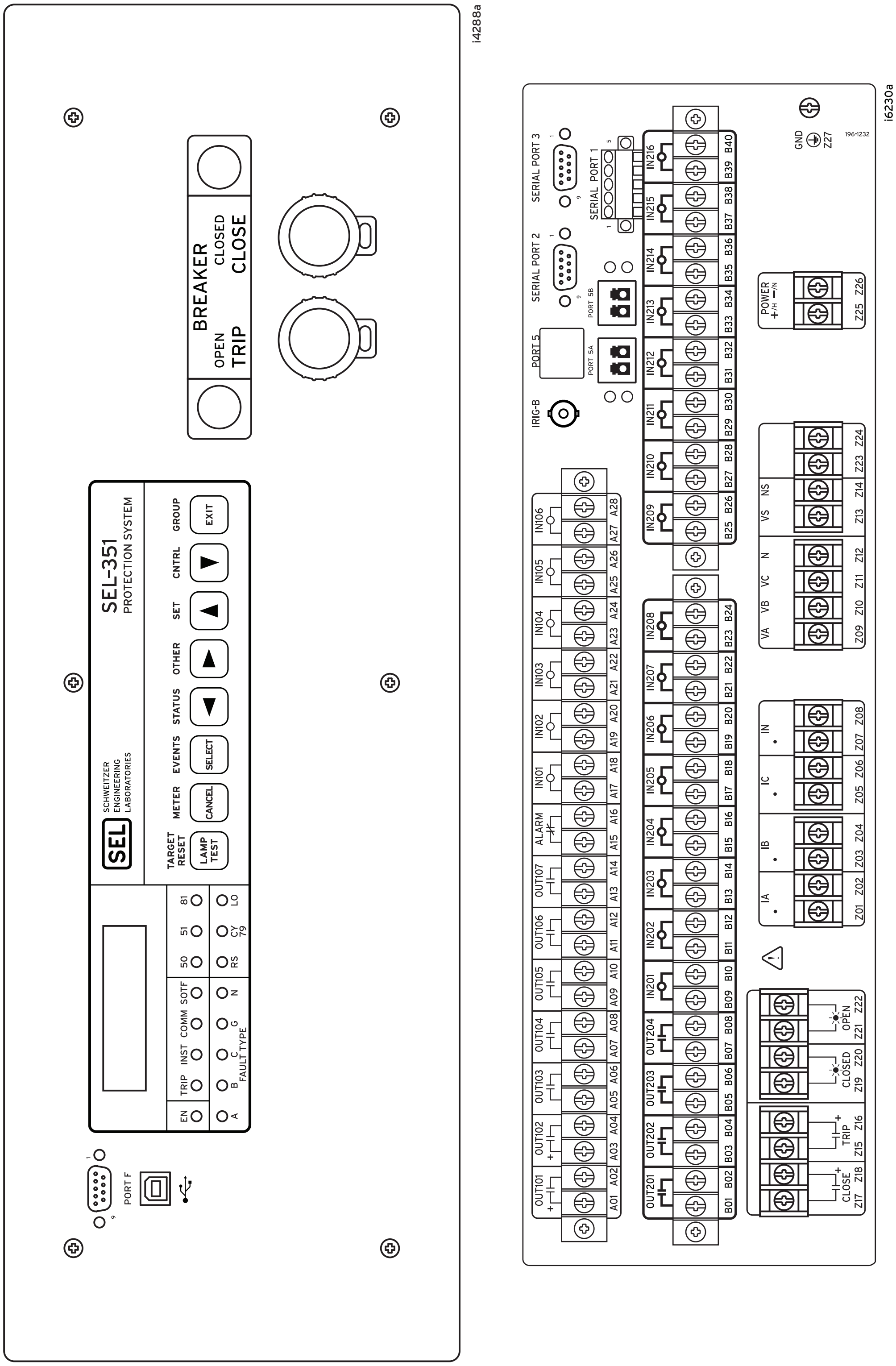


Figure 2.5 SEL-351 Front- and Rear-Panel Drawings; Horizontal Panel-Mount With Optional Front-Panel USB Port and SafeLock Trip/Close Pushbuttons, Optional Extra I/O Board With 4 Standard Outputs and 16 Inputs, Optional Dual Fiber-Optic Ethernet, and EIA-485 Port

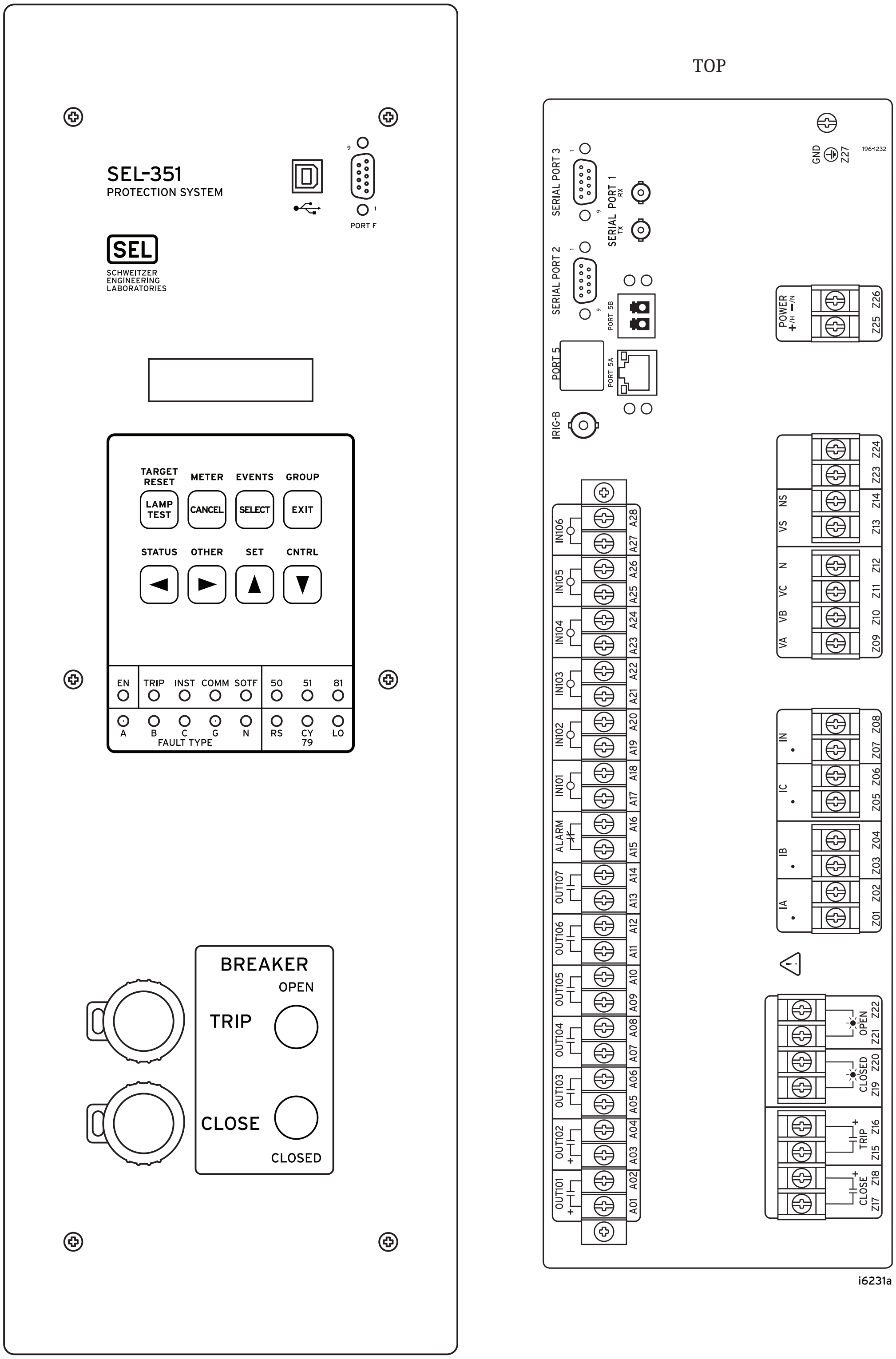


Figure 2.6 SEL-351 Front- and Rear-Panel Drawings; Vertical Panel-Mount With Optional Front-Panel USB Port, Optional SafeLock Trip/Close Pushbuttons, and Optional Dual Copper/Fiber-Optic Ethernet With Fiber-Optic Serial Port

Making Rear-Panel Connections

Refer to *Figure 2.15–Figure 2.28* for wiring examples of typical applications.

Required Equipment/General Connection Information

Tools: Phillips or slotted-tip screwdriver.

Parts: All screws in a standard relay shipment are size #6-32 Phil-slot. Contact SEL for optional screw types.

Ring terminals are recommended. Maximum tongue width is 7.9 mm (0.31 inches).

Chassis Ground

Ground the relay chassis at terminal **Z27** using a minimum #14 AWG copper conductor.

Power Supply

Connect control voltage to **POWER** terminals. Note the polarity indicators on terminals **Z25(+)** and **Z26(–)**. Control power passes through these terminals to a fuse and to the switching power supply. The control power circuitry is isolated from the relay chassis ground.

For compliance with IEC 60947-1 and IEC 60947-3, place a suitable external switch or circuit breaker in the power leads for the SEL-351S; this device should interrupt both the hot (**+/H**) and neutral (**–/N**) power leads. The maximum current rating for the power disconnect circuit breaker or optional overcurrent device (fuse) should be 15 A.

Refer to *Section 1: Introduction and Specifications* for power supply ratings. The relay power supply rating is listed on the serial number sticker on the relay rear panel.

Output Contacts

⚠**WARNING**
OUT101 and **OUT102** are not polarity-dependent in legacy SEL-351 Relays. See *Table 1.1* for features that distinguish a legacy SEL-351 from a new SEL-351. If you replace a legacy SEL-351 with a newer style SEL-351, ensure that the connection polarities for **OUT101** and **OUT102** are correct, and ensure that **OUT101** and **OUT102** are not connected to ac loads.

All relays come with polarity-dependent high-current interrupting output contacts for **OUT101** and **OUT102**, and with standard contacts for **OUT103–ALARM**.

See *High-Current Interrupting Output Contacts* on page 2.9.

Extra I/O

OUT201–OUT212 can be ordered with standard or high-current interrupting output contacts.

Refer to *Specifications* on page 1.4 for output contact ratings. Refer to the part number on the serial number sticker on the relay rear panel to determine the number and type of output contacts on the extra I/O board of your Model 0351 relay.

Standard Output Contacts

Model 0351 part numbers with a numeral “2” in the field in bold below (sample part number) indicate 12 standard output contacts on the extra I/O board (OUT201–OUT212):

035173A4E54**2**X1

Model 0351 part numbers with a numeral “4” in the field in bold below (sample part number) indicate four standard output contacts on the extra I/O board (OUT201–OUT204):

035173A4E54**4**X1

Standard output contacts are not polarity dependent.

High-Current Interrupting Output Contacts

All relay models have high-current interrupting output contacts for OUT101 and OUT102. Model 0351 part numbers with a numeral “6” in the field in bold below (sample part number) indicate high-current interrupting output contacts on the extra I/O board (OUT201–OUT212):

035153A4EB4**6**X1

NOTE: Do not use the high-current interrupting output contacts to switch ac control signals.

High-current interrupting output contacts are polarity dependent. Note the + polarity markings above terminals A01, A03, B02, B04, B06, ..., B24 in *Figure 2.5*. The extra I/O board of the relay in *Figure 2.4* does not show these + polarity markings (because it is the rear panel for an extra I/O board with standard output contacts).

As an example, consider the connection of terminals B01 and B02 (high-current interrupting output contact OUT201) in a circuit. Terminal B02 (+) must have a higher voltage potential than terminal B01 in the circuit. The same holds true for output contacts OUT202–OUT212. For OUT101 and OUT102, terminals A01 and A03 must have the higher potential.

Optoisolated Inputs

The optoisolated inputs in any of the SEL-351 models (e.g., IN102, IN207) are not polarity dependent. Refer to *General* on page 1.4 for optoisolated input ratings.

Inputs can be configured to respond to ac or dc control signals via Global settings IN101D–IN106D, IN201D–IN208D (I/O board option 2 or 6), or IN201D–IN216D (I/O board option 4).

Refer to the serial number sticker on the relay rear panel for the optoisolated input voltage rating (listed under the LOGIC INPUT label).

SafeLock Trip and Close Pushbuttons

NOTE: SafeLock Trip and Close pushbutton operations are not recorded in event reports or SER reports.

Trip and close your circuit breaker or control other devices using the optional SafeLock Trip and Close pushbuttons even when the relay is without power. Provide bright, easily visible breaker status or the status of other devices using the integral breaker status LEDs. These features are electrically isolated and function independently of the rest of the relay. *Figure 2.29* shows example trip and close circuit connections in a dc system. The SafeLock pushbuttons come configured from the factory for dc operation, with the internal arc suppressor enabled. SafeLock pushbuttons with the internal arc suppressor enabled will not be damaged even if they are released while trip or close current is still flowing. See *Specifications* on page 1.4 for current interrupting capability. When the arc suppressor is enabled, terminal **Z16(+)** must have a higher voltage potential than terminal **Z15**, and terminal **Z18(+)** must have a higher voltage potential than terminal **Z17**.

To use an ac trip or close potential, the arc suppression must be disabled for one or both pushbuttons. The arc suppressor should also be disabled when connecting the pushbuttons to loads that do not require arc suppression, such as certain magnetic actuator circuit breakers.

Jumpers on the pushbutton board in *Figure 2.33* determine if the arc suppressor on the SafeLock pushbuttons is enabled or disabled. See *Specifications* on page 1.4 for load current ratings that the pushbuttons can switch without the assistance of the internal arc suppressors.

The breaker indicator LEDs are suitable for use in ac and dc systems. The operating voltage ranges of the LEDs are configured by jumpers as shown in *Figure 2.33*.

See *Circuit Board Connections and Jumpers* on page 2.35 for instructions regarding access to circuit board jumpers.

SafeLock Pushbutton Lock and Tagout

The SafeLock pushbuttons have an extra deep protective sleeve to prevent inadvertent actuation. See *Figure 2.7*. Only an intentional button press will activate the buttons. Rotate the protective sleeve 90 degrees clockwise to lock the pushbuttons. In this locked position the button cannot be pressed, and the tab on the protective sleeve aligns with the tab on the button base. Use the aligned tabs to hang a lockout tag and prevent the button from being unlocked.

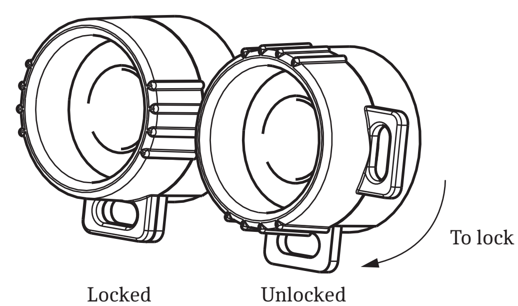


Figure 2.7 SafeLock Trip and Close Pushbuttons

Disabling the SafeLock Pushbutton Lock

Some applications do not permit a breaker control to be locked. Set-screws on the back of the button body behind the relay front panel allow you to freeze the rotating protective sleeve in the unlocked position, effectively disabling the locking mechanism. Follow these steps while referring to *Figure 2.8* to disable the locking mechanism.

⚠CAUTION
Ensure the button is unlocked before proceeding. Trying to freeze a button in the locked position may result in damage to the button mechanism.

1. Remove the relay front panel.
2. Locate the back of the button to be frozen in the unlocked position. Remove either mounting screw from the back of the button. Remove the spacer from the mounting screw. Retain the spacer in case you want to enable the locking mechanism in the future.
3. Reseat the mounting screw removed in Step 2 without the spacer sleeve, being careful not to torque it past 4 in-lb. (0.5 Nm).

4. Test the button to ensure the protective sleeve will no longer rotate (the button cannot be locked), and that the button still moves when pressed.
5. Reinstall the relay front panel.

⚠CAUTION
Ensure button is in unlocked position before reseating screw. Inserting the screw without the spacer with the button in the locked position will result in damage to the button.

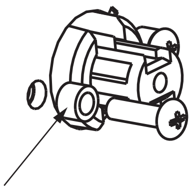


Figure 2.8 Remove Spacer and Reseat Screw to Disable Locking Mechanism

Current Transformer Inputs

Note the polarity dots above terminals Z01, Z03, Z05, and Z07. Refer to *Figure 2.15–Figure 2.28* for typical CT wiring examples.

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

Refer to the serial number sticker on the relay rear panel for the nominal current ratings (5 A or 1 A) for the phase (IA, IB, IC) and neutral (IN) current inputs (listed under label AMPS AC). The neutral (IN) current input also has 0.05 A and 0.2 A nominal current options.

Potential Transformer Inputs

Note the signal labels (VA, VB, VC, N, VS, NS) on terminals Z09–Z14. *Figure 2.9* shows the internal connection for terminals VA, VB, VC, and N. Note also that VS-NS is a separate single-phase voltage input.

Voltage Input Rating

The continuous voltage input rating for the SEL-351 is 300 Vac.

This voltage rating applies to the three-phase voltage inputs (VA-N, VB-N, VC-N) as well as to the VS-NS voltage input. The voltage rating is for V_{LN} when the relay is wye-connected (three-phase, four-wire), or V_{LL} when the relay is delta-connected (three-phase, three-wire). This voltage rating also applies to a single-phase voltage input connected line-neutral or line-to-line. The following three subsections explain the wye, delta, and single-phase voltage input connections.

Wye-Connected Voltages (Global Setting PTCONN = WYE)

Any voltage input (i.e., VA-N, VB-N, VC-N, or VS-NS) can be connected to voltages to as much as 300 V continuous. *Figure 2.15–Figure 2.20* and *Figure 2.23–Figure 2.25* show examples of wye-connected voltages. System frequency is determined from V_{alpha} (refer to *Table 3.16* for PTCONN = WYE).

Additionally, voltage input VS-NS measures frequency on the other side of an open breaker for synchronism-check applications (see *Synchronism-Check Elements* on page 3.36).

Delta-Connected Voltages (Global Setting PTCONN = DELTA)

Make Global setting PTCONN = DELTA to accept an open-delta PT connection. Phase-to-phase voltages to as much as 300 V continuous can be connected to voltage inputs **VA-N** or **VC-N**, when the relay is connected as shown in *Figure 2.26* or *Figure 2.27*. This connection requires an external jumper between the **VB** terminal (**Z10**) and the **N** terminal (**Z12**).

In this configuration, the relay cannot measure zero-sequence voltage ($3V_0$) from the input terminals **VA-N** or **VC-N** because the open-delta connection blocks zero-sequence voltage information. Relay functions that require zero-sequence voltage may be disabled, unless another $3V_0$ voltage source is supplied to the relay via terminal **VS-NS** (see *Broken-Delta VS Connection (Global Setting VSCONN = 3V0)* on page 2.13).

Referring to *Figure 2.26* and *Figure 2.27*, when Global setting PTCONN = DELTA, the relay interprets the voltage signal detected across the **VA-N** terminals as V_{AB}, and the voltage signal detected across the **VC-N** terminals as V_{CB} (or $-V_{BC}$). Phase-to-phase voltage V_{CA} is derived internally with the equation $V_{CA} = V_{CB} - V_{AB}$. The relay does not use the voltage signal detected across the **VB-N** terminals, which should effectively be zero because of the jumper between **VB** and **N**. Unfiltered (raw) event reports are the only means by which signals applied to relay voltage terminals **VA-N**, **VB-N**, and **VC-N** can be directly observed. See *Unfiltered Event Reports With PTCONN = DELTA* on page 12.18.

System frequency is determined from V_{alpha} (refer to *Table 3.16* for PTCONN = DELTA).

Additionally, voltage input **VS-NS** measures frequency on the other side of an open breaker for synchronism-check applications (see *Synchronism-Check Elements* on page 3.36).

Single-Phase Voltage Connection (Global Setting PTCONN = SINGLE)

Some installations do not have all three voltage phases available to connect to the relay. In those cases the relay will retain some of the voltage-based functions as shown in *Table 2.1* if you connect a single-phase voltage to the VA input of the relay. Make Global setting PTCONN = SINGLE to enable the relay to make use of a single-phase voltage connected to the VA input. When Global setting PTCONN = SINGLE, additional Global setting PHANTV becomes available.

Use setting PHANTV to inform the relay of the source of the single-phase voltage connected to VA. For example, if the single-phase voltage connected to VA is actually derived from the power system VBC phase-to-phase voltage, then set PHANTV = VBC. When PHANTV ≠ OFF, the relay uses the single-phase voltage at VA to create a balanced, three-phase set of virtual voltage inputs. The relay uses setting PHANTV to properly adjust for phase and magnitude so the relay meters accurately, as if a balanced three-phase set of voltages were connected to the relay. Setting PHANTV does not impact relay protection algorithms in any way. It is only used to create phantom phase voltages for the purposes of metering.

With a single-phase voltage connected to the **VA-N** input (refer to the frequency in *Table 3.17*), the relay accurately measures and tracks the frequency of the power system even if PHANTV = OFF. When the VA-N voltage is unavailable for more than two seconds, the relay sets the measured frequency to nominal, as selected by Global setting NFREQ.

Throughout this instruction manual, relay functions, specifications, or features that are different for delta-connected, wye-connected, and single-phase PTs are identified, either with “wye-connected”, “delta-connected”, or “single-phase” text, or with “PTCONN = WYE”, “PTCONN = DELTA”, or “PTCONN = SINGLE” text.

Table 2.1 Voltage-Based Functions Retained When Single-Phase Voltage Connected to Relay

Feature/Element	Available When Single-Phase Voltage Connected to VA and Global Setting PTCONN = SINGLE
Overcurrent	Yes
Overvoltage, Undervoltage	Phase (not phase-to-phase or sequence) elements enabled
Synchronism Check	Yes
Frequency Elements	Yes
Frequency Tracking	Yes
Frequency Estimation	Yes
Voltage Sag, Swell, Interruption	Disabled
Power Elements	Single-phase power elements function properly if voltages and currents from the same system are connected to the phase inputs on the relay. See *Special Considerations for Using Power Elements When PTCONN = SINGLE* on page 3.74.
Loss-of-Potential	Disabled
Load Encroachment	Disabled
Directional Control	Current-polarized elements enabled, zero-sequence voltage-polarized elements enabled if Global setting VSCONN = 3V0
Energy Metering	Available when Global setting PHANTV ≠ OFF
Min/Max Metering	Yes
Synchrophasors	IEEE-C37.118 only. See *Appendix N: Synchrophasors* for more information.
Load Profile	VS reports normally. Other voltages report according to PHANTV settings.
Fault Locator	Disabled
Communications-Assisted Tripping (ECOMM)	Disabled

Synchronism Check VS Connection (Global Setting VSCONN = VS)

When setting VSCONN = VS, voltage input **VS** is in its traditional role of voltage input for the synchronism-check elements. *Figure 2.15–Figure 2.18*, *Figure 2.27*, and *Figure 2.28* show examples of synchronism-check voltage inputs applied to relay terminals **VS-NS**. See *Synchronism-Check Elements* on page 3.36.

Broken-Delta VS Connection (Global Setting VSCONN = 3V0)

Global setting VSCONN = 3V0 adjusts the relay to accept a $3V_0$ zero-sequence voltage signal connected to voltage input **VS-NS**. This signal is usually derived from PTs connected wye (primary)/broken-delta (secondary):

$$V_S = V_A + V_B + V_C = 3V_0.$$

This signal is passed to certain relay functions that require zero-sequence voltage, such as zero-sequence voltage-polarized ground directional elements or wattmetric and incremental conductance elements (for Petersen Coil-grounded systems). Because setting VSCONN = 3V0, these elements use the $3V_0$ zero-sequence voltage measured by the **VS-NS** voltage input, even if wye-connected PTs are connected to voltage inputs VA-VB-VC-N (PTCONN = WYE; see *Figure 2.11*).

To prevent a broken-delta voltage source from exceeding the rated voltage of the relay voltage inputs, some applications require an external step-down transformer. *Figure 2.9* and *Figure 2.11* show the PT wiring, including an instrumentation step-down transformer, for using relay terminals **VS-NS** as a zero-sequence voltage source. Group setting PTRS accommodates the ratio of the step-down transformer. See *Settings Explanations* on page 9.17 for an example setting of PTRS when VSCONN = 3V0. For a complete listing of the changes caused by setting VSCONN = 3V0, see *Table 9.6*, *Table 9.7*, and related discussions.

Selecting Global setting VSCONN = 3V0 disables the synchronism-check element. Therefore, input terminals **VS-NS** cannot be used for zero-sequence voltage measurement and as a synchronism-check voltage input at the same time.

Polarity Check for VSCONN = 3V0

Refer to *Figure 2.9* (wye-connected PTs) or *Figure 2.11* (open-delta-connected PTs). With setting VSCONN = 3V0, voltage input **VS** (terminals **VS-NS**) expects $3V_0$ voltage ($V_S = 3V_0 = V_A + V_B + V_C$) with the polarity shown. However, in a nonfault, balanced system condition, voltage $V_S = 3V_0 \approx 0$. The result is that a polarity problem with voltage input **VS**, such as when secondary wires on terminals **VS-NS** are on the wrong terminals, will not necessarily be apparent until a ground fault occurs or testing is performed.

Wye-Connected PT Example

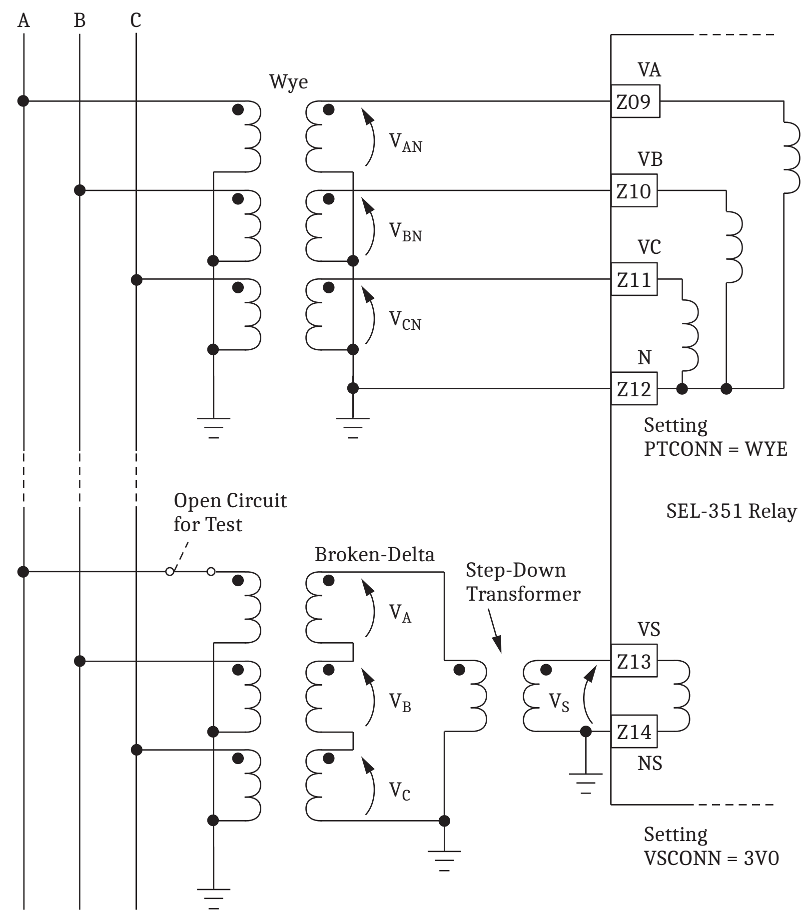


Figure 2.9 Broken-Delta Secondary Connection to Voltage Input VS, Wye-Connected PTs

To verify the correct polarity on voltage input **VS**, perform the following test on the primary side of one of the PTs connected in broken-delta secondary (refer to *Figure 2.9*) and observe the resultant voltage phase angle differences:

Open circuit the primary side of the PT connected to power system phase A. With the resultant collapse of secondary voltage V_A ($V_A = 0$) in the broken-delta secondary circuit, the voltage at voltage input **VS** is:

$$V_S = 3V_0 = V_A + V_B + V_C = V_B + V_C$$

Figure 2.10 shows the resultant voltage V_S, with respect to the wye-connected power system voltages connected to the voltage inputs **VA**, **VB**, **VC** (ABC rotation used in this example). For this scenario of the collapse of secondary voltage V_A ($V_A = 0$) in the broken-delta secondary, note that voltage V_S is 180 degrees out-of-phase with voltage V_A (from voltage input **VA**).

Use the **METER** command (via serial port or front panel) to compare these voltage phase angles. If the phase angle difference between V_S and V_A is 180 degrees (within a few degrees), then the polarity of voltage input **VS** is deemed correct. If the phase angle difference between V_S and V_A is 0 degrees (again, within a few degrees), then the secondary wires from the broken-delta secondary in *Figure 2.9* need to be swapped in connection to terminals **VS-NS**.

NOTE: "3V0" in the **METER** command (via serial port or front panel) is derived internally from the **VA**, **VB**, and **VC** voltage inputs, not from voltage input **VS**, regardless of setting VSCONN.

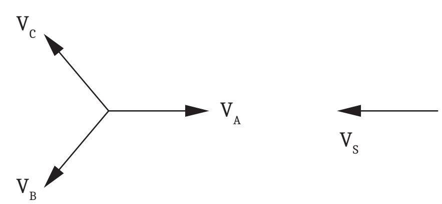


Figure 2.10 Resultant Voltage V_S From the Collapse of Voltage V_A in the Broken-Delta Secondary (Compared to the Wye-Connected Power System Voltages)

Open-Delta-Connected PT Example

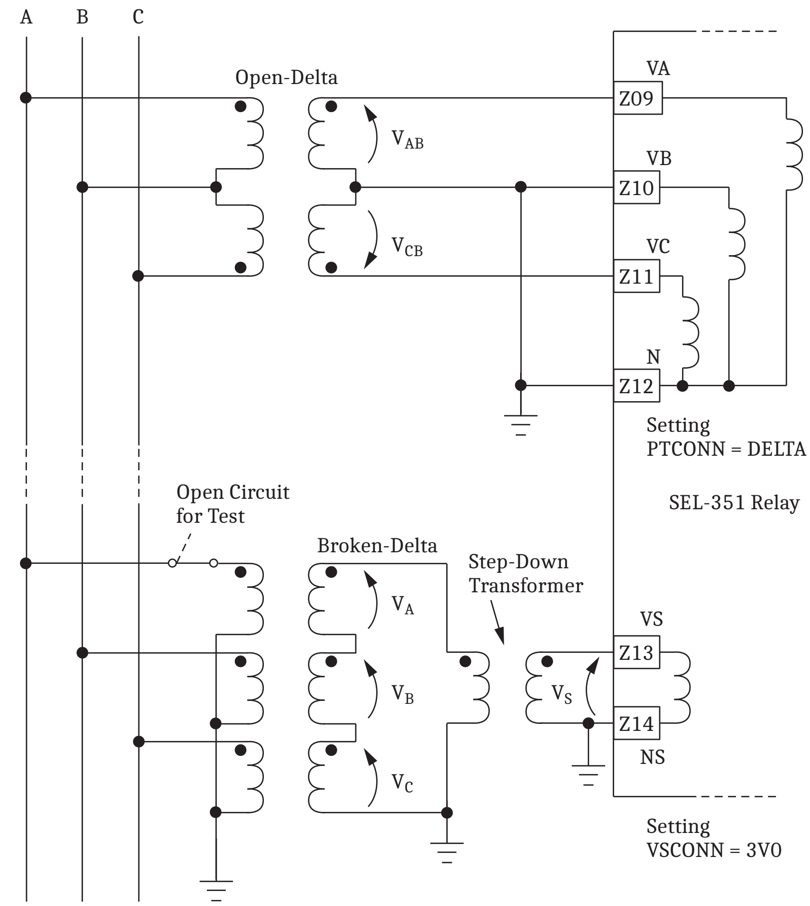


Figure 2.11 Broken-Delta Secondary Connection to Voltage Input VS, Delta-Connected PTs

To verify the correct polarity on voltage input **VS**, perform the following test on the primary side of one of the PTs connected in broken-delta secondary (refer to *Figure 2.11*) and observe the resultant voltage phase angle differences.

Open circuit the primary side of the PT connected to power system phase A. With the resultant collapse of secondary voltage V_A ($V_A = 0$) in the broken-delta secondary circuit, the voltage at voltage input **VS** is:

$$V_S = 3V_0 = V_A + V_B + V_C = V_B + V_C$$

Figure 2.12 shows the resultant voltage V_S, with respect to the delta-connected power system voltages connected to the voltage inputs **VA**, **VB**, **VC** (ABC rotation used in this example). For this scenario of the collapse of secondary voltage V_A ($V_A = 0$) in the broken-delta secondary, note that voltage V_S is 150 degrees out-of-phase with voltage V_{AB} (from voltage input **VA**).

Use the **METER** command (via serial port or front panel) to compare these voltage phase angles. If the phase angle difference between V_S and V_{AB} is 150 degrees (within a few degrees), then the polarity of voltage input **VS** is deemed correct. If the phase angle difference between V_S and V_{AB} is 30 degrees (again, within a few degrees), then the secondary wires from the broken-delta secondary in *Figure 2.11* need to be swapped in connection to terminals **VS-NS**.

NOTE: When the relay is connected to open-delta PTs and Global setting PTCONN = DELTA, there is no "3V0" value in the **METER** command (via serial port or front panel).

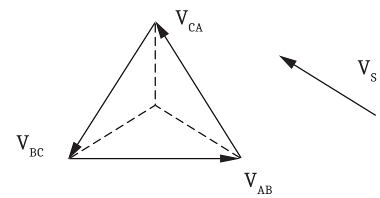


Figure 2.12 Resultant Voltage V_S From the Collapse of Voltage V_A in the Broken-Delta Secondary (Compared to the Delta-Connected Power System Voltages)

Making Communications Connections

USB Port

The optional front-panel USB port is intended for fast local access to the relay. Use SEL cable C664 to connect a personal computer to the relay USB port. See *Establishing Communications Using the USB Port* on page 10.2.

Ethernet Ports

The SEL-351 is equipped with either one or two fiber-optic or twisted-pair rear-panel Ethernet ports. Connect the relay to an Ethernet switch using SEL fiber-optic cable C808 with LC connectors, or SEL CAT5 cable C627 with RJ45 connectors. Many computers support auto-crossover, so cable C627 can also be used to connect the relay directly to these computers. For computers that do not support auto-crossover, use crossover cable C628. See *Establishing Communications Using an Ethernet Port and Telnet or the Read-Only Web Server* on page 10.6.

The 1300 nm fiber-optic Ethernet ports are designed for 62.5 µm fiber with LC connectors. The total link budget is 11 dB. See the Fiber-Optic Products and Applications data sheet on the SEL website for instructions on how to calculate fiber system losses.

Serial Ports

Optional serial **PORT 1** on all the SEL-351 models is either a 4-wire EIA-485 port or an SEL-2812 compatible fiber-optic port. Either option can be configured for SEL ASCII, SEL LMD, Modbus, DNP3, PMU, or MIRRORED BITS protocols. The EIA-485 plug-in connector accepts wire size AWG 24 to 12. Strip the wires 0.31 inches (8 mm) and install with a small slotted-tip screwdriver.

The optional 820 nm fiber-optic serial port is designed for multimode fiber with ST connectors. *Table 2.2* shows the link budget when the SEL-351 is connected to various SEL devices.

NOTE: The fiber-optic serial port transmitter has a metal barrel. The receiver has a plastic barrel.

Table 2.2 Link Budget for Fiber-Optic Serial Ports

Multimode Fiber Size	Link Budget Typical[a] (Minimum[b])	Fiber Loss	Maximum Distance Typical[a] (Minimum[b])
200 µm	20 dB (12 dB)	–10.6 dB/km	1.9 km (1.1 km)
62.5/125 µm	15 dB (8 dB)	–4 dB/km	3.8 km (2.0 km)
50/125 µm	9.6 dB (4.2 dB)	–4 dB/km	2.4 km (1.0 km)

[a] +26 °C.
[b] –40 to +85 °C.

See the Fiber-Optic Products and Applications data sheet on the SEL website for instructions on how to calculate fiber system losses. When paired with an SEL-2812MT or SEL-2812FT fiber-optic transceiver and SEL communications processor, automation controller, or satellite-synchronized clock, the fiber-optic serial port operates as an IRIG-B input, in addition to providing serial communications.

All EIA-232 ports accept 9-pin D-subminiature male connectors. **PORT 2** and **PORT 3** can be configured for SEL ASCII, SEL LMD, Modbus, DNP3, PMU, or MIRRORED BITS protocols. **PORT 1** can be configured for SEL ASCII, SEL LMD, DNP3, PMU, or MIRRORED BITS protocols. **PORT 2** on all the SEL-351 models includes the IRIG-B time-code signal input (see *Table 10.4*; see following discussion on IRIG-B time-code input).

The pin definitions for all the ports are detailed in *Table 10.4–Table 10.6*.

Refer to *Table 2.3* for a list of cables available from SEL for various communication applications. Refer to *Communications Cables* on page 10.12 for detailed cable diagrams for selected cables.

NOTE: Listing of devices not manufactured by SEL in *Table 2.3* is for the convenience of our customers. SEL does not specifically endorse or recommend such products, nor does SEL guarantee proper operation of those products, or the correctness of connections, over which SEL has no control.

For example, to connect any EIA-232 port to the 9-pin male connector on a laptop computer, order cable number C234A and specify the length needed (standard length is eight feet). To connect the SEL-351 **PORT 2** to an SEL Communications Processor or Automation Controller that supplies the communication link and the IRIG-B time synchronization signal, order cable number C273A. For connecting devices at distances farther than 50 feet, SEL offers fiber-optic transceivers. The SEL-2800 family of transceivers provides fiber-optic links between devices for electrical isolation and long distance signal transmission. Contact SEL for further information on these products.

Table 2.3 Communication Cables to Connect the SEL-351 to Other Devices

SEL-351 EIA-232 Serial Ports	Connect to Device (gender refers to the device)	SEL Cable No.
All EIA-232 ports	PC, 25-Pin Male (DTE)	C227A
All EIA-232 ports	Laptop PC, 9-Pin Male (DTE)	C234A
All EIA-232 ports	PC, USB	C662
Front-panel USB port	PC, USB	C664
All EIA-232 ports	SEL Communications Processor, Automation Controller, or SEL-2100 without IRIG-B	C272A
2	SEL Communications Processor, Automation Controller, SEL-2100 with IRIG-B	C273A
All EIA-232 ports	SEL-PRTU	C231
All EIA-232 ports	SEL-DTA2	C272A
2[a] 3[a]	Port-powered modem, 5 Vdc Powered	C220[a]
All EIA-232 ports	Standard Modem, 25-Pin Female (DCE)	C222

[a] A corresponding main board jumper must be installed to power the modem with +5 Vdc (0.5 A limit) from the SEL-351 (see *Figure 2.30*).

See *Establishing Communications Using a Serial Port* on page 10.1 for more information.

IRIG-B Time-Code Input

The SEL-351 accepts a demodulated IRIG-B time signal to synchronize the relay internal clock with an external source. The demodulated IRIG-B time signal can come via an SEL Communications Processor or the SEL-2100 Logic Processor listed in *Table 2.3*, or from a satellite-synchronized clock, such as the SEL-2407 or SEL-2401. The IRIG-B time signal can be input to the rear-panel BNC connector labeled **IRIG**, to **PORT 2**, or to the optional fiber-optic serial port.

Connect the rear-panel BNC connector directly to a high-accuracy satellite-synchronized clock such as the SEL-2407 or SEL-2401 to synchronize the relay internal clock within one microsecond and enable high-accuracy synchrophasors. See *Appendix N: Synchrophasors* for more information on enabling and using synchrophasors in the SEL-351.

A demodulated IRIG-B time code can be input into serial **PORT 2** by connecting serial **PORT 2** of the SEL-351 to an SEL Communications Processor or Automation Controller using Cable SEL-C273A.

Optional fiber-optic serial **Port 1** can be used to bring IRIG-B Input to the relay as shown in *Figure 2.13* and *Figure 2.14*, or directly from the fiber-optic port of an SEL-2407.

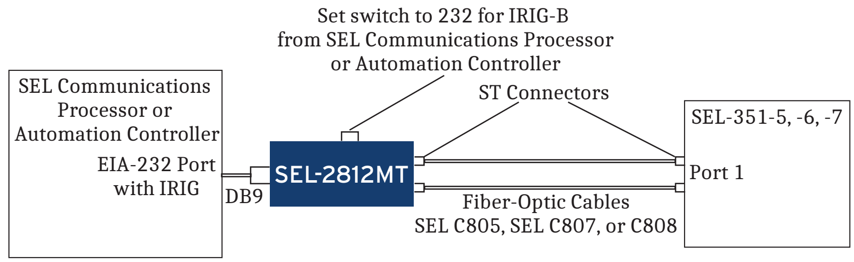


Figure 2.13 IRIG-B Input Via Fiber-Optic Port 1 (SEL Communications Processor or Automation Controller Source)

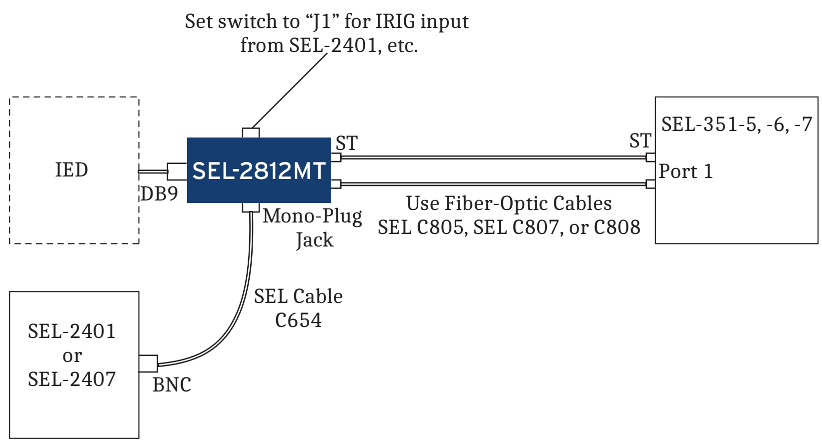


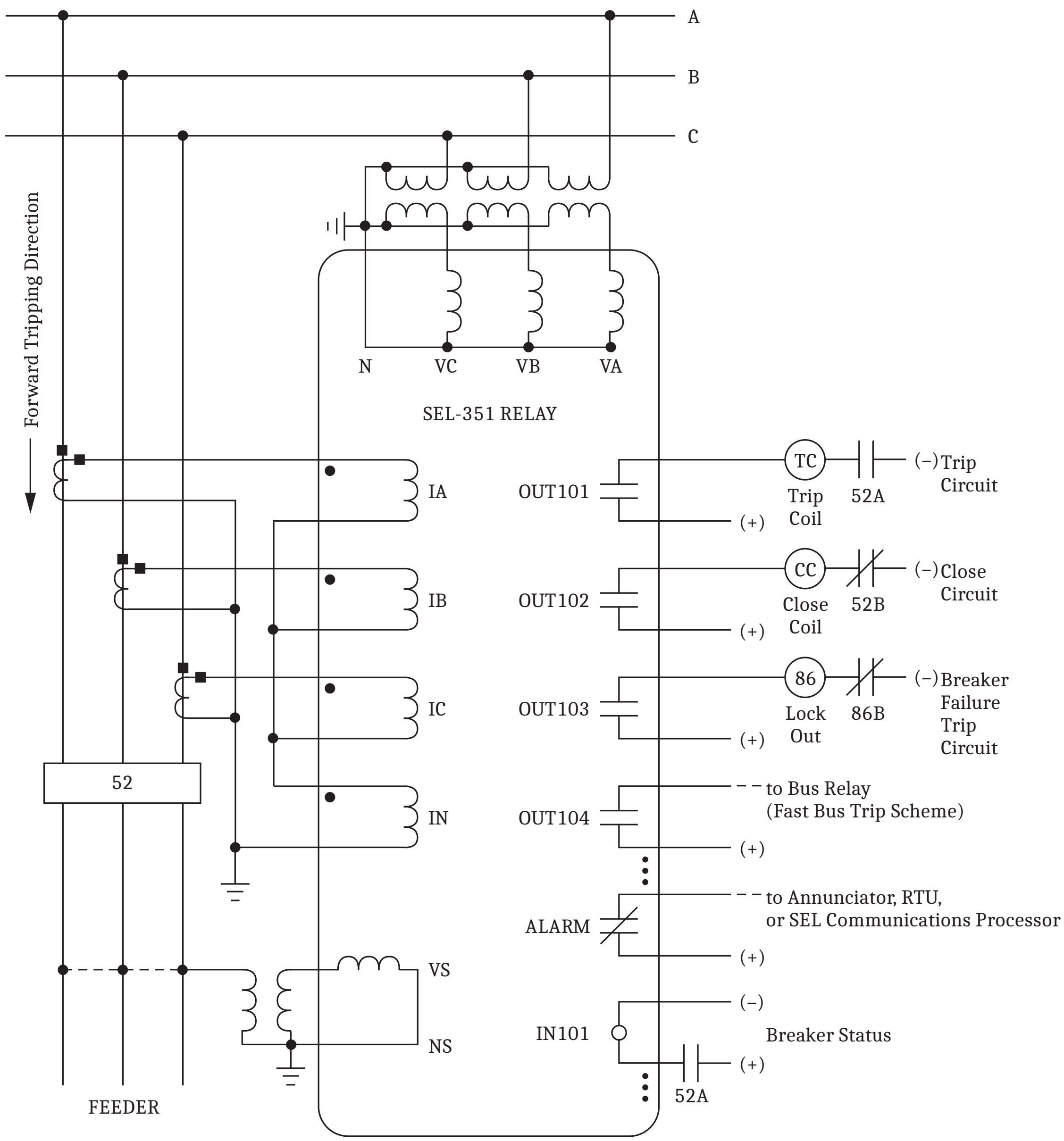
Figure 2.14 IRIG-B Input Via Fiber-Optic Port 1 (SEL-2401/SEL-2407 Time Source)

The IRIG-B signal from the fiber-optic serial port is not suitable for synchrophasor applications.

If IRIG-B signals are connected to multiple inputs, the relay selects the source for time-synchronization in the following order:

1. BNC connector
2. Port 2
3. Optional Port 1 fiber-optic port

SEL-351 AC/DC Connection Diagrams for Various Applications

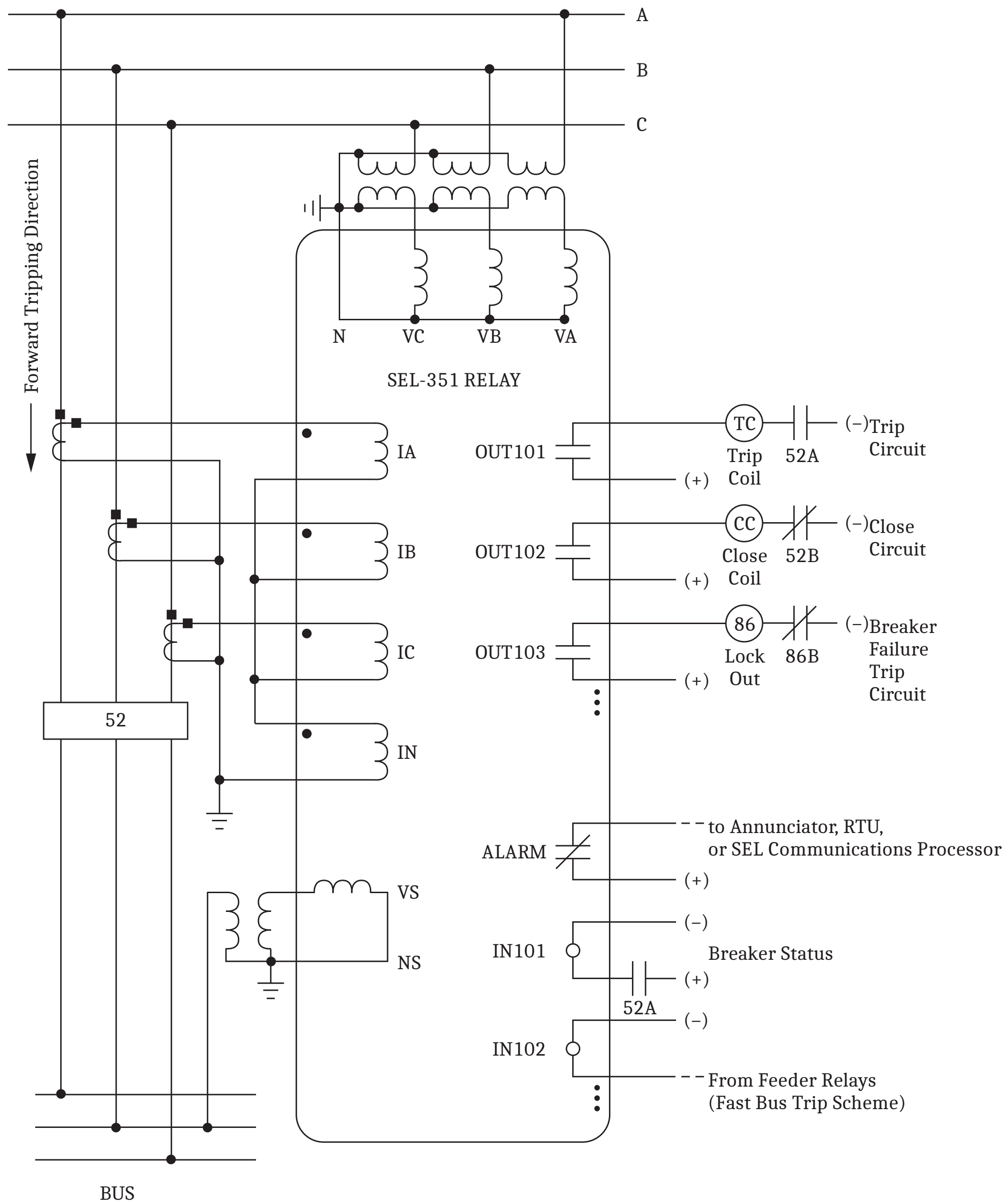


For line recloser control installations (see bottom of *Figure 1.1*), an SEL-351 is connected much like this example.

The voltage inputs do not need to be connected. Voltage is needed for voltage elements, synchronism-check elements, frequency elements, voltage-polarized directional elements, fault location, metering (i.e., voltage, MW, MVAR), frequency tracking, and frequency estimation. Voltage Channel **VS** is shown connected for use in voltage and synchronism-check elements and voltage metering. See *Synchronism Check VS Connection (Global Setting VSCONN = VS)* on page 2.13 and *Broken-Delta VS Connection (Global Setting VSCONN = 3V0)* on page 2.13.

Current Channel **IN** does not need to be connected. Channel **IN** provides current I_N for the neutral-ground overcurrent elements. Separate from Channel **IN**, the residual ground overcurrent elements operate from the internally derived residual current I_G ($I_G = 3I_0 = I_A + I_B + I_C$). But in this residual connection example, the neutral ground and residual ground overcurrent elements operate the same because $I_N = I_G$.

Figure 2.15 Utility Distribution Feeder Overcurrent Protection and Reclosing, Including Fast Bus Trip Scheme (Wye-Connected PTs)



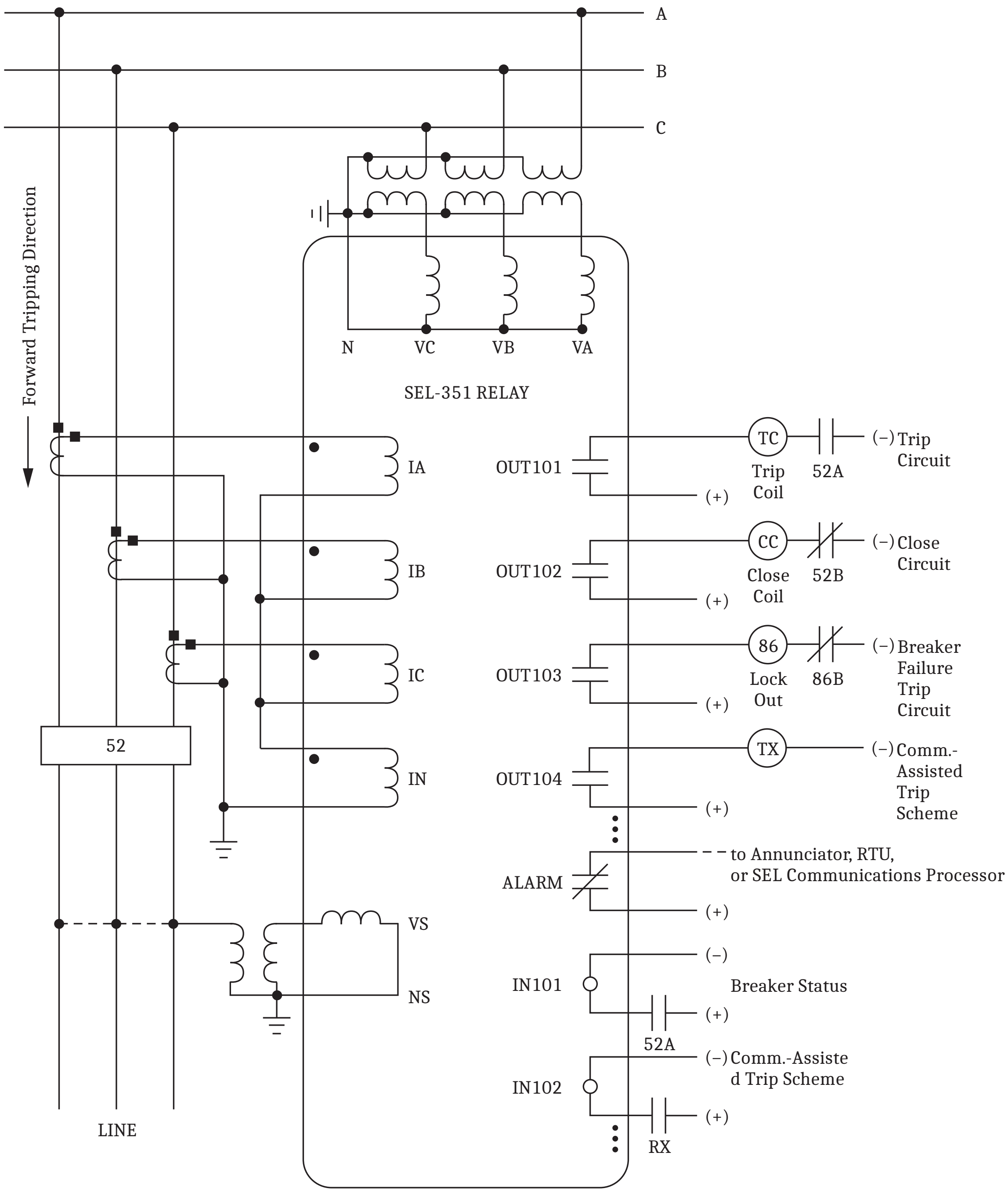
The fast bus trip scheme is often referred to as a reverse-interlocking or zone-interlocking scheme.

The voltage inputs do not need to be connected. Voltage is needed for voltage elements, synchronism-check elements, frequency elements, voltage-polarized directional elements, fault location, metering (i.e., voltage, MW, MVAR), frequency tracking, and frequency estimation. Voltage Channel **VS** is shown connected for use in voltage and synchronism-check elements and voltage metering. See *Synchronism Check VS Connection (Global Setting VSCONN = VS)* on page 2.13 and *Broken-Delta VS Connection (Global Setting VSCONN = 3V0)* on page 2.13. In this example, terminals **VS-NS** are connected B-phase-to-neutral.

Current Channel **IN** does not need to be connected. Channel **IN** provides current I_N for the neutral-ground overcurrent elements. Separate from Channel **IN**, the residual ground overcurrent elements operate from the internally derived residual current I_G ($I_G = 3I_0 = I_A + I_B + I_C$). But in this residual connection example, the neutral ground and residual ground overcurrent elements operate the same because $I_N = I_G$.

Although automatic reclosing is probably not needed in this example, output contact **OUT102** can close the circuit breaker via initiation from various means (serial port communications, optoisolated input assertion, etc.), with desired supervision (e.g., synchronism check).

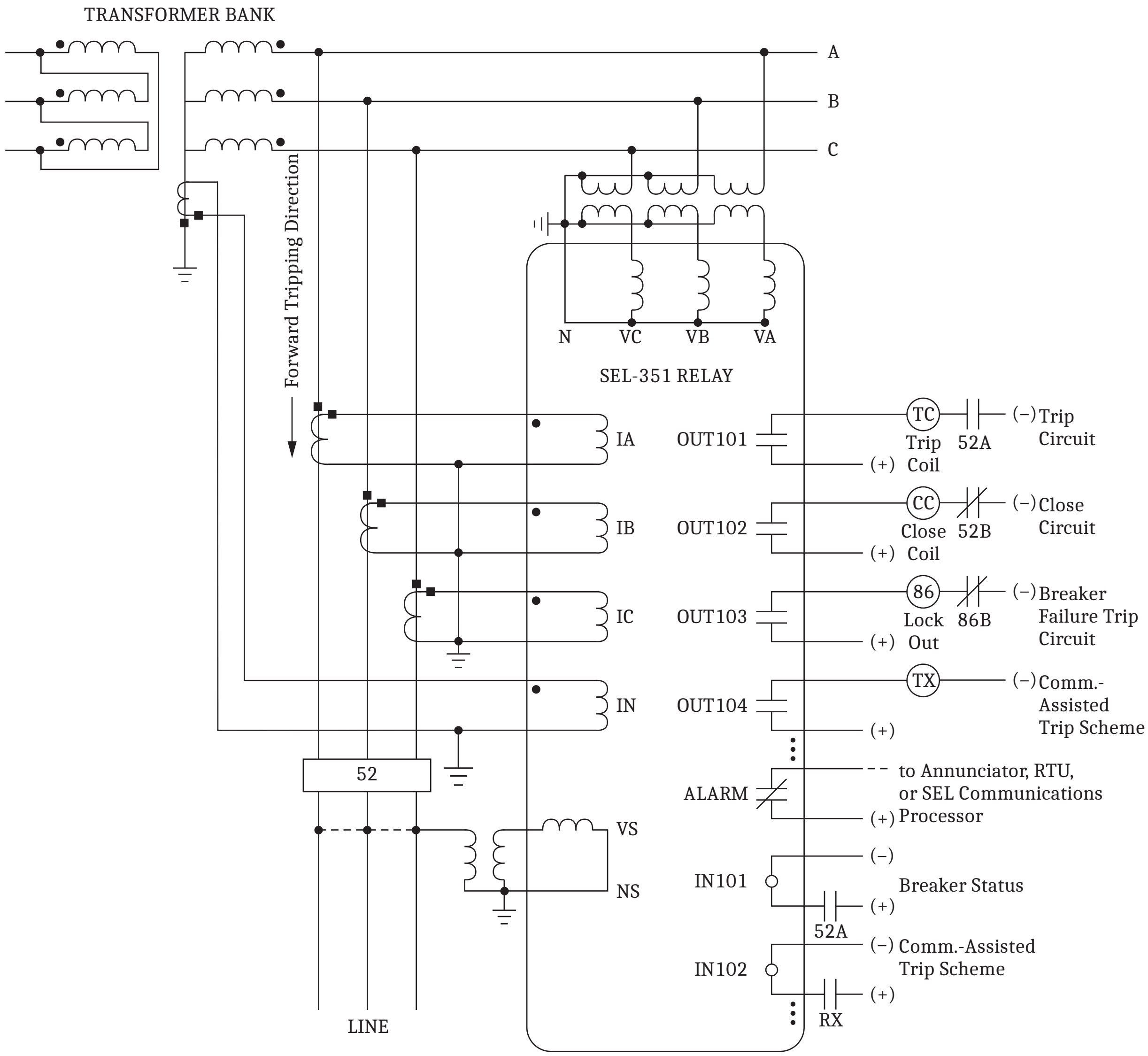
Figure 2.16 Distribution Bus Overcurrent Protection, Including Fast Bus Trip Scheme (Wye-Connected PTs)



Voltage Channel **VS** does not need to be connected. Here, it is shown connected for use in voltage and synchronism-check elements and voltage metering. See *Synchronism Check VS Connection (Global Setting VSCONN = VS)* on page 2.13 and *Broken-Delta VS Connection (Global Setting VSCONN = 3V0)* on page 2.13.

Current Channel **IN** does not need to be connected. Channel **IN** provides current I_N for the neutral-ground overcurrent elements. Separate from Channel **IN**, the residual ground overcurrent elements operate from the internally derived residual current I_G ($I_G = 3I_0 = I_A + I_B + I_C$). But in this residual connection example, the neutral ground and residual ground overcurrent elements operate the same because $I_N = I_G$.

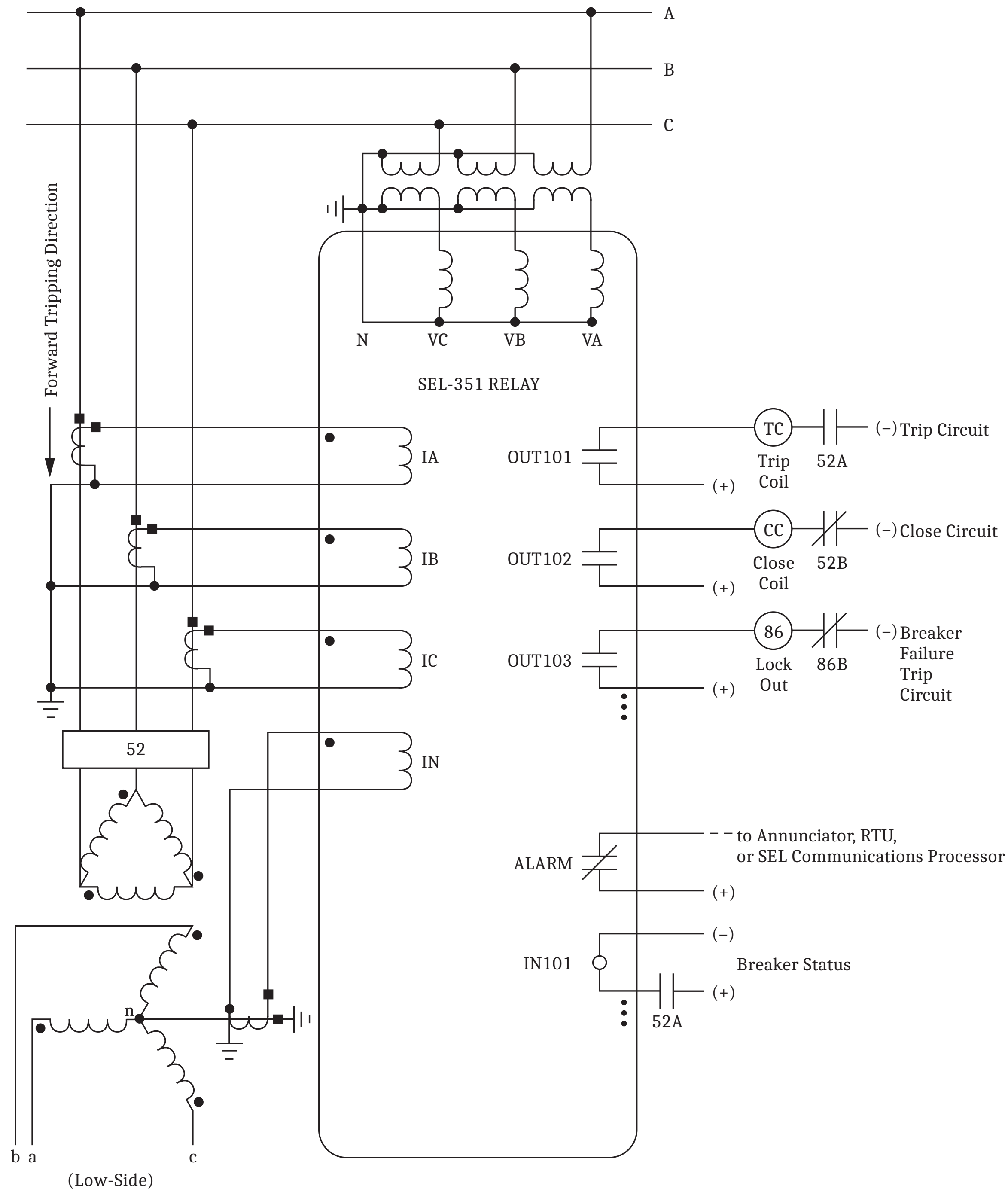
Figure 2.17 Transmission Line Directional Overcurrent Protection and Reclosing (Wye-Connected PTs)



Voltage Channel **VS** does not need to be connected. Here, it is shown connected for use in voltage and synchronism-check elements and voltage metering. See *Synchronism Check VS Connection (Global Setting VSCONN = VS)* on page 2.13 and *Broken-Delta VS Connection (Global Setting VSCONN = 3V0)* on page 2.13.

In this example, current Channel **IN** provides current polarization for a directional element used to control ground overcurrent elements. Separate from Channel **IN**, the residual ground overcurrent elements operate from the internally derived residual current I_G ($I_G = 3I_0 = I_A + I_B + I_C$).

Figure 2.18 Transmission Line Directional Overcurrent Protection and Reclosing With Current-Polarization Source Connected to Channel IN (Wye-Connected PTs)

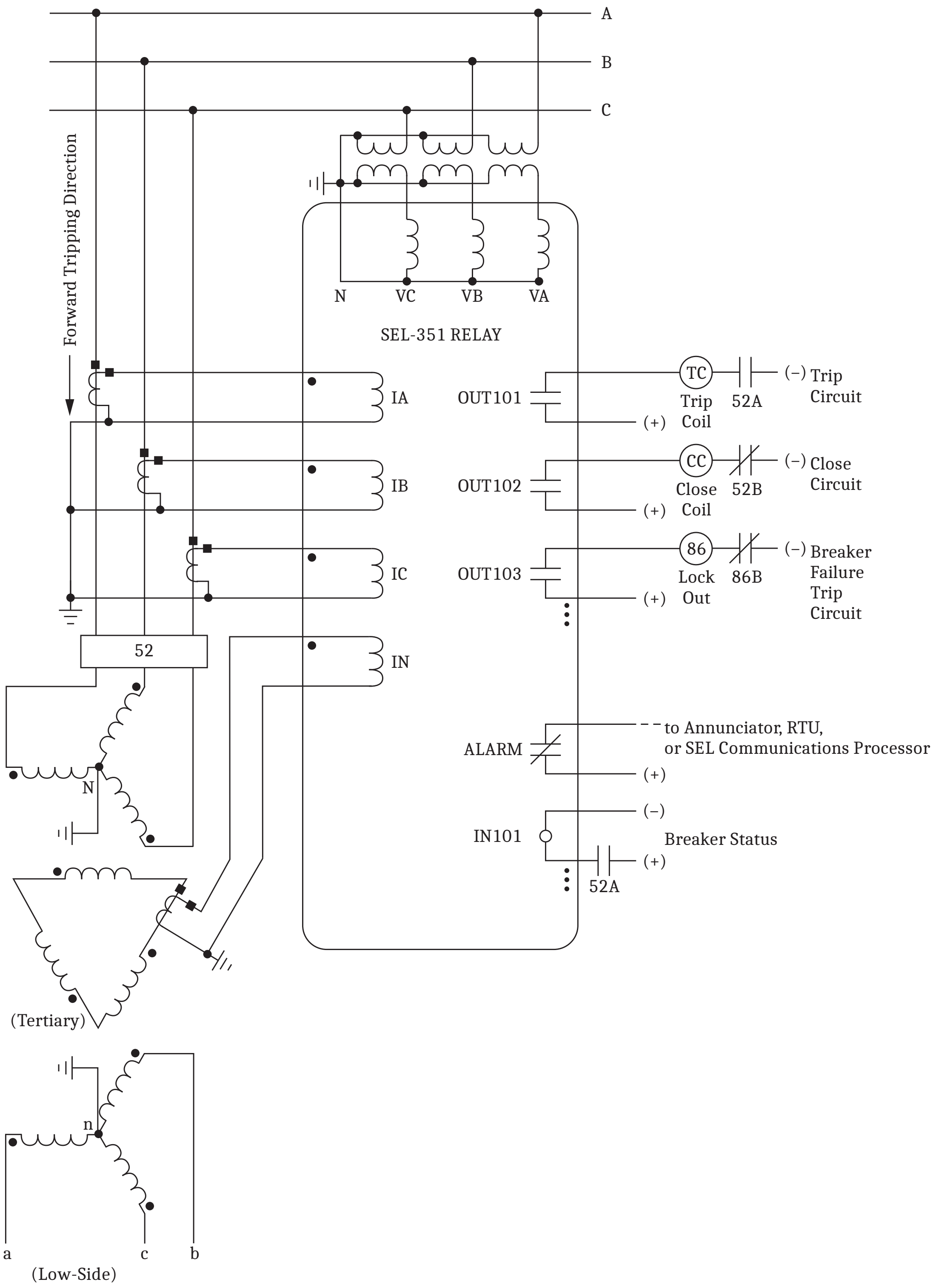


The voltage inputs do not need to be connected. Voltage is needed for voltage elements, synchronism-check elements, frequency elements, voltage-polarized directional elements, fault location, metering (i.e., voltage, MW, MVAR), frequency tracking, and frequency estimation.

Although automatic reclosing is probably not needed in this example, output contact **OUT102** can close the circuit breaker via initiation from various means (serial port communications, optoisolated input assertion, etc.), with desired supervision (e.g., hot bus check).

For sensitive earth fault (SEF) applications, the SEL-351 should be ordered with channel **IN** rated at 0.2 A or 0.05 A nominal. See current input specifications in *General* on page 1.4. See neutral-ground overcurrent element pickup specifications in *Section 3: Overcurrent, Harmonic Blocking, Voltage, Synchronism Check, Frequency, and Power Elements*. See also the note following *Table 4.4*.

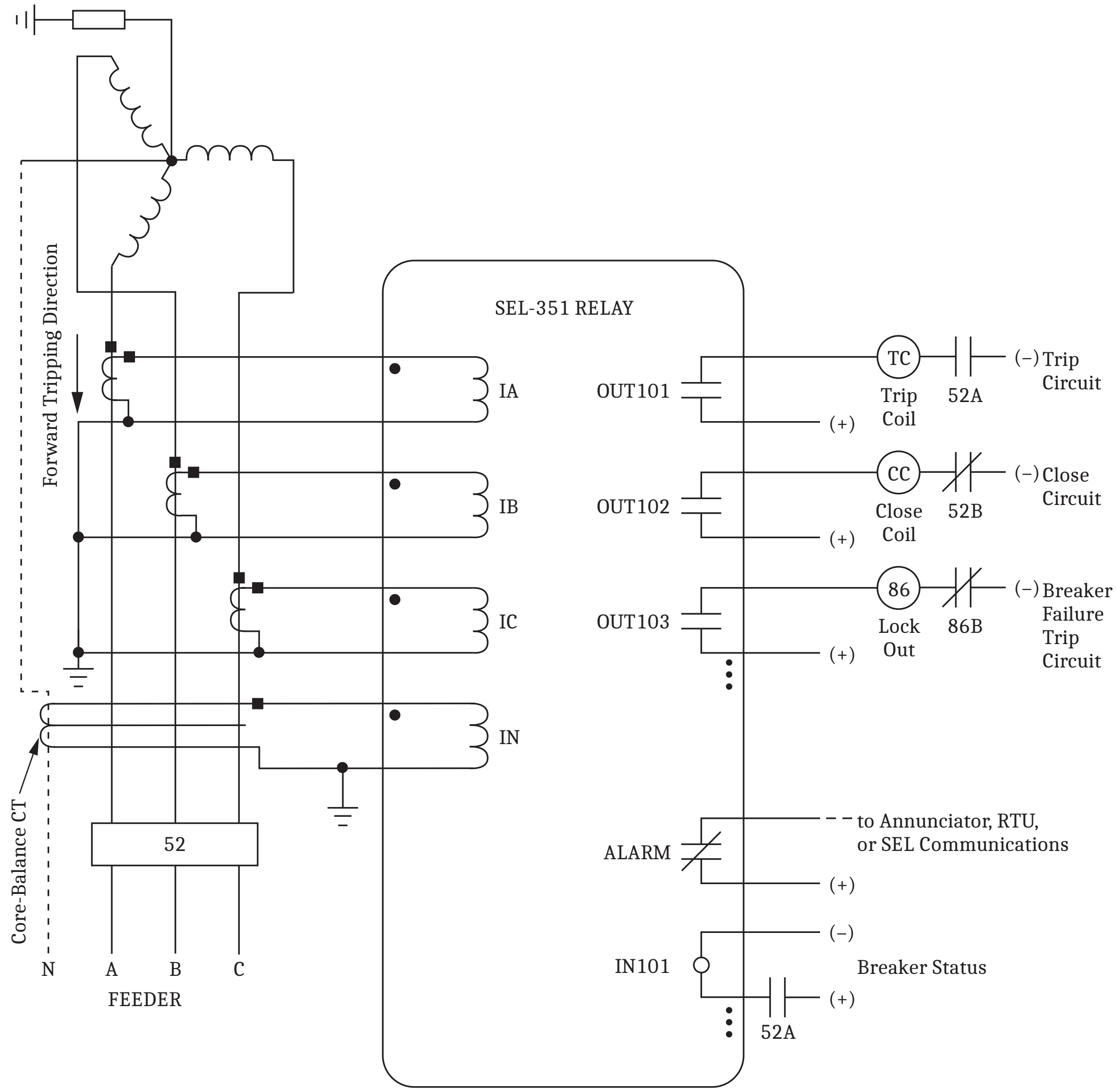
Figure 2.19 Delta Wye Transformer Bank Overcurrent Protection (Wye-Connected PTs)



The voltage inputs do not need to be connected. Voltage is needed for voltage elements, synchronism-check elements, frequency elements, voltage-polarized directional elements, fault location, metering (i.e., voltage, MW, MVAR), frequency tracking, and frequency estimation.

Although automatic reclosing is probably not needed in this example, output contact **OUT102** can close the circuit breaker via initiation from various means (serial port communications, optoisolated input assertion, etc.), with desired supervision (e.g., hot bus check).

Figure 2.20 Overcurrent Protection for a Transformer Bank With a Tertiary Winding (Wye-Connected PTs)



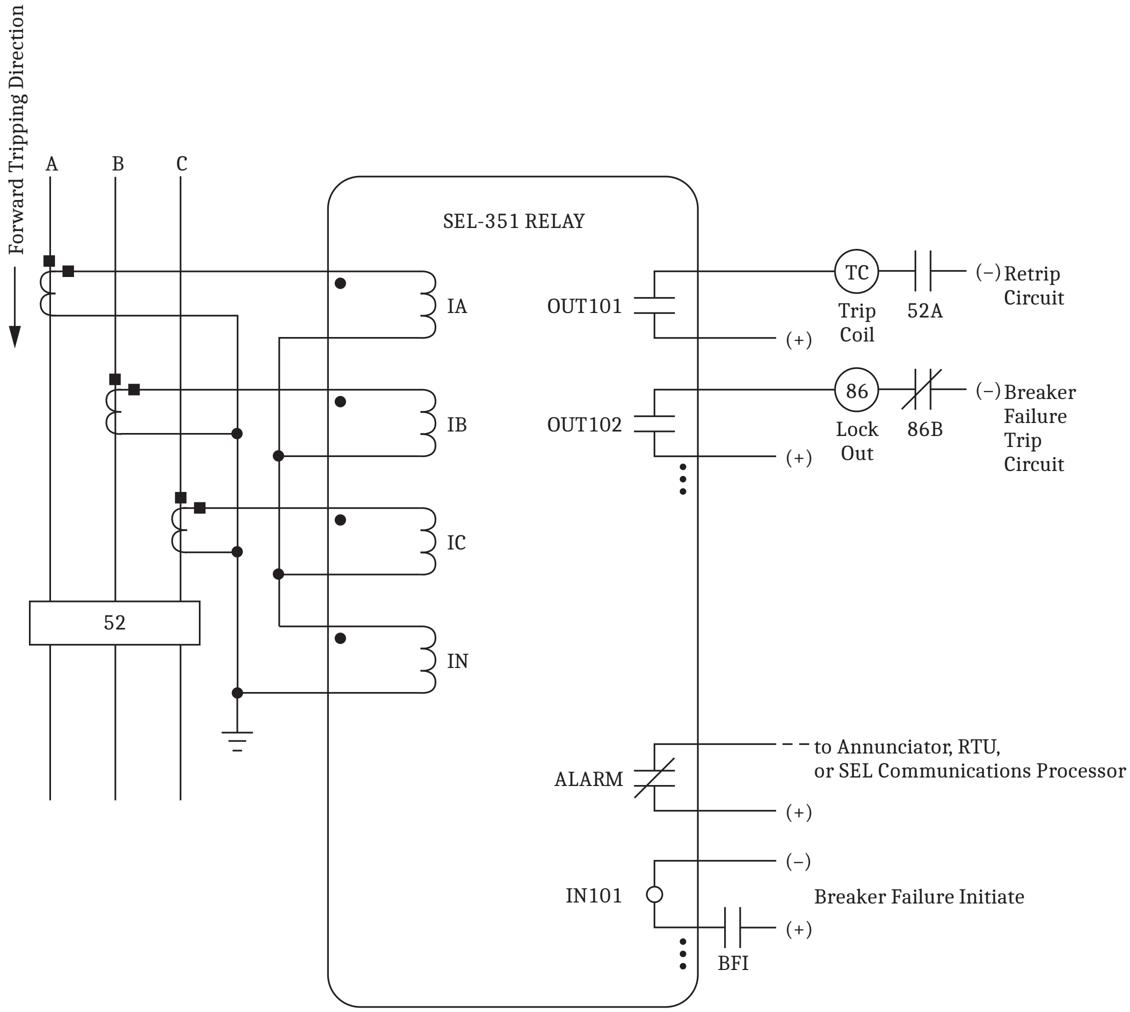
A core-balance current transformer is often referred to as a zero-sequence, ground fault, or window current transformer.

Pass neutral (N) through the core-balance CT only if the neutral is brought out and it is grounded only at the source.

Although automatic reclosing is probably not needed in this example, output contact **OUT102** can close the circuit breaker via initiation from various means (serial port communications, optoisolated input assertion, etc.), with desired supervision.

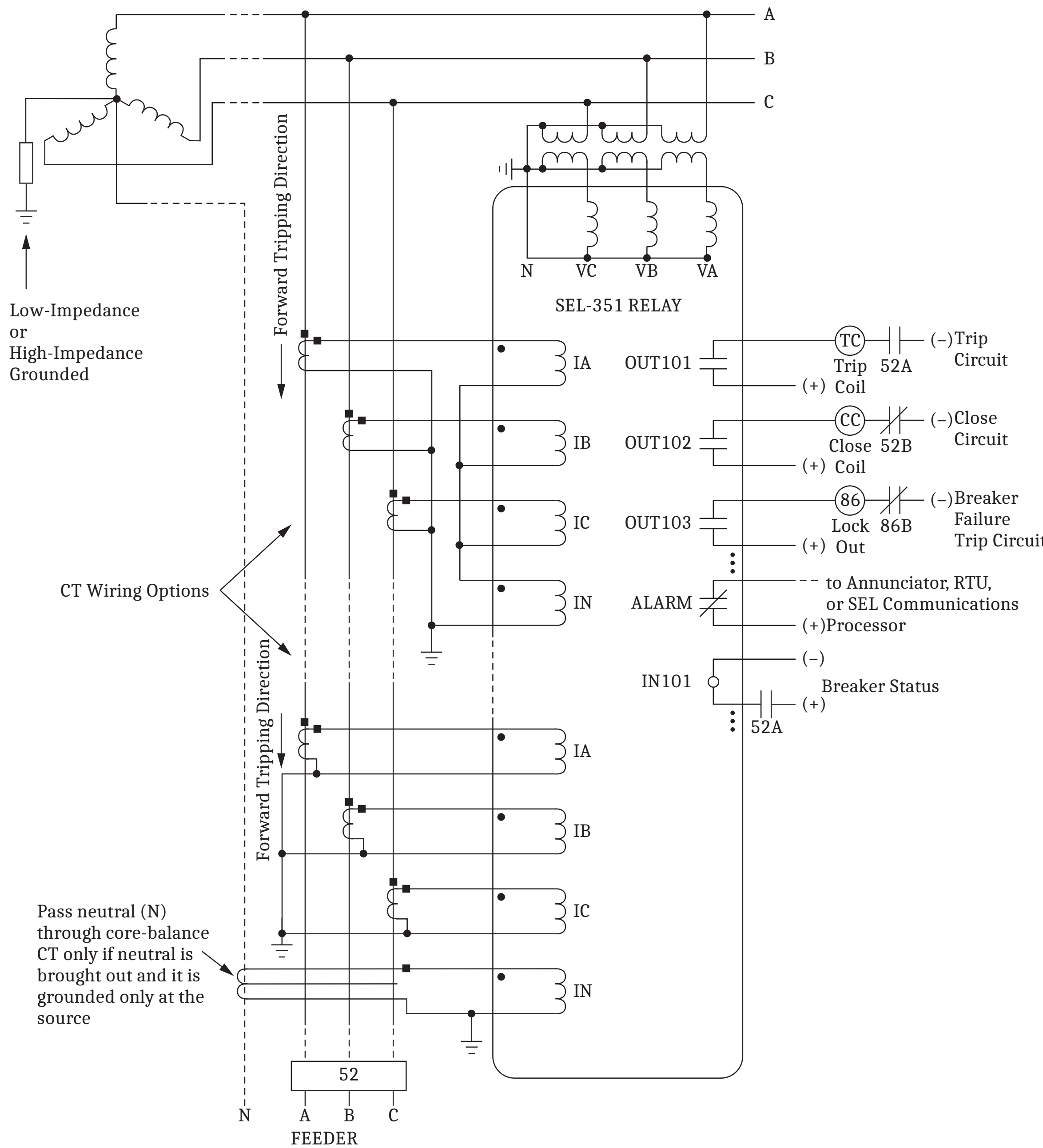
For sensitive earth fault (SEF) applications, the SEL-351 should be ordered with channel **IN** rated at 0.2 A or 0.05 A nominal. See current input specifications in *General* on page 1.4. See neutral-ground overcurrent element pickup specifications in *Section 3: Overcurrent, Harmonic Blocking, Voltage, Synchronism Check, Frequency, and Power Elements*. See also the note following *Table 4.4*.

Figure 2.21 Industrial Distribution Feeder Overcurrent Protection (Core-Balance Current Transformer Connected to Channel IN)



Current Channel **IN** does not need to be connected. Channel **IN** provides current I_N for the neutral-ground overcurrent elements. Separate from Channel **IN**, the residual ground overcurrent elements operate from the internally derived residual current I_G ($I_G = 3I_0 = I_A + I_B + I_C$). But in this residual connection example, the neutral ground and residual ground overcurrent elements operate the same because $I_N = I_G$.

Figure 2.22 Dedicated Breaker Failure Protection

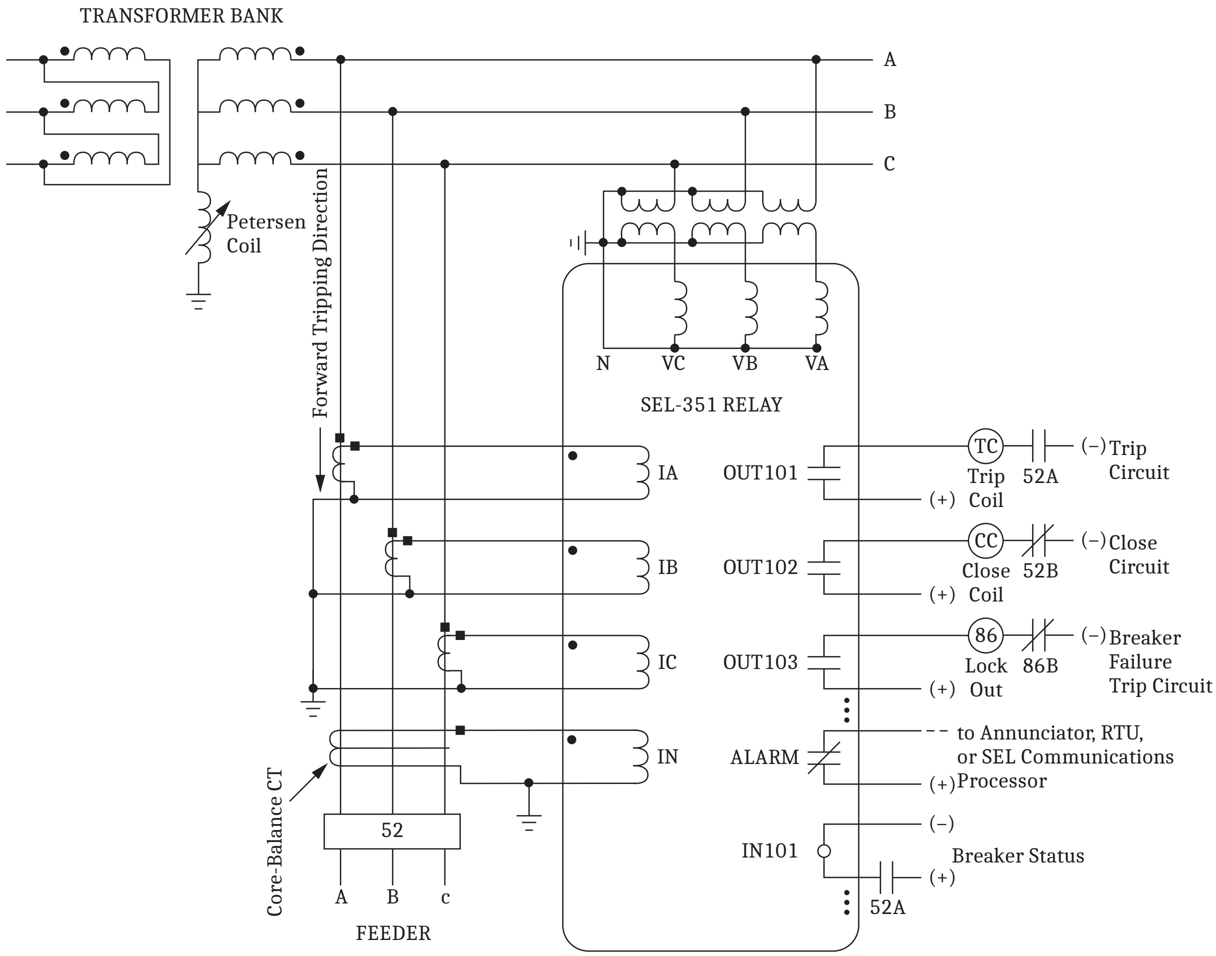


A core-balance current transformer is often referred to as a zero-sequence, ground fault, or window current transformer.

The lower CT wiring option (with the core-balance current transformer) is the preferred option (greater sensitivity; no false residual currents as a result of CT saturation, etc.).

Directional control for a low-impedance grounded system is selected with setting ORDER containing S. Directional control for a high-impedance grounded system is selected with setting ORDER = U (see *Table 4.4–Table 4.6*). Nondirectional sensitive earth fault (SEF) protection is also available.

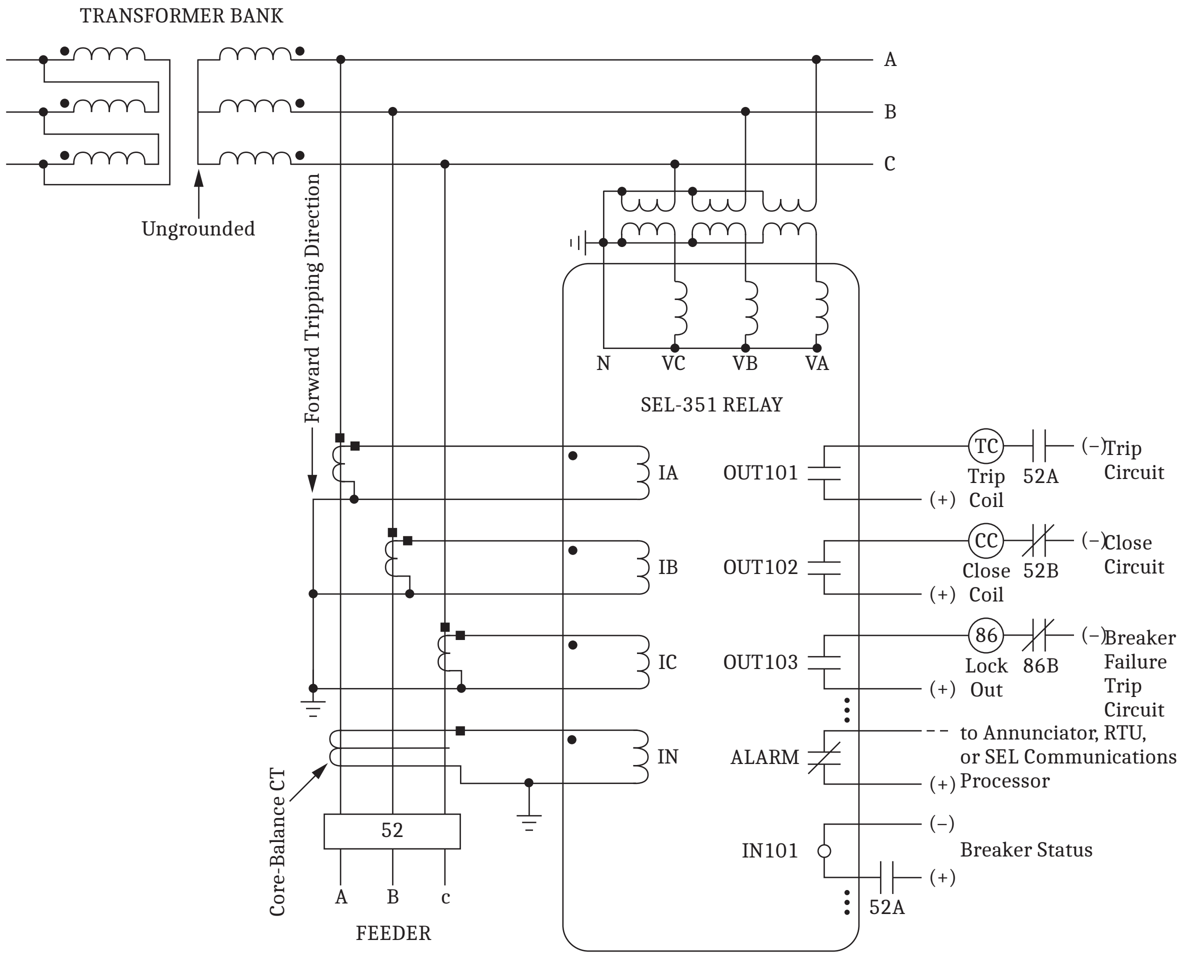
Figure 2.23 Overcurrent Protection for a High-Impedance or Low-Impedance Grounded System (Wye-Connected PTs)



A core-balance current transformer is often referred to as a zero-sequence, ground fault, or window current transformer.

Directional control for a Petersen Coil-grounded system is selected with setting ORDER containing P (see *Table 4.4*–*Table 4.6*). Nondirectional sensitive earth fault (SEF) protection is also available.

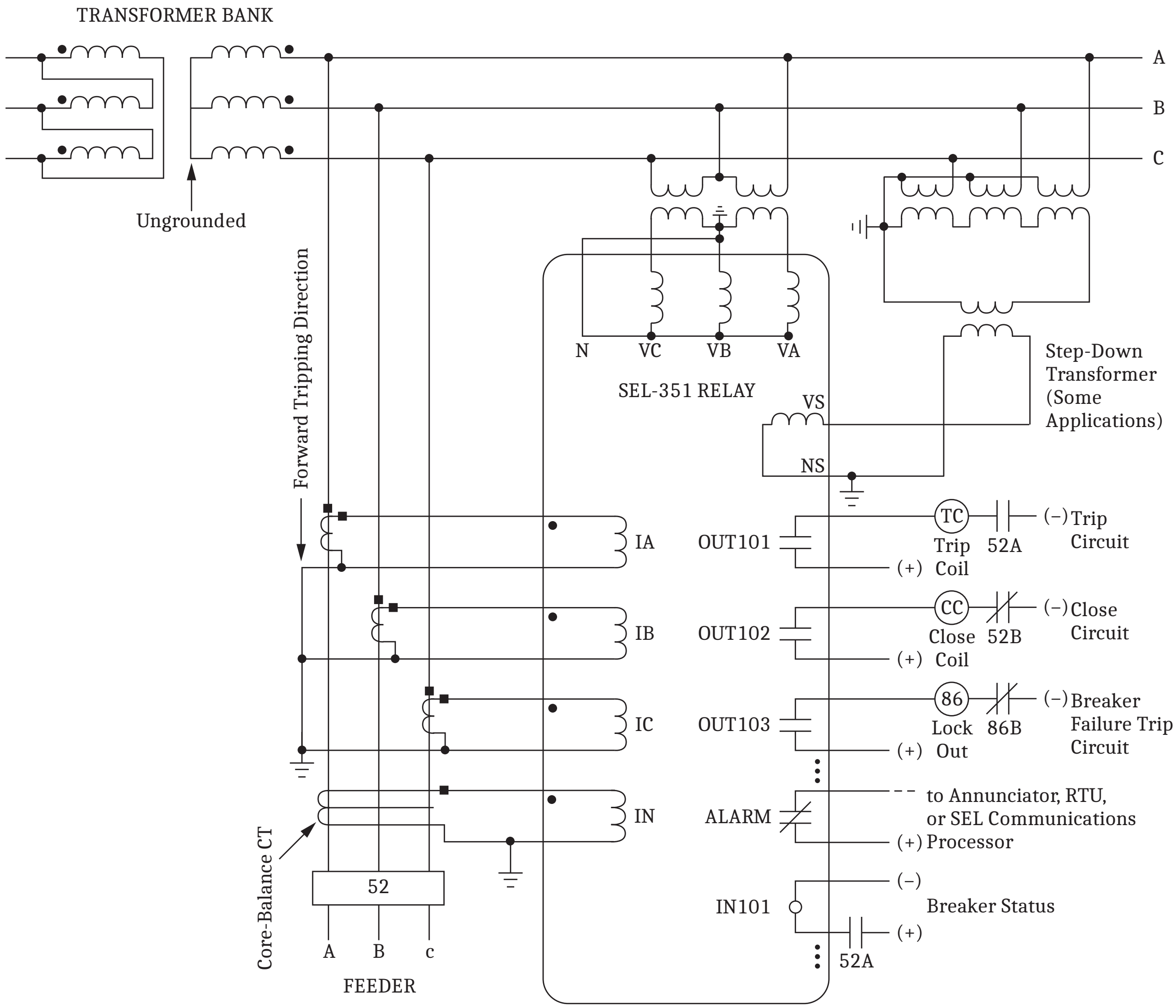
Figure 2.24 Petersen Coil-Grounded System Overcurrent Protection (Wye-Connected PTs)



A core-balance current transformer is often referred to as a zero-sequence, ground fault, or window current transformer.

Directional control for an ungrounded system is selected with setting ORDER = U (see *Table 4.4–Table 4.6*).
Nondirectional sensitive earth fault (SEF) protection is also available.

Figure 2.25 Ungrounded System Overcurrent Protection (Wye-Connected PTs)



A core-balance current transformer is often referred to as a zero-sequence, ground fault, or window current transformer.

Directional control for an ungrounded system is selected with setting ORDER = U (see *Table 4.4–Table 4.6*). Nondirectional sensitive earth fault (SEF) protection is also available.

The voltage inputs can accept open-delta PT (three-wire) connection (as shown) when Global setting PTCONN = DELTA.

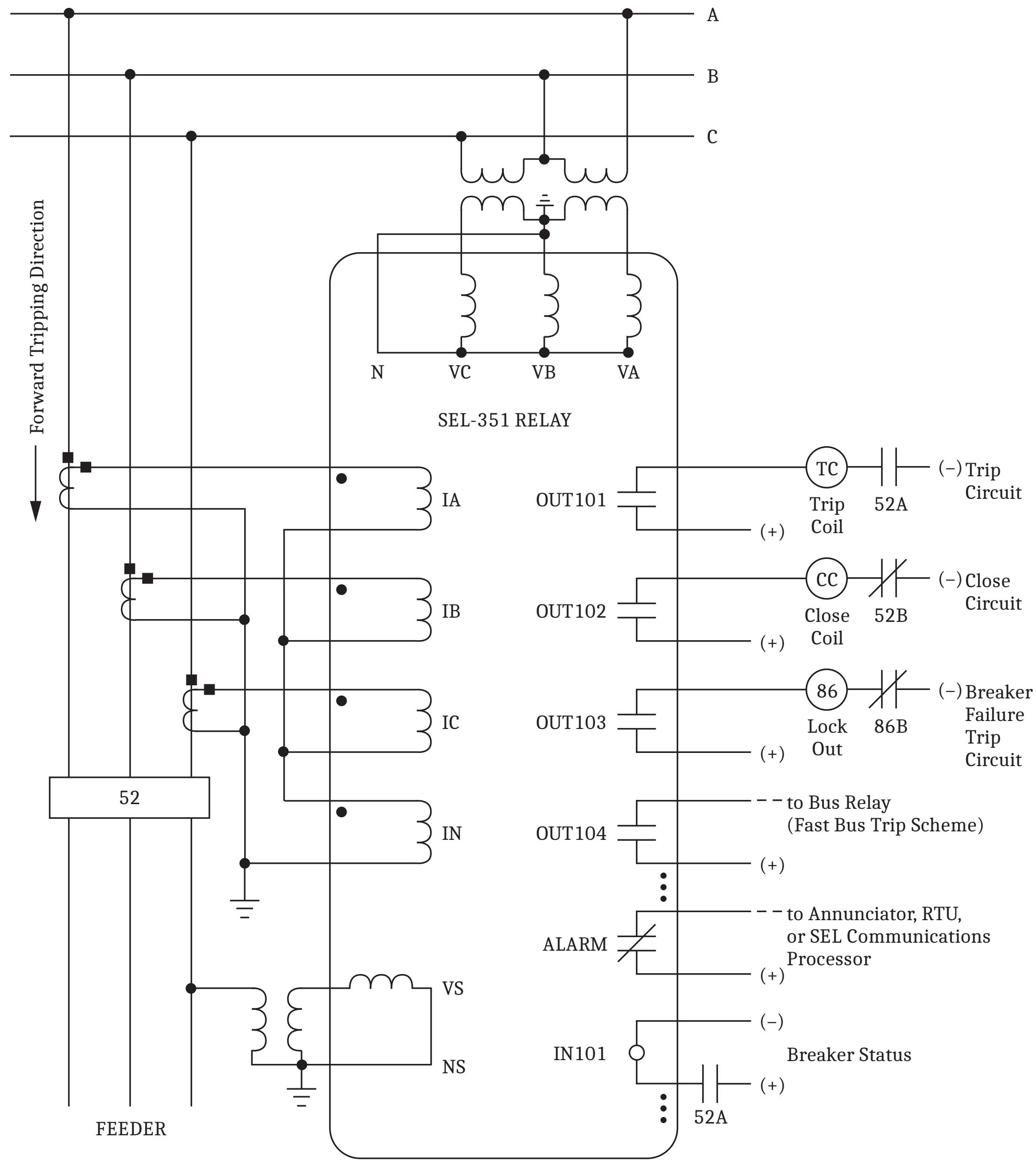
Voltage terminal **VB (Z10)** must be tied to voltage terminal **N (Z12)**, as shown.

The residual voltage 3V0 (from the "broken-delta" connection) is shown coming from a step-down instrumentation transformer, and connecting to relay terminal **VS-NS** (**Z13** and **Z14**, respectively). To use this connection, make Global setting VSCONN = 3V0. Make group setting PTRS as shown in *Section 9: Setting the Relay*.

The step-down transformer is required when the maximum expected residual voltage exceeds the relay voltage channel rating. See *Voltage Input Rating* on page 2.11.

The polarity of the **VS-NS** connection should be verified prior to placing the relay into service. See *Polarity Check for VSCONN = 3V0* on page 2.14 for a suggested procedure.

Figure 2.26 Ungrounded System Overcurrent Protection (Delta-Connected PTs, Broken-Delta 3V0 Connection)



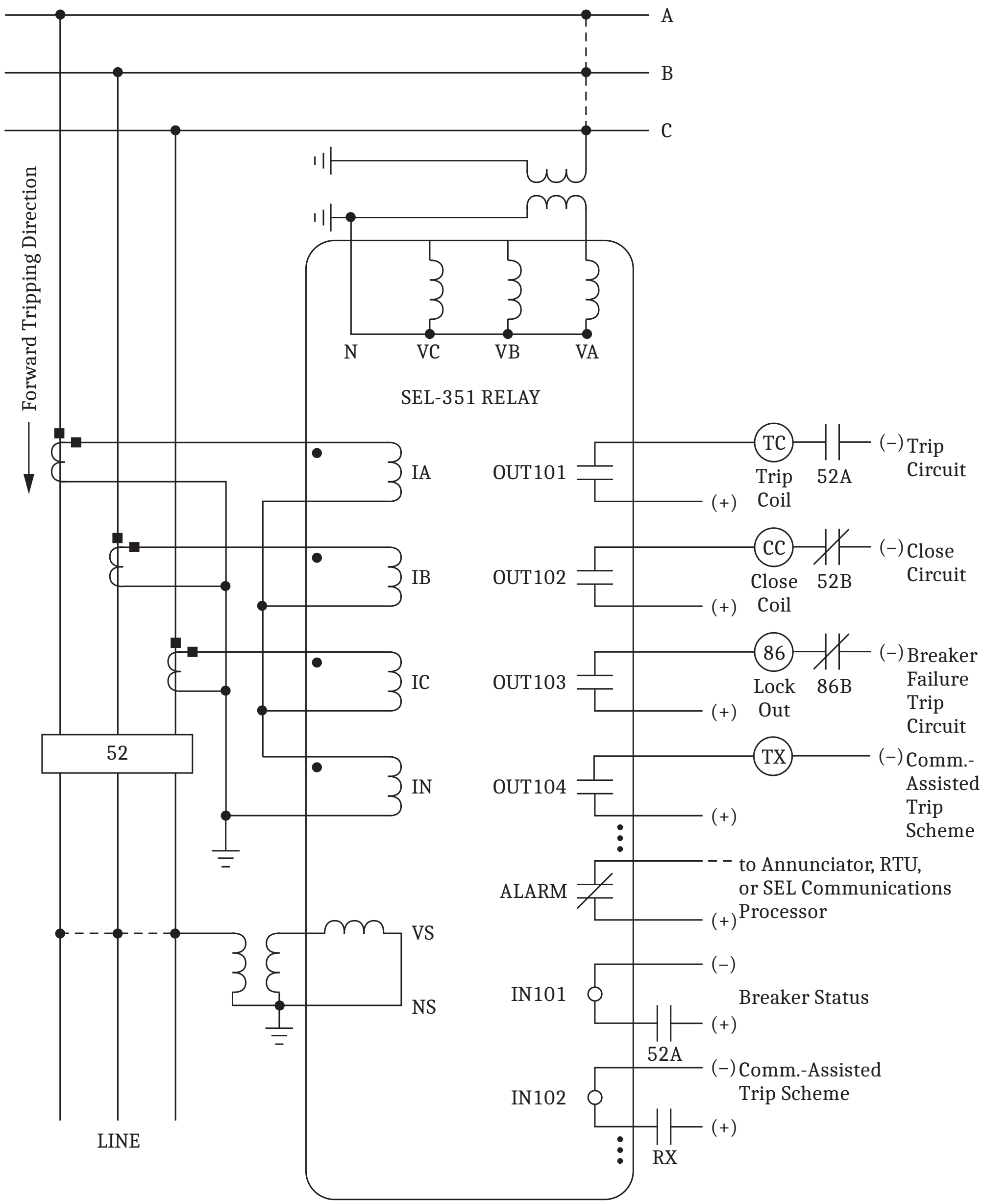
The voltage inputs can accept open-delta PT (three-wire) connection (as shown) when Global setting PTCONN = DELTA.

Voltage terminal **VB (Z10)** must be tied to voltage terminal **N (Z12)**, as shown.

Voltage Channel **VS** is shown connected for use in voltage and synchronism-check elements and voltage metering. See *Synchronism Check VS Connection (Global Setting VSCONN = VS)* on page 2.13. The synchronism-check voltage is shown coming from C-phase, via a line-to-ground connection. To account for the phase difference between V_C and V_{AB}, use group setting SYNCP = 270 (degrees lagging V_{AB}, with ABC rotation). See *Synchronism-Check Elements* on page 3.36.

Current Channel **IN** does not need to be connected. Channel **IN** provides current I_N for the neutral-ground overcurrent elements. Separate from Channel **IN**, the residual ground overcurrent elements operate from the internally derived residual current I_G ($I_G = 3I_0 = I_A + I_B + I_C$). But, in this residual connection example, the neutral ground and residual ground overcurrent elements operate the same because $I_N = I_G$.

Figure 2.27 Utility Distribution Feeder Overcurrent Protection and Reclosing (Delta Connected PTs and Line-to-Ground Synchronism-Check Connection)



Voltage must be applied between relay terminals **VA** and **N** (**Z09** and **Z12**, respectively) to deassert the undervoltage block of the frequency elements (setting 27B81P). Make Global setting PTCONN = SINGLE.

The phase of the single-phase voltage connected to **VA-N** does not matter. For example, it could come from VB or VCA. It should come from the same bus section to which the associated breaker is connected, preferably from the "normally hot" side.

In the configuration shown, certain voltage-based functions are disabled.

Voltage Channel **VS** does not need to be connected. Here, it is shown connected for use in voltage and synchronism-check elements and voltage metering. See *Synchronism Check VS Connection (Global Setting VSCONN = VS)* on page 2.13 and *Broken-Delta VS Connection (Global Setting VSCONN = 3V0)* on page 2.13.

Current Channel **IN** does not need to be connected. Channel **IN** provides current I_N for the neutral-ground overcurrent elements. Separate from Channel **IN**, the residual ground overcurrent elements operate from the internally derived residual current I_G ($I_G = 3I_0 = I_A + I_B + I_C$). But, in this residual connection example, the neutral ground and residual ground overcurrent elements operate the same because $I_N = I_G$.

Figure 2.28 Utility Distribution Feeder Underfrequency Load Shedding, Overcurrent Protection, and Reclosing (Single-Voltage Connection)

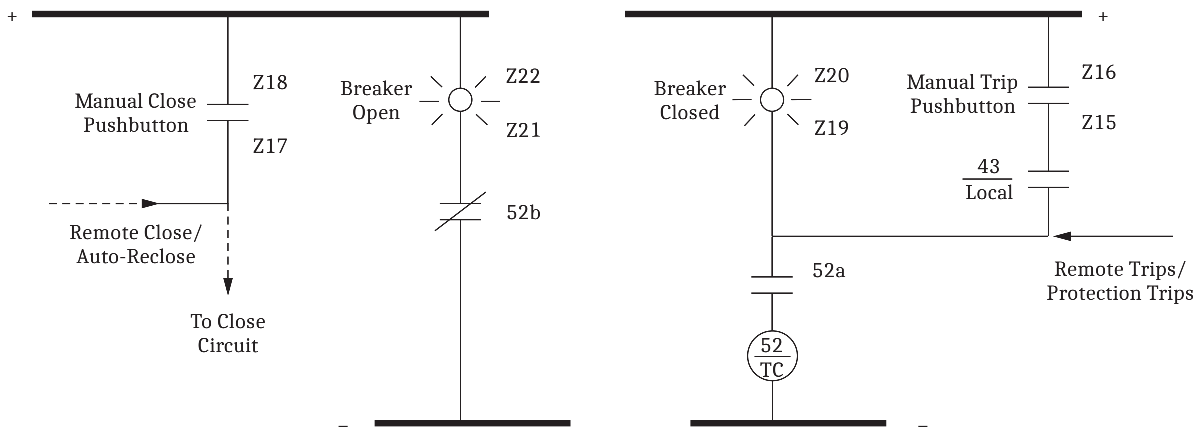


Figure 2.29 SEL-351 Example Wiring Diagram Using the SafeLock Trip/Close Pushbuttons

Circuit Board Connections and Jumpers

Accessing the Relay Circuit Boards

CAUTION
Remove all sources of voltage from the relay before removing equipment covers or disassembling the relay.

CAUTION
The relay contains devices sensitive to Electrostatic Discharge (ESD). When working on the relay with the front panel removed, work surfaces and personnel must be properly grounded or equipment damage may result.

NOTE: Optional USB and Ethernet connections reside on daughter cards that attach to the bottom of the main board. Be careful not to damage these daughter cards when handling the main board.

To change circuit board jumpers or replace the clock battery, refer to *Figure 2.30–Figure 2.33* and perform the following steps:

Step 1. De-energize the relay.

Step 2. Remove any cables connected to communications ports on the front and rear panels or the BNC connector on the rear panel.

Step 3. Loosen the six front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 4. Remove the 40-pin ribbon cable from the front panel.

Step 5. Remove the LED connectors from the front panel, if equipped.

Step 6. Identify which boards must be removed to accomplish the desired tasks.

a. To access the Access jumper, breaker jumper, serial port +5 V jumpers, extra alarm output jumper, the battery for the battery-backed clock, or the A/B output jumpers for OUT101 through ALARM, remove the main board only. The main board is the top most board in the relay chassis. If the relay has not yet been installed in a panel, the top cover can be removed by loosening the seven cover screws.

b. To access the A/B output jumpers for OUT201 through OUT212 if equipped, remove the main board, then remove the extra I/O board below the main board.

c. To access the arc suppression jumpers and the breaker status LED voltage input jumpers on the SafeLock pushbutton board, remove the relay top cover and main board, then remove the extra I/O board below the main board, if equipped. It is not necessary to remove the SafeLock pushbutton board.

Step 7. Disconnect circuit board cables as necessary to allow the desired board and drawout tray to be removed. Removal of the extra I/O board requires removal of the main board first. Ribbon cables can be removed by grasping the connector of the gray cable and pulling forward.

Step 8. Grasp the drawout assembly of the board and pull the assembly from the relay chassis.

Step 9. Locate the jumper(s) or battery to be changed (refer to *Figure 2.30–Figure 2.33*).

Make the desired changes. Note that the output contact jumpers are soldered in place.

Step 10. When finished, slide the drawout assembly into the relay chassis.

Step 11. Reconnect the cables and replace the relay front-panel cover.

Step 12. Replace any cables previously connected to the relay rear panel.

Step 13. Re-energize the relay.

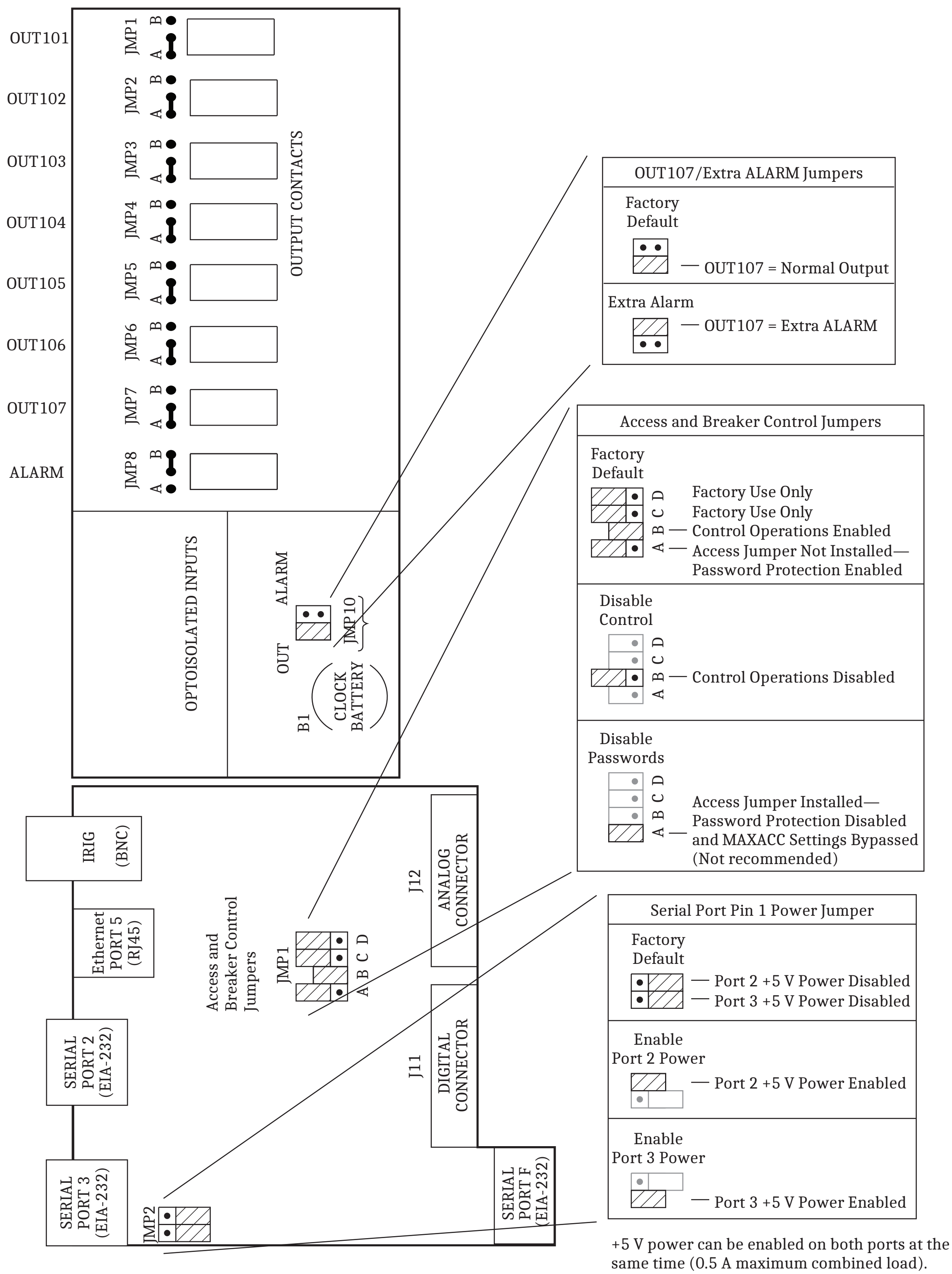


Figure 2.30 Jumper, Connector, and Major Component Locations on the SEL-351 Main Board

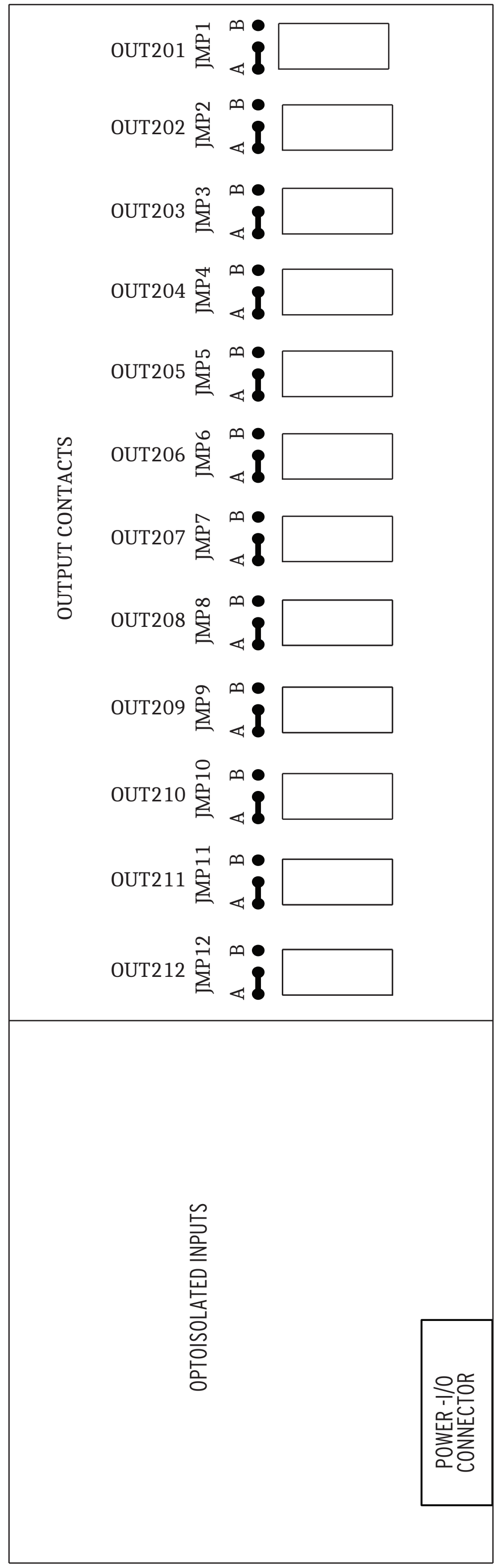


Figure 2.31 Jumper, Connector, and Major Component Locations on the SEL-351 Extra I/O Board (Extra I/O Board Options 2 and 6)

Figure 2.32 Jumper, Connector, and Major Component Locations on the SEL-351 Extra I/O Board With Four Standard Outputs (Extra I/O Board Option 4)

Output Contact Jumpers

Figure 2.30, *Figure 2.31*, and *Figure 2.32* show the exact location of jumpers that determine output contact type (Form A or Form B). With a jumper in the A position, the corresponding output contact is a Form A output contact. A Form A output contact is open when the output contact coil is de-energized and closed when the output contact coil is energized. With a jumper in the B position, the corresponding output contact is a Form B output contact. A Form B output contact is closed when the output contact coil is de-energized and open when the output contact coil is energized. These jumpers are soldered in place.

⚠WARNING
The jumpers that determine if an output is Form A or Form B are soldered into the circuit board. Follow proper desoldering and soldering procedures when changing those jumpers, or return the relay to the factory to have the jumpers changed.

Note that the **ALARM** output contact is a Form B output contact and the other output contacts are all Form A output contacts. This is how these jumpers are configured in a standard relay shipment. Refer to *Figure 7.28–Figure 7.29* for examples of output contact operation for different output contact types. All outputs on the main board and extra I/O boards are jumper-configurable.

"Extra Alarm" Output Contact Control Jumper

The SEL-351 has one output contact designated as the alarm output and labeled **ALARM** on the relay rear panel. This output can be programmed to accommodate custom alarm schemes using SELOGIC control equation ALRMOUT. See *Output Contacts* on page 7.33.

Often more than one alarm output contact is necessary for such applications as local or remote annunciation, backup schemes, etc. An extra alarm output contact can be programmed without the addition of any external hardware. Output contact **OUT107** can be converted to operate as an "extra alarm" output contact by moving a jumper on the main board.

Figure 2.30 shows the location, function, and default factory configuration of **JMP10**, the jumper that controls **OUT107**. With the jumper in the "out" position, the output contact operates regularly. With the jumper in the "alarm" position, the output contact is driven by the same signal that operates the **ALARM** output contact.

If **OUT107** is operating as an "extra alarm," it is driven by the same signal that operates the **ALARM** output contact. In a standard relay shipment, **OUT107** will be in the state opposite that of the **ALARM** output contact, because the **ALARM** output contact comes as a Form B output contact and all the other output contacts (including **OUT107**) come as Form A output contacts.

The output contact type for any output contact can be changed (see *Output Contact Jumpers* on page 2.40). Thus, the **ALARM** output contact and the "extra alarm" output contact can be configured as the same output contact type if desired (e.g., both can be configured as Form B type output contacts).

See *Output Contacts* on page 7.33 and *Relay Self-Tests* on page 13.7 for details on the operation and settings for the **ALARM** and "extra alarm" outputs.

Access and Breaker Jumpers

Figure 2.30 shows the location, function, and factory default configuration for the Access and Breaker Control jumpers.

NOTE: The Access jumper was formerly called the Password jumper.

Use the Access jumper to enable access to any front-panel communications port, any enabled rear-panel communications ports, and the front panel user interface. When the Access jumper is installed, passwords are disabled, and connection to any enabled communications port is allowed full access to inspect/change/reset all reports, settings, etc., to upgrade firmware, and to control the circuit breaker (if the Breaker jumper is installed as described below) without password authentication.

The Access jumper also affects the relay behavior for settings EPORT and MAXACC at power-up as follows:

- For the front-panel serial port (Port F), and the optional USB port, the Access jumper overrides the port enable setting EPORT = N, and enables the port(s) with EIA-232 Port F default settings for PROTO, SPEED, BITS, PARITY, STOP, and RTSCTS. If the Port F setting EPORT was already set to Y, the front port(s) remain enabled, and the EIA-232 Port F uses its previous settings.
- For the front-panel serial port (Port F), and the optional USB port, the Access jumper overrides the Port F MAXACC setting and allows access to security levels 1, B, 2, or C without a password.
- For rear-panel serial ports (Port 1, 2, or 3), and Ethernet Port 5 Telnet sessions, if that port has setting EPORT = Y, the Access jumper overrides that port's MAXACC setting, and allows access to security levels 1, B, 2, or C without a password.
- For rear-panel serial ports (Port 1, 2, or 3), and Ethernet Port 5, if that port has setting EPORT = N, the Access jumper has no effect, and the port remains disabled.

Use the Breaker jumper to enable or disable breaker control **OPEN**, **CLOSE** and **PULSE** commands through the SEL ASCII protocol, and breaker operations through the SEL Fast Operate protocol, DNP, Modbus, and the front-panel menu-driven user interface. Note that the Breaker jumper does *not* supervise operation of Local Bits, Remote Bits, or the SafeLock Trip/Close pushbuttons shown in *Figure 2.4–Figure 2.6*.

EIA-232 Serial Port Voltage Jumpers

Figure 2.30 shows the location, function, and default factory configuration of the serial port Pin 1 power jumpers. These two jumpers connect or disconnect +5 Vdc to Pin 1 on the corresponding EIA-232 serial ports. The +5 Vdc is rated at 0.5 A maximum combined for both ports. See *Table 10.5* for EIA-232 serial port pin functions.

In a standard relay shipment, the jumpers are “OFF” (not in place) so that the +5 Vdc is not connected to Pin 1 on the corresponding EIA-232 serial ports. Put the jumpers “ON” (in place) so that the +5 Vdc is connected to Pin 1 on the corresponding EIA-232 serial ports.

Condition of Acceptability for North American Product Safety Compliance

To meet product safety compliance for end-use applications in North America, use an external fused rated 3 A or less in-line with the +5 Vdc source on Pin 1. SEL fiber-optic transceivers include a fuse that meets this requirement.

SafeLock Trip/Close Pushbutton and Breaker Status LED Jumpers

Jumpers on the pushbutton board are used to select the proper control voltage for breaker open/closed indicating LEDs on the front panel of the relay. *Figure 2.33* shows the jumper locations and their functions. The jumpers come preset from the factory with the voltage range set the same as the control input voltage, as determined by the part number at order time.

The voltage setting can be different for each LED. To access these jumpers, the relay front cover, top cover, main board, and any additional I/O board (if present) must first be removed. See instructions and precautions in *Accessing the Relay Circuit Boards* on page 2.35.

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

Jumpers on the pushbutton board in *Figure 2.33* determine if the arc suppressor on the SafeLock pushbuttons is enabled or disabled. Disable the arc suppressor when connecting the pushbuttons to loads that do not require arc suppression, such as certain magnetic actuator circuit breakers, or when controlling ac loads. See *Specifications* on page 1.4 for load current ratings that the pushbuttons can switch without the assistance of the internal arc suppressors. Arc suppression comes enabled from the factory.

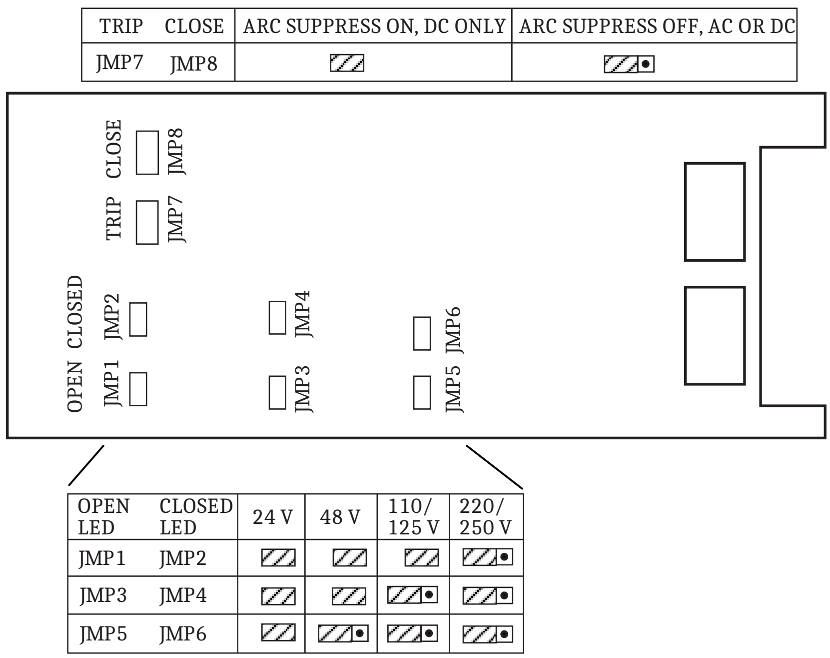


Figure 2.33 Jumper Locations for the SEL-351 SafeLock Pushbutton Board

Clock Battery

Refer to *Figure 2.30* for clock battery location (front of main board). A lithium battery powers the relay clock (date and time) if the external dc source is lost or removed. The battery is a 3 V lithium coin cell. At room temperature (25°C), the battery will nominally operate for 10 years at rated load.

If the dc source is lost or disconnected, the battery powers the clock. When the relay is powered from an external source, the battery only experiences a low self-discharge rate. Thus, battery life can extend well beyond the nominal 10 years because the battery rarely has to discharge after the relay is installed. The battery cannot be recharged.

⚠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. See Owner's Manual for safety instructions. The battery used in this device may present a fire or chemical burn hazard if mistreated. Do not recharge, disassemble, heat above 100°C or incinerate. Dispose of used batteries according to the manufacturer's instructions. Keep battery out of reach of children.

If the relay does not maintain the date and time after power loss, replace the battery. Follow the instructions in *Accessing the Relay Circuit Boards* on page 2.35 to remove the relay main board.

Step 1. Remove the battery from beneath the clip and install a new one. The positive side (+) of the battery faces up.

Step 2. Reassemble the relay as described in *Accessing the Relay Circuit Boards*.

Step 3. Set the relay date and time via serial communications port or front panel (see *Section 10: Communications* or *Section 11: Front-Panel Interface*, respectively).

SECTION 3

Overcurrent, Harmonic Blocking, Voltage, Synchronism Check, Frequency, and Power Elements

Overview

This section provides a detailed explanation for each of the SEL-351 protection functions. Each subsection provides an explanation of the function, along with a list of the corresponding settings and Relay Word bits. Logic diagrams are included for many functions.

The protection functions in this section are as follows:

Protection element accuracy information is listed in *Specifications* on page 1.4

Instantaneous/Definite-Time Overcurrent Elements

Phase Instantaneous/Definite-Time Overcurrent Elements

Four levels of phase instantaneous/definite-time overcurrent elements are available. Two additional levels of phase instantaneous overcurrent elements (Levels 5 and 6) are also available. The different levels are enabled with the E50P enable setting, as shown in *Figure 3.1*, *Figure 3.2*, and *Figure 3.3*.

Level 2 element 67P2S in *Figure 3.3* is used in directional comparison blocking schemes (see *Directional Comparison Blocking (DCB) Logic* on page 5.27). All the other phase instantaneous/definite-time overcurrent elements are available for use in any tripping or control scheme.

Settings Ranges

Setting range for pickup settings 50P1P–50P6P:

OFF, 0.25–100.00 A secondary
(5 A nominal phase current inputs, **IA**, **IB**, **IC**)

OFF, 0.05–20.00 A secondary
(1 A nominal phase current inputs, **IA**, **IB**, **IC**)

Setting range for definite-time settings 67P1D–67P4D:

0.00–16000.00 cycles, in 0.25-cycle steps

Setting range for definite-time setting 67P2SD (used in the DCB logic):

0.00–60.00 cycles, in 0.25-cycle steps

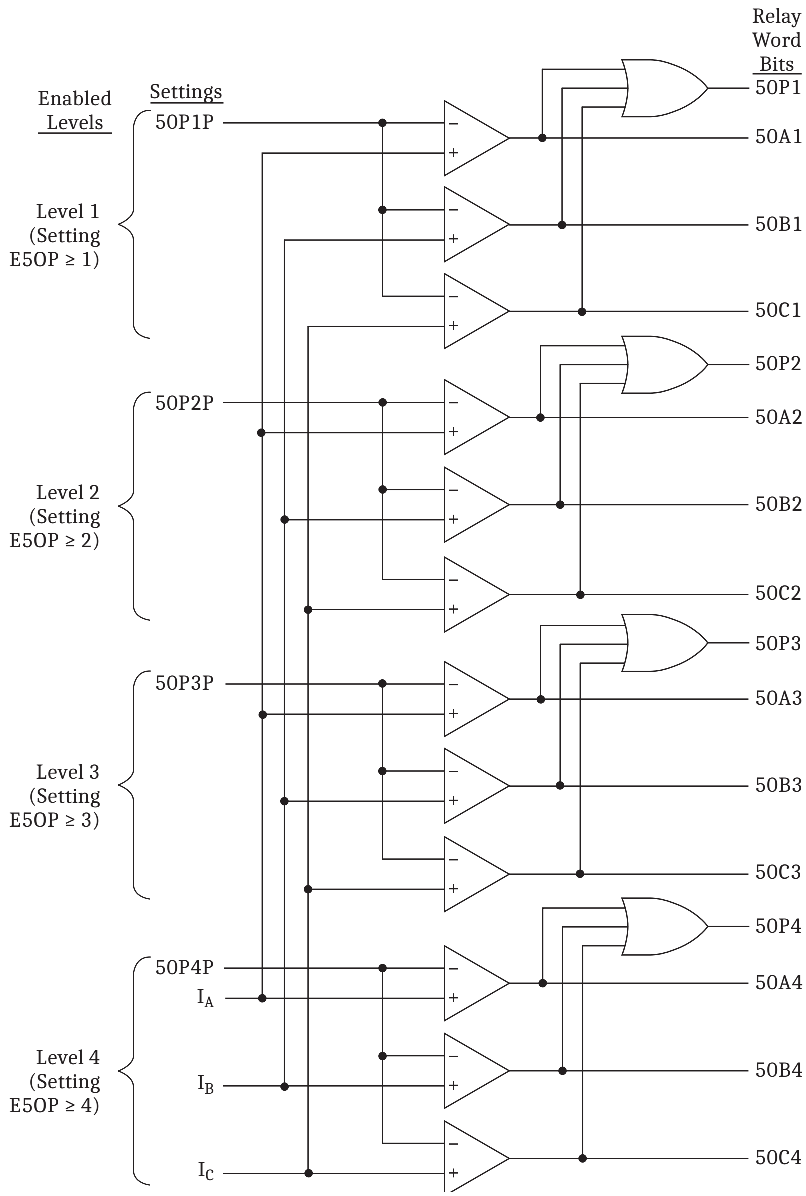


Figure 3.1 Levels 1 Through 4 Phase Instantaneous Overcurrent Elements

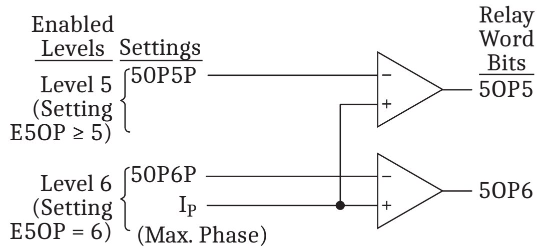


Figure 3.2 Levels 5 Through 6 Phase Instantaneous Overcurrent Elements

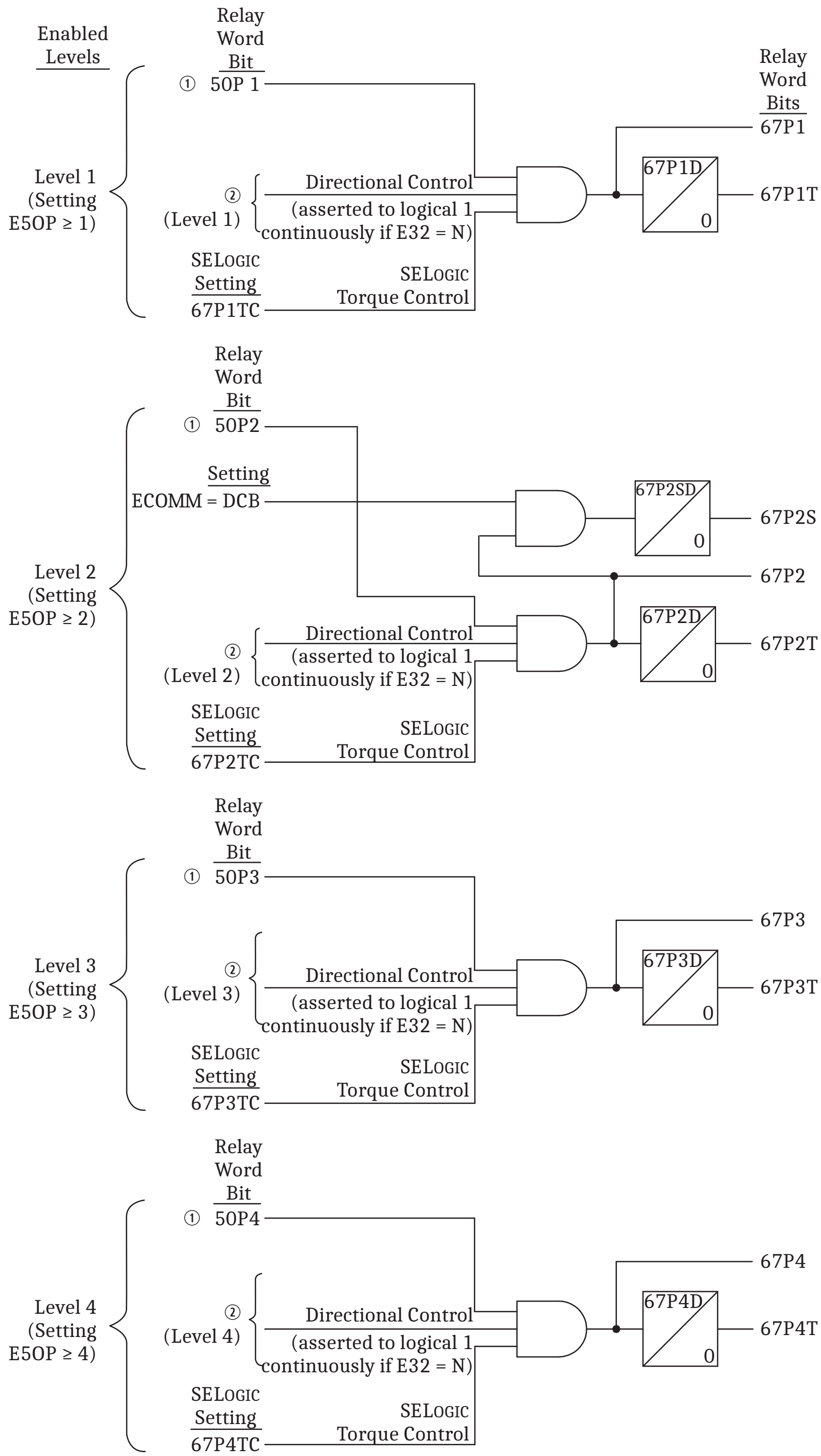
Pickup Operation

The phase instantaneous/definite-time overcurrent element logic begins with *Figure 3.1* and *Figure 3.2*. The pickup settings for each level (50P1P–50P6P) are compared to the magnitudes of the individual phase currents I_A, I_B, and I_C. The logic outputs in *Figure 3.1* and *Figure 3.2* are Relay Word bits and operate as follows (Level 1 example shown):

50A1 = 1 (logical 1), if I_A > pickup setting 50P1P
= 0 (logical 0), if $I_A \leq$ pickup setting 50P1P
50B1 = 1 (logical 1), if I_B > pickup setting 50P1P
= 0 (logical 0), if $I_B \leq$ pickup setting 50P1P
50C1 = 1 (logical 1), if I_C > pickup setting 50P1P
= 0 (logical 0), if $I_C \leq$ pickup setting 50P1P
50P1 = 1 (logical 1), if at least one of the Relay Word bits 50A1, 50B1, or 50C1 is asserted (e.g., 50B1 = 1)
= 0 (logical 0), if all three Relay Word bits 50A1, 50B1, and 50C1 are deasserted (50A1 = 0, 50B1 = 0, and 50C1 = 0)

Note that single-phase overcurrent elements are not available in Levels 5 and 6 (see *Figure 3.2*).

Ideally, set 50P1P > 50P2P > 50P3P > 50P4P so that instantaneous/definite-time overcurrent elements 67P1–67P4 will display in an organized fashion in event reports (see *Figure 3.3* and *Table 12.4*).



① From *Figure 3.1*. ② From *Figure 4.29*.

Figure 3.3 Levels 1 Through 4 Phase Instantaneous/Definite-Time Overcurrent Elements (With Directional Control Option)

Directional Control Option

The phase instantaneous overcurrent element Relay Word bit outputs in *Figure 3.1* (50P1, 50P2, 50P3, and 50P4) are inputs into the phase instantaneous/definite-time overcurrent element logic in *Figure 3.3*.

Levels 1 through 4 in *Figure 3.3* have corresponding directional control options. See *Figure 4.24* for more information on this optional directional control. If the directional control enable setting E32 is set:

E32 = **N**

then directional control is defeated, and the directional control inputs into all four phase instantaneous/definite-time overcurrent element levels in *Figure 3.3* are asserted to logical 1 continuously. Then only the corresponding SELOGIC control equation torque-control settings have to be considered in the control of the phase instantaneous/definite-time overcurrent elements.

For example, consider the Level 1 phase instantaneous/definite-time overcurrent elements 67P1/67P1T in *Figure 3.3*. If the directional control enable setting E32 is set:

E32 = **N**

then the directional control input from *Figure 4.23* (Level 1) is asserted to logical 1 continuously. Then only the corresponding SELOGIC control equation torque-control setting 67P1TC has to be considered in the control of the phase instantaneous/definite-time overcurrent elements 67P1/67P1T.

Torque Control

NOTE: Most overcurrent element SELOGIC control equation torque-control settings are set directly to logical 1 (e.g., 67P1TC = 1) for the **factory default settings**. See **SHO *(Show/View Settings)*** on page 10.68 for a list of the factory default settings.

Levels 1 through 4 in *Figure 3.3* have corresponding SELOGIC control equation torque-control settings 67P1TC–67P4TC. SELOGIC control equation torque-control settings cannot be set directly to logical 0. The following are torque-control setting examples for Level 1 phase instantaneous/definite-time overcurrent elements 67P1/67P1T.

67P1TC = **1** Setting 67P1TC set directly to logical 1:

Then only the corresponding directional control input from *Figure 4.24* has to be considered in the control of phase instantaneous/definite-time overcurrent elements 67P1/67P1T.

If directional control enable setting E32 = N, then phase instantaneous/definite-time overcurrent elements 67P1/67P1T are enabled and nondirectional.

67P1TC = **IN105** Input **IN105** deasserted (67P1TC = IN105 = logical 0):

Then phase instantaneous/definite-time overcurrent elements 67P1/67P1T are defeated and nonoperational, regardless of any other setting.

Input **IN105** asserted (67P1TC = IN105 = logical 1):

Then only the corresponding directional control input from *Figure 4.24* has to be considered in the control of phase instantaneous/definite-time overcurrent elements 67P1/67P1T.

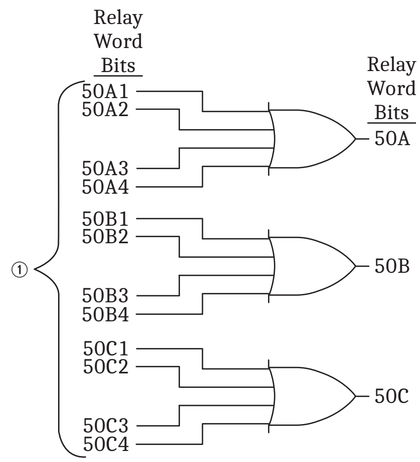
If directional control enable setting E32 = N, then phase instantaneous/definite-time overcurrent elements 67P1/67P1T are enabled and nondirectional.

Sometimes SELOGIC control equation torque-control settings are set to provide directional control. See *Directional Control Provided by Torque-Control Settings* on page 4.69.

Combined Single-Phase Instantaneous Overcurrent Elements

The single-phase instantaneous overcurrent element Relay Word bit outputs in *Figure 3.1* are combined together in *Figure 3.4* on a per phase basis, producing Relay Word bit outputs 50A, 50B, and 50C.

Relay Word bits 50A, 50B, and 50C can be used to indicate the presence or absence of current in a particular phase.



① From *Figure 3.1*.

Figure 3.4 Combined Single-Phase Instantaneous Overcurrent Elements

Pickup and Reset Time Curves

NOTE: The pickup time curve in *Figure 3.5* is not valid for conditions with a saturated CT, where the resultant current to the relay is non-sinusoidal.

Figure 3.5 and *Figure 3.6* show pickup and reset time curves applicable to all nondirectional instantaneous overcurrent elements with sinosoidal waveforms applied (60 Hz or 50 Hz relays). These times do not include output contact operating time and, thus, are accurate for determining element operation time for use in internal SELOGIC control equations. Output contact pickup/dropout time is defined in *Specifications* on page 1.4. Add the appropriate time to the values from *Figure 3.5* and *Figure 3.6* to determine operate times for testing and commissioning.

If instantaneous overcurrent elements are made directional, the pickup time curve in *Figure 3.5* is adjusted as follows:

multiples of pickup setting ≤ 4: add 0.25 cycle

multiples of pickup setting > 4: add 0.50 cycle

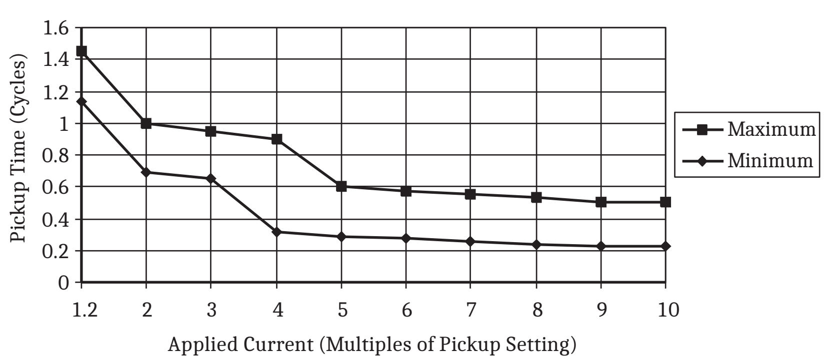


Figure 3.5 Nondirectional Instantaneous Overcurrent Element Pickup Time Curve

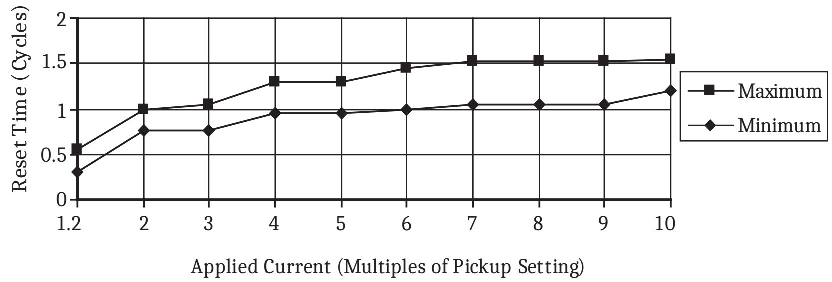


Figure 3.6 Nondirectional Instantaneous Overcurrent Element Reset Time Curve

CT Saturation Protection

The SEL-351 phase instantaneous overcurrent elements normally operate using the output of a cosine filter algorithm. During heavy fault currents when the relay detects severe CT saturation, the overcurrent elements can operate on the adaptive current algorithm.

The adaptive current algorithm is only used for phase instantaneous overcurrent elements if and only if the corresponding pickup setting is greater than eight times the nominal phase current. For example, if 50P1P = 45 A (in a 5 A nominal phase current relay), then the 50P1, 50A1, 50B1, and 50C1 elements operate on the adaptive current algorithm. However, if 50P1P = 35 A, then the 50P1, 50A1, 50B1, and 50C1 elements operate on the output of a cosine filter algorithm. No other overcurrent elements use the adaptive current algorithm.

Based on the level of a "harmonic distortion index," the adaptive current is either the output of the cosine filter or the output of the bipolar peak detector. When the harmonic distortion index exceeds the fixed threshold that indicates severe CT saturation, the adaptive current is the output of the bipolar peak detector. When the harmonic distortion index is below the fixed threshold, the adaptive current is the output of the cosine filter.

The cosine filter provides excellent performance in removing dc offset and harmonics. However, the bipolar peak detector has the best performance in situations of severe CT saturation when the cosine filter magnitude estimation is degraded. Combining the two filters provides an elegant solution for ensuring dependable phase instantaneous overcurrent element operation.

Phase-to-Phase Instantaneous Overcurrent Elements

Four levels of phase-to-phase instantaneous overcurrent elements are available. The different levels are enabled with the E50P enable setting, as shown in *Figure 3.7*.

Setting Range

Setting range for pickup settings 50PP1P–50PP4P:

OFF, 1.00–170.00 A secondary

(5 A nominal phase current inputs, IA, IB, IC)

OFF, 0.20–34.00 A secondary

(1 A nominal phase current inputs, IA, IB, IC)

Pickup Operation

The pickup settings for each level (50PP1P–50PP4P) are compared to the magnitudes of the individual phase-to-phase difference currents I_{AB}, I_{BC}, and I_{CA}. The logic outputs in *Figure 3.7* are the following Relay Word bits (Level 1 example shown):

50AB1 = 1 (logical 1), if I_{AB} > pickup setting 50PP1P
= 0 (logical 0), if $I_{AB} \leq$ pickup setting 50PP1P
50BC1 = 1 (logical 1), if I_{BC} > pickup setting 50PP1P
= 0 (logical 0), if $I_{BC} \leq$ pickup setting 50PP1P
50CA1 = 1 (logical 1), if I_{CA} > pickup setting 50PP1P
= 0 (logical 0), if $I_{CA} \leq$ pickup setting 50PP1P

Pickup and Reset Time Curves

See *Figure 3.5* and *Figure 3.6*.

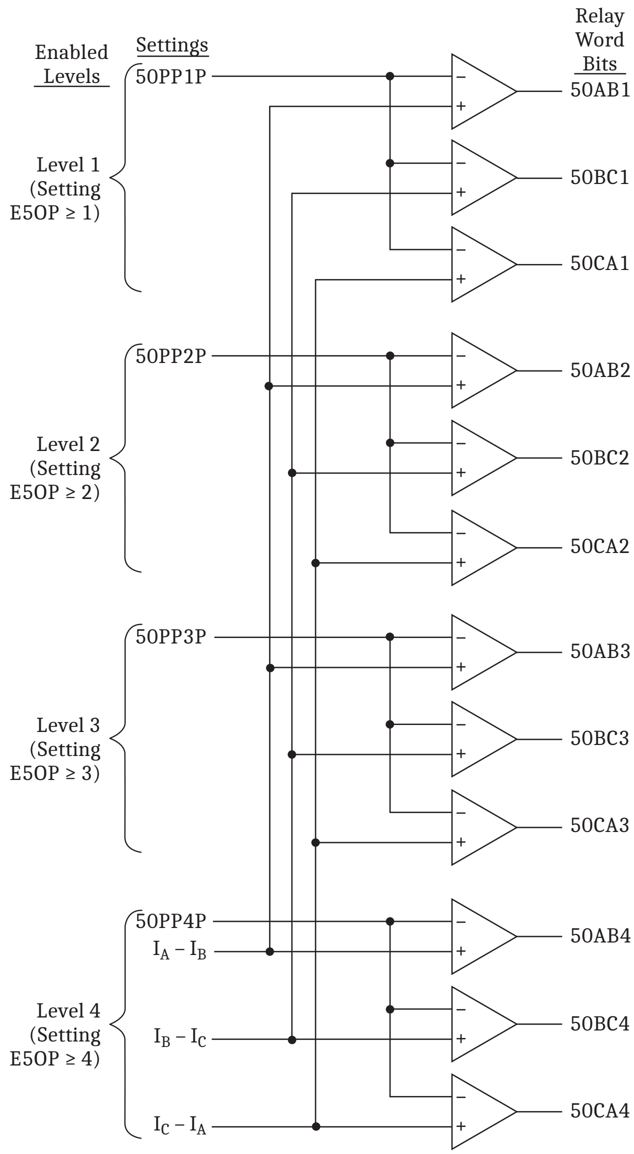


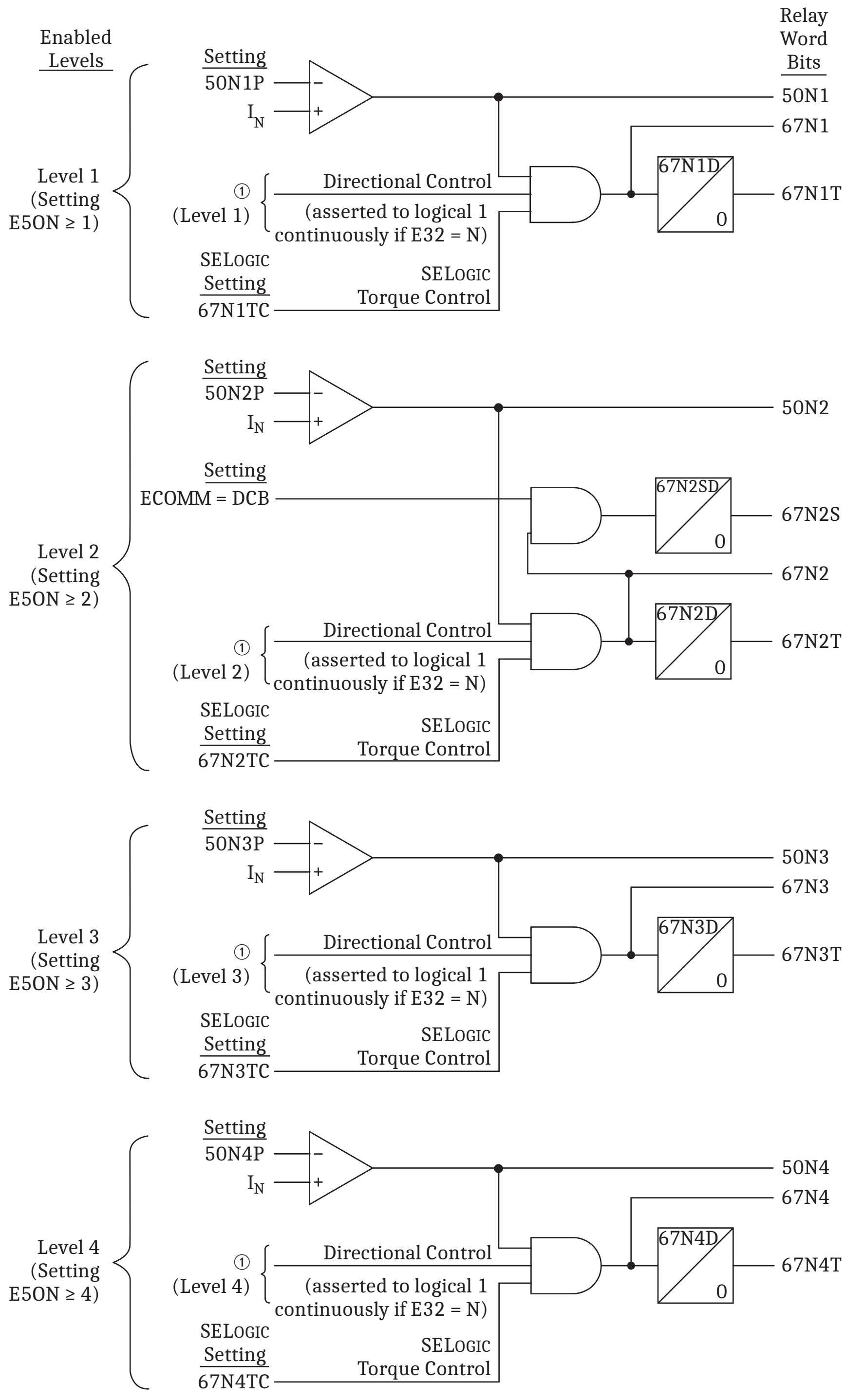
Figure 3.7 Levels 1 Through 4 Phase-to-Phase Instantaneous Overcurrent Elements

Neutral Ground Instantaneous/Definite-Time Overcurrent Elements

Four levels of neutral ground instantaneous/definite-time overcurrent elements are available. Two additional levels of neutral ground instantaneous overcurrent elements (Levels 5 and 6) are also available. The different levels are enabled with the E50N enable setting, as shown in *Figure 3.8* and *Figure 3.9*.

Level 2 element 67N2S in *Figure 3.8* is used in directional comparison blocking schemes (see *Directional Comparison Blocking (DCB) Logic* on page 5.27). All the other neutral ground instantaneous/definite-time overcurrent elements are available for use in any tripping or control scheme.

To understand the operation of *Figure 3.8* and *Figure 3.9*, follow the explanation given for *Figure 3.1*, *Figure 3.2*, and *Figure 3.3* in *Phase Instantaneous/Definite-Time Overcurrent Elements* on page 3.1, substituting current I_N (channel IN current) for phase currents and substituting like settings and Relay Word bits.



① From *Figure 4.23*.

Figure 3.8 Levels 1 Through 4 Neutral Ground Instantaneous/Definite-Time Overcurrent Elements (With Directional Control Option)

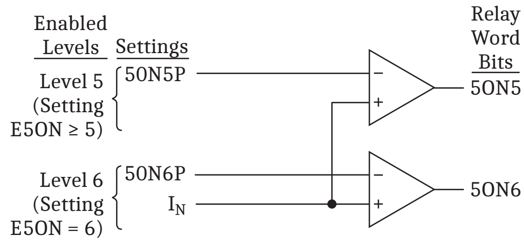


Figure 3.9 Levels 5 Through 6 Neutral Ground Instantaneous Overcurrent Elements

See *Table 4.4* and accompanying note for a list of the directional features available with each neutral channel (IN) rating.

Settings Ranges

NOTE: If channel IN is rated 0.2 A nominal or 0.05 A nominal, then there is an additional 2-cycle time delay on all the neutral ground instantaneous (50N1–50N6, 67N1–67N6) and definite-time (67N1T–67N4T) elements. Any time delay provided by the definite-time settings (67N1D–67N4D) is in **addition** to this 2-cycle time delay.

Setting range for pickup settings 50N1P–50N6P:

OFF, 0.250–100.000 A secondary (5 A nominal channel **IN** current input)

OFF, 0.050–20.000 A secondary (1 A nominal channel **IN** current input)

OFF, 0.005–2.500 A secondary (0.2 A nominal channel **IN** current input)

OFF, 0.005–1.500 A secondary (0.05 A nominal channel **IN** current input)

Setting range for definite-time settings 67N1D–67N4D:

0.00–16000.00 cycles, in 0.25-cycle steps

Setting range for definite-time setting 67N2SD (used in DCB logic):

0.00–60.00 cycles, in 0.25-cycle steps

Pickup and Reset Time Curves

See *Figure 3.5* and *Figure 3.6*.

Residual Ground Instantaneous/Definite-Time Overcurrent Elements

Four levels of residual ground instantaneous/definite-time overcurrent elements are available. Two additional levels of residual ground instantaneous overcurrent elements (Levels 5 and 6) are also available. The different levels are enabled with the E50G enable setting, as shown in *Figure 3.10* and *Figure 3.11*.

Level 2 element 67G2S in *Figure 3.10* is used in directional comparison blocking schemes (see *Directional Comparison Blocking (DCB) Logic* on page 5.27). All the other residual ground instantaneous/definite-time overcurrent elements are available for use in any tripping or control scheme.

To understand the operation of *Figure 3.10* and *Figure 3.11*, follow the explanation given for *Figure 3.1*, *Figure 3.2*, and *Figure 3.3* in *Phase Instantaneous/Definite-Time Overcurrent Elements* on page 3.1, substituting residual ground current I_G ($I_G = 3I_0 = I_A + I_B + I_C$) for phase currents and substituting like settings and Relay Word bits.

Settings Ranges

Setting range for pickup settings 50G1P–50G6P:

OFF, 0.050–100.00 A secondary in 0.010 A steps
(5 A nominal phase current inputs, **IA**, **IB**, **IC**)

OFF, 0.010–20.00 A secondary in 0.002 A steps
(1 A nominal phase current inputs, **IA**, **IB**, **IC**)

Setting range for definite-time settings 67G1D–67G4D:

0.00–16000.00 cycles, in 0.25-cycle steps

Setting range for definite-time setting 67G2SD (used in DCB logic):

0.00–60.00 cycles, in 0.25-cycle steps

NOTE: For pickup settings less than:

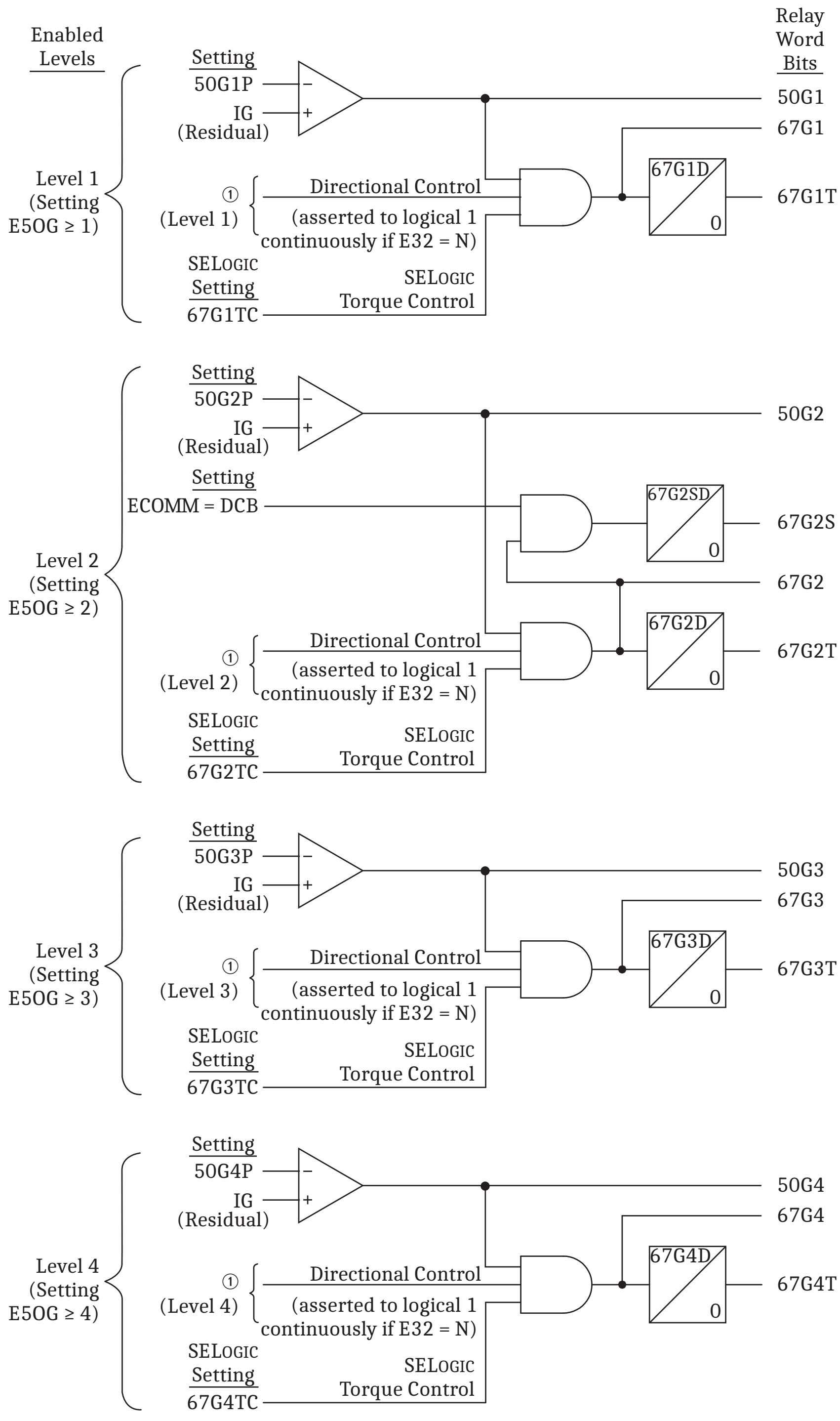
0.25 A secondary (5 A nominal)

0.05 A secondary (1 A nominal)

an additional 2-cycle time delay is added on all residual ground instantaneous (50G1–50G6, 67G1–67G4) and definite-time (67G1T–67G4T) overcurrent elements. Any time delay provided by the definite-time settings (67G1D–67G4D) is in **addition** to this 2-cycle time delay.

Pickup and Reset Time Curves

See *Figure 3.5* and *Figure 3.6*.



① From *Figure 4.22*.

Figure 3.10 Levels 1 Through 4 Residual Ground Instantaneous/Definite-Time Overcurrent Elements (With Directional Control Option)

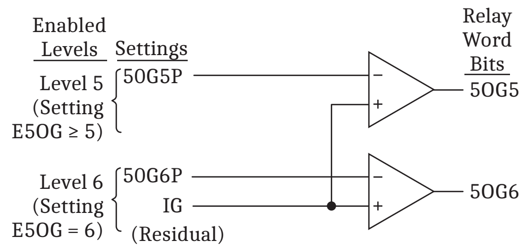


Figure 3.11 Levels 5 Through 6 Residual Ground Instantaneous Overcurrent Elements

Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements

Four levels of negative-sequence instantaneous/definite-time overcurrent elements are available. Two additional levels of negative-sequence instantaneous overcurrent elements (Levels 5 and 6) are also available. The different levels are enabled with the E50Q enable setting, as shown in *Figure 3.12* and *Figure 3.13*.

Level 2 element 67Q2S in *Figure 3.12* is used in directional comparison blocking schemes (see *Directional Comparison Blocking (DCB) Logic* on page 5.27). All the other negative-sequence instantaneous/definite-time overcurrent elements are available for use in any tripping or control scheme.

NOTE: See *Appendix G: Setting Negative-Sequence Overcurrent Elements* for information on setting negative-sequence overcurrent elements.

To understand the operation of *Figure 3.12* and *Figure 3.13*, follow the explanation given for *Figure 3.1*, *Figure 3.2*, and *Figure 3.3* in *Phase Instantaneous/Definite-Time Overcurrent Elements* on page 3.1, substituting negative-sequence current:

$3I_2 = I_A + a^2 \bullet I_B + a \bullet I_C$ (Global setting PHROT = ABC)

$3I_2 = I_A + a^2 \bullet I_C + a \bullet I_B$ (Global setting PHROT = ACB)

where:

$a = 1 \angle 120°$

$a^2 = 1 \angle -120°$

for phase currents and substituting like settings and Relay Word bits.

Settings Ranges

Setting range for pickup settings 50Q1P–50Q6P:

OFF, 0.25–100.00 A secondary
(5 A nominal phase current inputs, **IA**, **IB**, **IC**)

OFF, 0.05–20.00 A secondary
(1 A nominal phase current inputs, **IA**, **IB**, **IC**)

Setting range for definite-time settings 67Q1D–67Q4D:

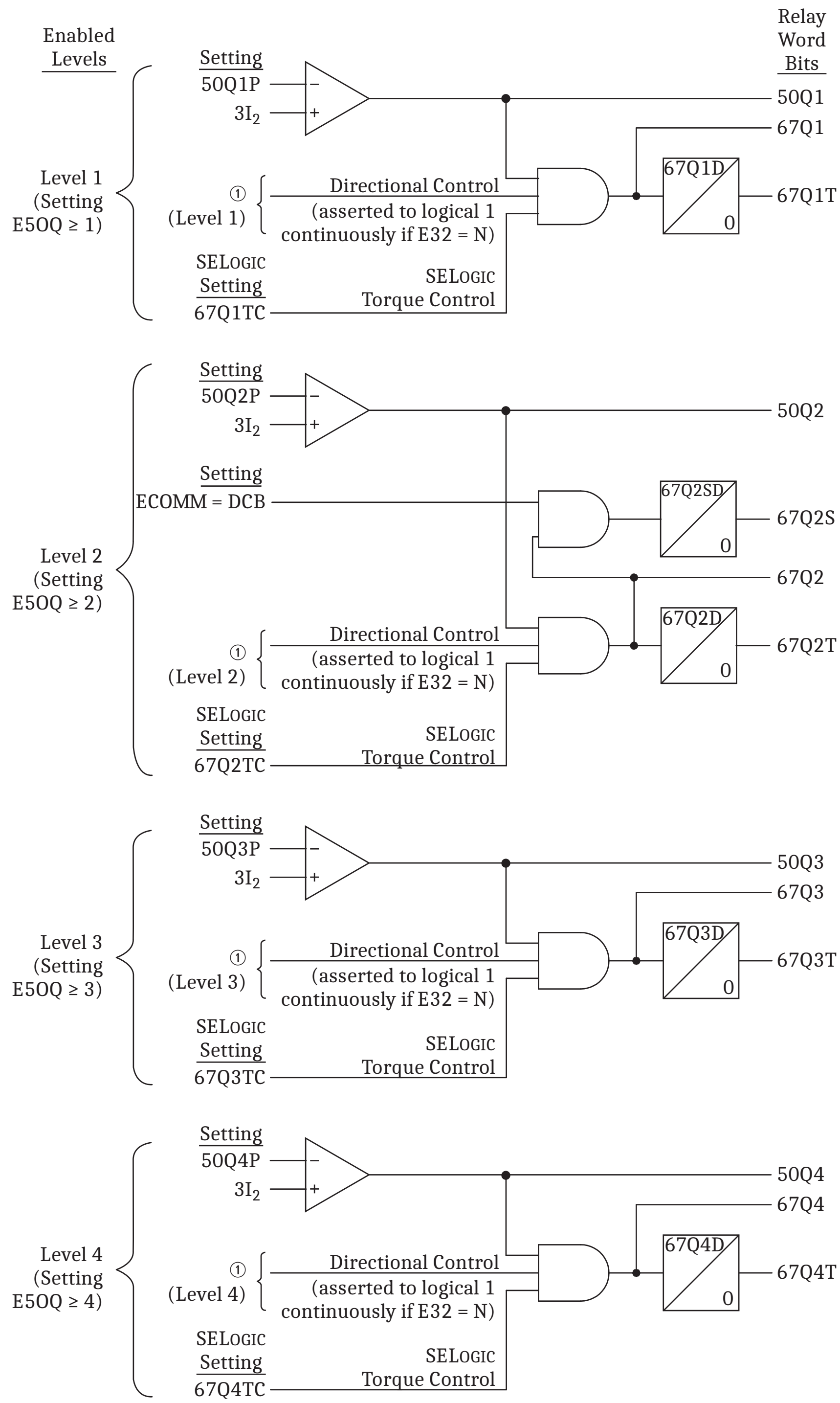
0.00–16000.00 cycles, in 0.25-cycle steps

Setting range for definite-time setting 67Q2SD (used in DCB logic):

0.00–60.00 cycles, in 0.25-cycle steps

Pickup and Reset Time Curves

See *Figure 3.5* and *Figure 3.6*.



① From *Figure 4.28*.

Figure 3.12 Levels 1 Through 4 Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements (With Directional Control Option)

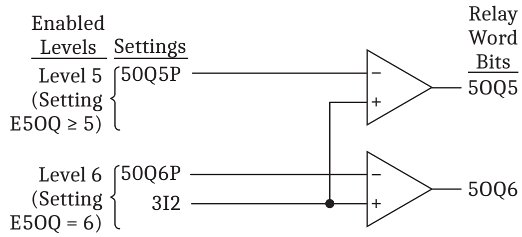


Figure 3.13 Levels 5 Through 6 Negative-Sequence Instantaneous Overcurrent Elements

Time-Overcurrent Elements

Phase Time-Overcurrent Elements

Four phase time-overcurrent elements are available. The elements are enabled with the E51P enable setting as follows:

Table 3.1 Available Phase Time-Overcurrent Elements

Time-Overcurrent Element	Enabled With Setting	Operating Current	See Figure
51PT	E51P = 1 or 2	I_P, maximum of A-, B-, and C-Phase currents	*Figure 3.14*
51AT	E51P = 2	I_A, A-Phase current	*Figure 3.15*
51BT	E51P = 2	I_B, B-Phase current	*Figure 3.16*
51CT	E51P = 2	I_C, C-Phase current	*Figure 3.17*

The following is an example of 51PT element operation. The other phase time-overcurrent elements operate similarly (note the similarity among the logic in *Figure 3.14*, *Figure 3.15*, *Figure 3.16*, and *Figure 3.17*).

Settings Ranges (51PT Element Example)

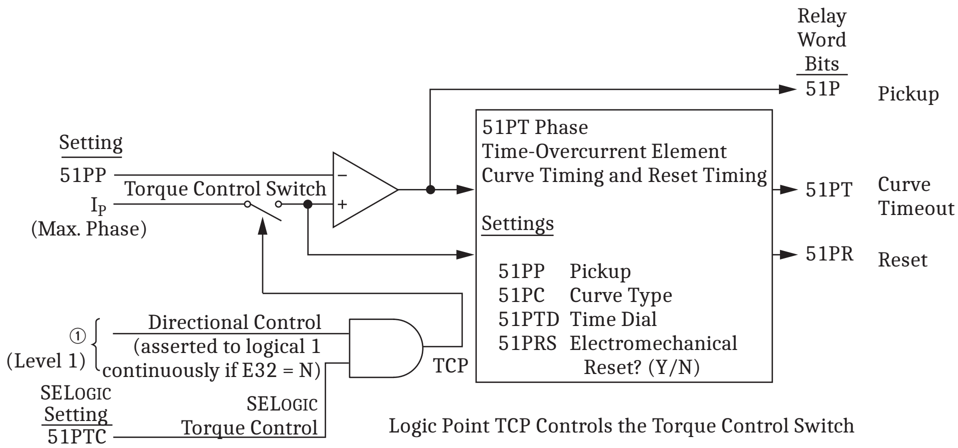
Besides the settings involved with the Torque-Control Switch operation in *Figure 3.14*, the 51PT phase time-overcurrent element has the following settings:

Table 3.2 Phase Time-Overcurrent Element (Maximum Phase) Settings

Setting	Definition	Range
51PP	pickup	OFF, 0.25–16.00 A secondary (5 A nominal phase current inputs, IA, IB, IC) OFF, 0.05–3.20 A secondary (1 A nominal phase current inputs, IA, IB, IC)
51PC	curve type	U1–U5 (US curves) see *Figure 9.1–Figure 9.10* C1–C5 (IEC curves)
51PTD	time dial	0.50–15.00 (US curves) see *Figure 9.1–Figure 9.10* 0.05–1.00 (IEC curves)
51PRS	electromechanical reset timing	Y, N
51PTC	SELOGIC control equation torque-control setting	Relay Word bits referenced in *Table D.1* or set directly to logical 1 (=1)[a]

[a] SELOGIC control equation torque-control settings (e.g., 51PTC) cannot be set directly to logical 0.

See *Section 9: Setting the Relay* for additional time-overcurrent element setting information.



Logic Point TCP Controls the Torque Control Switch

TCP State	Torque Control Switch Position	Setting 51PRS =	Reset Timing
Logical 1	Closed	Y	Electromechanical
Logical 0	Open	N	1 Cycle

① From *Figure 4.29*.

Figure 3.14 Phase Time-Overcurrent Element 51PT (With Directional Control Option)

Logic Outputs (51PT Element Example)

The resultant logic outputs in *Figure 3.14* are the following Relay Word bits:

Table 3.3 Phase Time-Overcurrent Element (Maximum Phase) Logic Outputs

Relay Word Bit	Definition/Indication	Application
51P	Maximum phase current, I_P, is greater than phase time-overcurrent element pickup setting 51PP.	Element pickup testing or other control applications. See *Trip Logic* on page 5.1.
51PT	Phase time-overcurrent element is timed out on its curve.	Tripping and other control applications. See *Trip Logic* on page 5.1.
51PR	Phase time-overcurrent element is fully reset.	Element reset testing or other control applications.

Torque-Control Switch Operation (51PT Element Example)

Torque-Control Switch Closed

The pickup comparator in *Figure 3.14* compares the pickup setting (51PP) to the maximum phase current, I_P, if the Torque-Control Switch is closed. I_P is also routed to the curve timing/reset timing functions. The Relay Word bits logic outputs operate as follows with the Torque-Control Switch closed:

51P = (logical 1), if I_P > pickup setting 51PP and the phase time-overcurrent element is timing or is timed out on its curve
= 0 (logical 0), if $I_P \leq$ pickup setting 51PP

51PT = 1 (logical 1), if I_P > pickup setting 51PP and the phase time-overcurrent element is timed out on its curve
= 0 (logical 0), if I_P > pickup setting 51PP and the phase time-overcurrent element is timing, but not yet timed out on its curve
= 0 (logical 0), if $I_P \leq$ pickup setting 51PP

51PR = 1 (logical 1), if $I_P \leq$ pickup setting 51PP and the phase time-overcurrent element is fully reset

= 0 (logical 0), if $I_P \leq$ pickup setting 51PP and the phase time-overcurrent element is timing to reset (not yet fully reset)

= 0 (logical 0), if $I_P >$ pickup setting 51PP and the phase time-overcurrent element is timing or is timed out on its curve

Torque-Control Switch Open

If the Torque-Control Switch in *Figure 3.14* is open, maximum phase current, I_P, *cannot* get through to the pickup comparator (setting 51PP) and the curve timing/reset timing functions. For example, suppose that the Torque-Control Switch is closed, I_P is:

$I_P >$ pickup setting 51PP

and the phase time-overcurrent element is timing or is timed out on its curve. If the Torque-Control Switch is then opened, I_P effectively appears as a magnitude of zero (0) to the pickup comparator:

$I_P = 0$ A (effective) < pickup setting 51PP

resulting in Relay Word bit 51P deasserting to logical 0. I_P also effectively appears as a magnitude of zero (0) to the curve timing/reset timing functions, resulting in Relay Word bit 51PT also deasserting to logical 0. The phase time-overcurrent element then starts to time to reset. Relay Word bit 51PR asserts to logical 1 when the phase time-overcurrent element is fully reset.

Control of Logic Point TCP

Refer to *Figure 3.14*.

The Torque-Control Switch is controlled by logic point TCP. Logic point TCP is controlled by directional control (optional) and SELOGIC control equation torque-control setting 51PTC.

If logic point TCP = logical 1, the Torque-Control Switch is closed and maximum phase current, I_P, is routed to the pickup comparator (setting 51PP) and the curve timing/reset timing functions.

If logic point TCP = logical 0, the Torque-Control Switch is open and maximum phase current, I_P, *cannot* get through to the pickup comparator and the curve timing/reset timing functions. The maximum phase current, I_P, effectively appears as a magnitude of zero (0) to the pickup comparator and the curve timing/reset timing function.

Directional Control Option

Refer to *Figure 3.14*.

See *Figure 4.24* for more information on the optional directional control. If the directional control enable setting E32 is set:

E32 = **N**

then directional control is defeated, and the directional control input into logic point TCP in *Figure 3.14* is asserted to logical 1 continuously. Then, only the corresponding SELOGIC control equation torque-control setting 51PTC has to be considered in the control of logic point TCP (and, thus, in the control of the Torque-Control Switch and phase time-overcurrent element 51PT).

Torque Control

NOTE: All overcurrent element SELOGIC control equation torque-control settings are set directly to logical 1 (e.g., 51PTC = 1) for the factory default settings. See **SHO *(Show/View Settings)*** on page 10.68 for a list of the factory default settings.

Refer to *Figure 3.14*.

SELOGIC control equation torque-control settings (e.g., 51PTC) cannot be set directly to logical 0. The following are setting examples of SELOGIC control equation torque-control setting 51PTC for phase time-overcurrent element 51PT.

51PTC = 1 — Setting 51PTC set directly to logical 1:

Then only the corresponding directional control input from *Figure 4.24* has to be considered in the control of logic point TCP (and, thus, in the control of the Torque-Control Switch and phase time-overcurrent element 51PT).

If directional control enable setting E32 = N, then logic point TCP = logical 1 and, thus, the Torque-Control Switch closes and phase time-overcurrent element 51PT is enabled and nondirectional.

51PTC = IN105 — Input **IN105** deasserted (51PTC = IN105 = logical 0):

Then logic point TCP = logical 0 and, thus, the Torque-Control Switch opens and phase time-overcurrent element 51PT is defeated and nonoperational, regardless of any other setting.

Input **IN105** asserted (51PTC = IN105 = logical 1):

Then only the corresponding directional control input from *Figure 4.24* has to be considered in the control of logic point TCP (and, thus, in the control of the Torque-Control Switch and phase time-overcurrent element 51PT).

If directional control enable setting E32 = N, then logic point TCP = logical 1 and, thus, the Torque-Control Switch closes and phase time-overcurrent element 51PT is enabled and nondirectional.

Sometimes SELOGIC control equation torque-control settings are set to provide directional control. See *Directional Control Provided by Torque-Control Settings* on page 4.69.

Reset Timing Details (51PT Element Example)

Refer to *Figure 3.14*.

Any time current I_P goes above pickup setting 51PP and the phase time-overcurrent element starts timing, Relay Word bit 51PR (reset indication) = logical 0. If the phase time-overcurrent element times out on its curve, Relay Word bit 51PT (curve time-out indication) = logical 1.

Setting 51PRS = Y

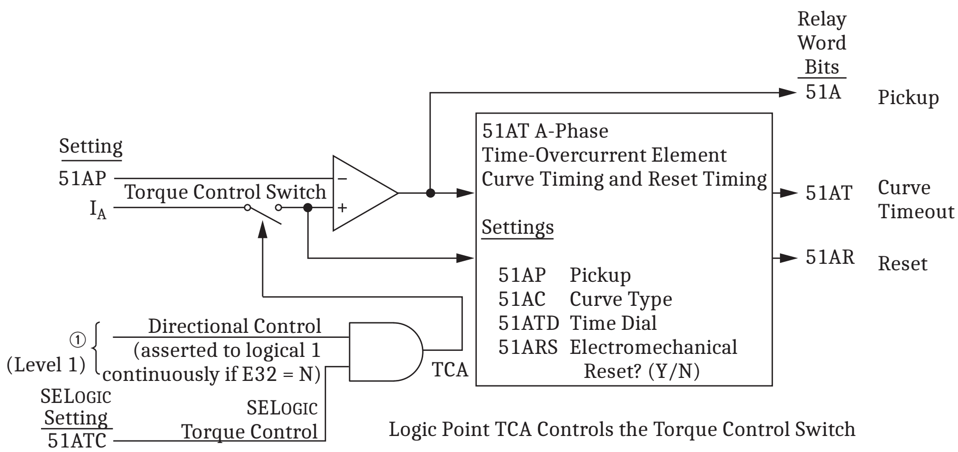
If electromechanical reset timing setting 51PRS = Y, the phase time-overcurrent element reset timing emulates electromechanical reset timing. If maximum phase current, I_P, goes above pickup setting 51PP (element is timing or already timed out) and then current I_P goes below 51PP, the element starts to time to reset, emulating electromechanical reset timing. Relay Word bit 51PR (resetting indication) = logical 1 when the element is fully reset.

Setting 51PRS = N

If reset timing setting 51PRS = N, element 51PT reset timing is a one-cycle drop-out. If current I_P goes above pickup setting 51PP (element is timing or already timed out) and then current I_P goes below pickup setting 51PP, there is a one-cycle delay before the element fully resets. Relay Word bit 51PR (reset indication) = logical 1 when the element is fully reset.

Operation of Single-Phase Time-Overcurrent Elements (51AT, 51BT, 51CT)

To understand the operation of *Figure 3.15*, *Figure 3.16*, and *Figure 3.17* follow the explanation given for *Figure 3.14* in *Phase Time-Overcurrent Elements* on page 3.16, substituting phase current I_A (or I_B or I_C) for maximum phase current I_P and substituting like settings and Relay Word bits. The settings ranges and accuracies for the single-phase time-overcurrent elements settings are the same as the corresponding settings in *Table 3.2*.

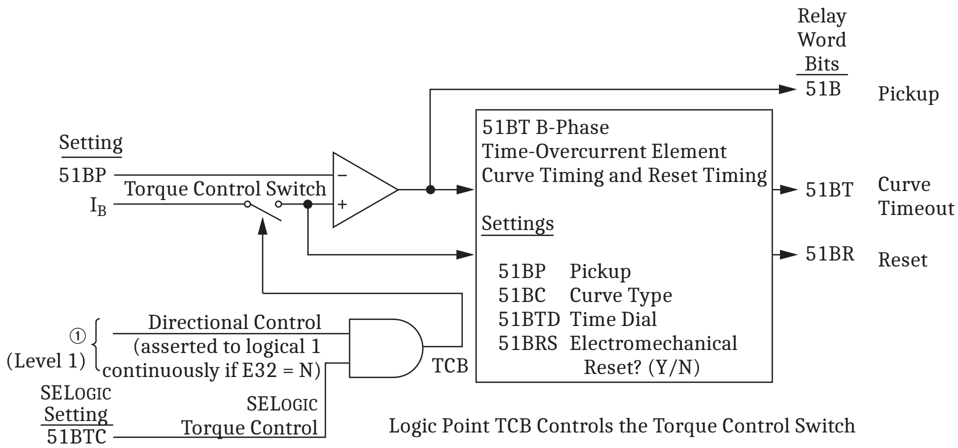


Logic Point TCA Controls the Torque Control Switch

TCA State	Torque Control Switch Position	Setting 51ARS =	Reset Timing
Logical 1	Closed	Y	Electromechanical
Logical 0	Open	N	1 Cycle

① From *Figure 4.29*.

Figure 3.15 A-Phase Time-Overcurrent Element 51AT (With Directional Control Option)

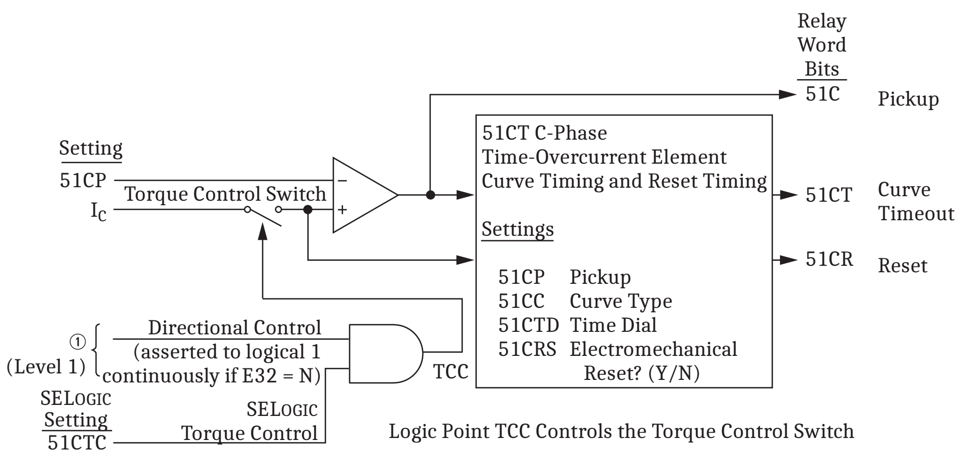


Logic Point TCB Controls the Torque Control Switch

TCB State	Torque Control Switch Position	Setting 51BRS =	Reset Timing
Logical 1	Closed	Y	Electromechanical
Logical 0	Open	N	1 Cycle

① From *Figure 4.29*.

Figure 3.16 B-Phase Time-Overcurrent Element 51BT (With Directional Control Option)



Logic Point TCC Controls the Torque Control Switch

TCC State	Torque Control Switch Position	Setting 51CRS =	Reset Timing
Logical 1	Closed	Y	Electromechanical
Logical 0	Open	N	1 Cycle

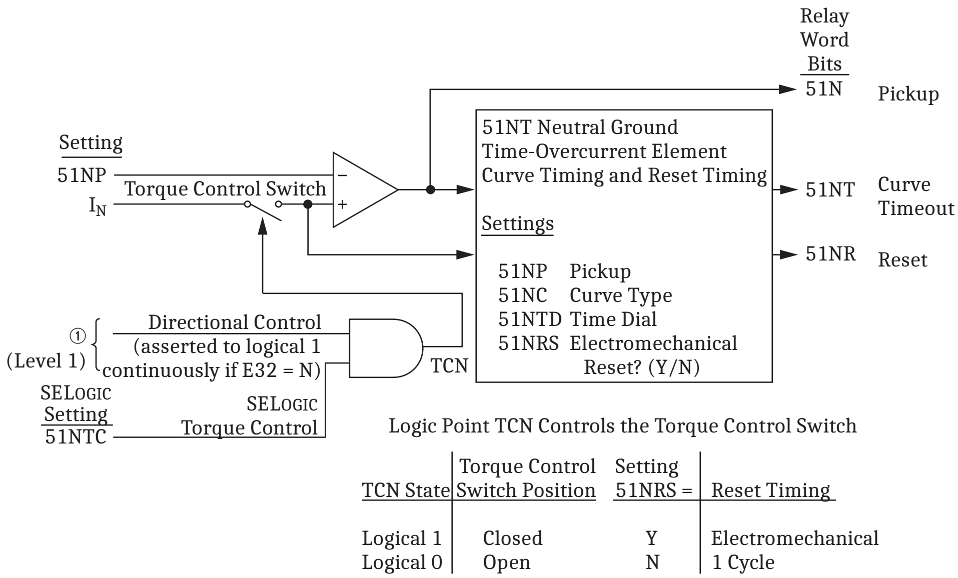
① From *Figure 4.29*.

Figure 3.17 C-Phase Time-Overcurrent Element 51CT (With Directional Control Option)

Neutral Ground Time-Overcurrent Element

To understand the operation of *Figure 3.18*, follow the explanation given for *Figure 3.14* in *Phase Time-Overcurrent Elements* on page 3.16, substituting current I_N (channel IN current) for maximum phase current I_P and substituting like settings and Relay Word bits.

See *Table 4.4* and the accompanying note for a list of the directional features available with each neutral channel (IN) rating.



① From *Figure 4.23*.

Figure 3.18 Neutral Ground Time-Overcurrent Element 51NT (With Directional Control Option)

Settings Ranges

Table 3.4 Neutral Ground Time-Overcurrent Element Settings

Setting	Definition	Range
51NP	pickup	OFF, 0.250–16.000 A secondary in 0.005 A steps (5 A nominal channel IN current input) OFF, 0.050–3.200 A secondary in 0.001 A steps (1 A nominal channel IN current input) OFF, 0.005–0.640 A secondary in 0.001 A steps (0.2 A nominal channel IN current input) OFF, 0.005–0.160 A secondary in 0.001 A steps (0.05 A nominal channel IN current input)
51NC	curve type	U1–U5 (US curves) see *Figure 9.1–Figure 9.10* C1–C5 (IEC curves)
51NTD	time dial	0.50–15.00 (US curves) see *Figure 9.1–Figure 9.10* 0.05–1.00 (IEC curves)
51NRS	electromechanical reset timing	Y, N
51NTC	SELOGIC control equation torque-control setting	Relay Word bits referenced in *Table D.1* or set directly to logical 1 (= 1)[a]

[a] SELOGIC control equation torque-control setting (e.g., 51NTC) cannot be set directly to logical 0.

See *Section 9: Setting the Relay* for additional time-overcurrent element setting information.

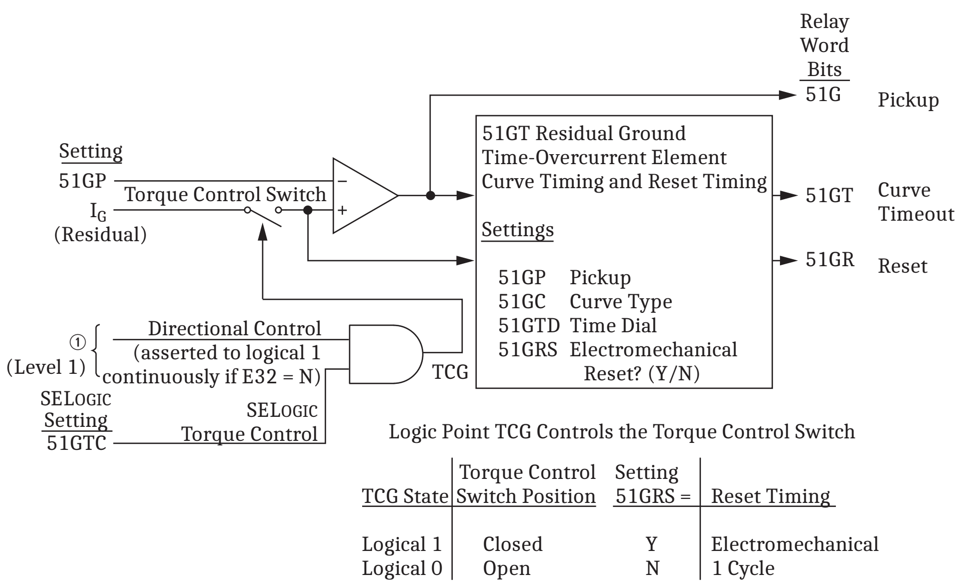
Residual Ground Time-Overcurrent Element

Two residual ground time-overcurrent elements (51GT and 51G2T) are available. These elements are enabled through the E51G setting as shown in *Table 3.5*.

Table 3.5 Available Residual Ground Time-Overcurrent Elements

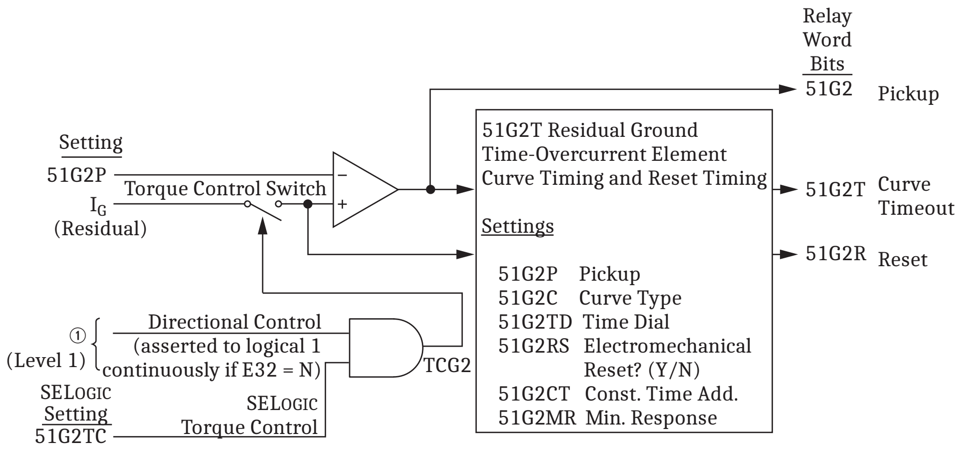
Time-Overcurrent Element	Enabled With Setting	Operating Channel	See Figure
51GT	E51G = 1 or 2	IG = 3I0 = calculated residual ground current	*Figure 3.19*
51G2T	E51G = 2	IG = 3I0 = calculated residual ground current	*Figure 3.20*

To understand the operation of *Figure 3.19* and *Figure 3.20*, follow the explanation given for *Figure 3.14* in *Phase Time-Overcurrent Elements* on page 3.16, substituting residual ground current I_G ($I_G = 3I_0 = I_A + I_B + I_C$) for maximum phase current I_P and substituting like settings and Relay Word bits.



① From *Figure 4.22*.

Figure 3.19 Residual Ground Time-Overcurrent Element 51GT (With Directional Control Option)



TCG2 State	Torque Control Switch Position	Setting 51G2RS =	Reset Timing
Logical 1	Closed	Y	Electromechanical
Logical 0	Open	N	1 Cycle

① From *Figure 4.22*.

Figure 3.20 Residual Ground Time-Overcurrent Element 51G2T (With Directional Control Option)

Settings Ranges

Table 3.6 Residual Ground Time-Overcurrent Element Settings

Setting	Definition	Range
51GP 51G2P	pickup	OFF, 0.10–16.00 A secondary (5 A nominal phase current inputs, IA, IB, IC) OFF, 0.02–3.20 A secondary (1 A nominal phase current inputs, IA, IB, IC)
51GC 51G2C	curve type	U1–U5 (US curves) see *Figure 9.1–Figure 9.10* C1–C5 (IEC curves)
51GTD 51G2TD	time dial	0.50–15.00 (US curves) 0.05–1.00 (IEC curves) see *Figure 9.1–Figure 9.10*
51GRS 51G2RS	electromechanical reset timing	Y, N
51GTC 51G2TC	SELOGIC control equation torque-control setting	Relay Word bits referenced in *Table D.1* or set directly to logical 1 (= 1)[a]

[a] SELOGIC control equation torque-control setting (e.g., 51GTC) cannot be set directly to logical 0.

See *Section 9: Setting the Relay* for additional time-overcurrent element setting information.

Negative-Sequence Time-Overcurrent Element

To understand the operation of *Figure 3.21*, follow the explanation given for *Figure 3.14* in *Phase Time-Overcurrent Elements* on page 3.16, substituting negative-sequence current $3I_2$.

$$3I_2 = I_A + a^2 \cdot I_B + a \bullet I_C \text{ (ABC rotation)}$$

$$3I_2 = I_A + a^2 \bullet I_C + a \bullet I_B \text{ (ACB rotation)}$$

where:

$$a = 1 \angle 120°$$

$$a^2 = 1 \angle -120°$$

NOTE: See *Appendix G: Setting Negative-Sequence Overcurrent Elements* for information on setting negative-sequence overcurrent elements.

for maximum phase current IP and like settings and Relay Word bits.

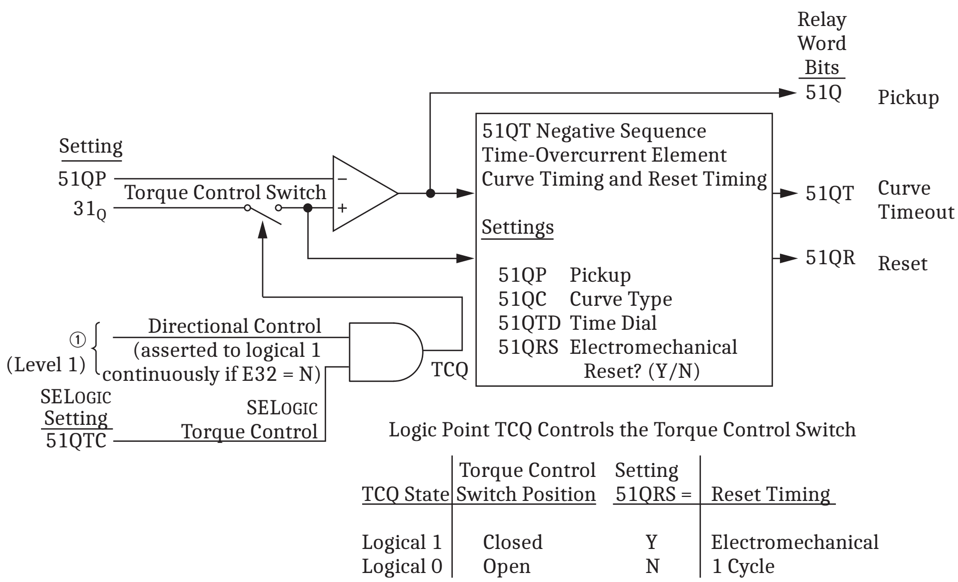


Figure 3.21 Negative-Sequence Time-Overcurrent Element 51QT (With Directional Control Option)

Settings Ranges

Table 3.7 Negative-Sequence Time-Overcurrent Element Settings

Setting	Definition	Range
51QP	pickup	OFF, 0.25–16.00 A secondary (5 A nominal phase current inputs, IA, IB, IC) OFF, 0.05–3.20 A secondary (1 A nominal phase current inputs, IA, IB, IC)
51QC	curve type	U1–U5 (US curves) see *Figure 9.1–Figure 9.10* C1–C5 (IEC curves)
51QTD	time dial	0.50–15.00 (US curves) see *Figure 9.1–Figure 9.10* 0.05–1.00 (IEC curves)
51QRS	electromechanical reset timing	Y, N
51QTC	SELOGIC control equation torque control setting	Relay Word bits referenced in *Table D.1* or set directly to logical 1 (= 1)[a]

[a] SELOGIC control equation torque-control setting (e.g., 51QTC) cannot be set directly to logical 0.

See *Section 9: Setting the Relay* for additional time-overcurrent element setting information.

Second Harmonic Blocking Logic

When a distribution feeder supplies many transformers, magnetizing inrush currents may cause sensitive overcurrent elements to operate when the line is energized. The second harmonic blocking logic can prevent this by blocking such elements until inrush currents have subsided. As shown in *Figure 3.22*, this logic uses the ratio of the second harmonic content of each phase to the fundamental current of the same phase to calculate the percent second harmonic content.

When SELOGIC torque-control equation HBL2TC evaluates to logical 1, and if the second harmonic content exceeds the adjustable pickup threshold, HBL2P, for the pickup time delay, HBL2PU, the blocking Relay Word bit for that phase asserts. Once the output is asserted, if the second harmonic content falls below the threshold for the dropout time delay, HBL2DO, the output de-asserts. If any of the phase outputs asserts, Relay Word bit HBL2T also asserts.

Table 3.8 Second Harmonic Blocking Settings

Setting	Definition	Range
EHBL2	Enable Second Harmonic Blocking	Y, N
HBL2P	Second Harmonic Pickup Threshold	5–100%
HBL2PU	Second Harmonic Blocking Timer Pickup	0–16,0000 cycles
HBL2DO	Second Harmonic Blocking Timer Dropout	0–16,0000 cycles
HBL2TC	Second Harmonic Blocking Torque Control	Relay Word bits referenced in *Table D.1* or set directly to logical 1 (= 1)[a]

[a] SELOGIC control equation torque-control settings (e.g., HBL2TC) cannot be set directly to logical 0.

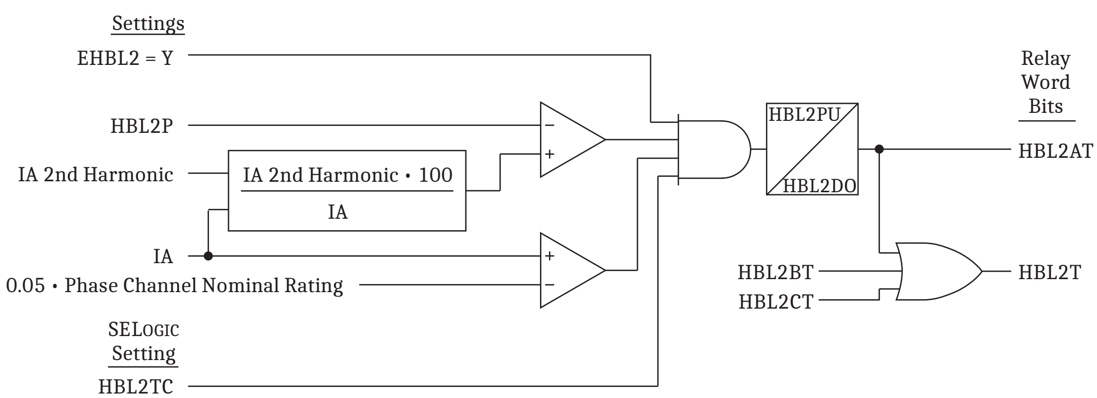


Figure 3.22 Second Harmonic Blocking Logic

Table 3.9 Second Harmonic Blocking Logic Outputs

Relay Word Bit	Definition	Application
HBL2AT	Phase A second harmonic element timed out	Overcurrent element control
HBL2BT	Phase B second harmonic element timed out	Overcurrent element control
HBL2CT	Phase C second harmonic element timed out	Overcurrent element control
HBL2T	One or more phases second harmonic element timed out	Overcurrent element control

Second harmonic blocking elements are typically used to supervise sensitive overcurrent elements. CT saturation during faults can cause the relay to measure second harmonic current. The second harmonic blocking element may also assert briefly when the fundamental frequency current changes. Either condition might delay the supervised element. Set an unsupervised element above the expected inrush current to provide fast protection during large faults. Set the second harmonic blocking timer pickup for more than one cycle in applications that cannot tolerate the element operating because of current changes.

Settings Examples

Instantaneous Overcurrent Element Blocking

In this example, including second harmonic blocking element HBL2T in the torque-control equation for Level 1 Phase Overcurrent element 67P1 helps prevent operation because of transformer inrush.

50P1P = **10.00 A**

50P2P = **20.00 A**

67P1D = **2.00 cycles**

67P1TC = **!HBL2T**

67P2TC = **1**

TR = **...+ 67P1T + 67P2T +...**

The Level 1 time delay 67P1D allows time for the blocking element to assert. Level 2 Phase Overcurrent element setting 50P2P is high enough that the element will not operate when the line is energized but low enough to operate for high current faults when current transformer saturation or fundamental frequency current change might briefly block the Level 1 element.

Time-Overcurrent Element Blocking

For time-overcurrent elements, it may be desirable for the element to continue timing when transformer inrush is detected, yet trip the breaker if the time-overcurrent element remains asserted after the inrush conditions have subsided.

51PP = **6.00 A**

51AP = **10.00 A**

51BP = **10.00 A**

51CP = **10.00 A**

HBL2DO = **2.00 cycles**

51PTC = **1**

51ATC = **1**

51BTC = **1**

51CTC = **1**

TR = **...+ 51PT * !HBL2T + 51AT + 51BT + 51CT +...**

ER = **...+ /51P + /51PT +...**

In this example, 51PT is allowed to assert regardless of the state of the second harmonic blocking element. However, 51PT cannot cause a trip if HBL2T is asserted. Dropout timer HBL2DO ensures that the blocking condition is maintained until 51PT deasserts. If electromechanical reset is disabled (51PRS = N), 51PT remains asserted for 1 cycle after the phase current falls below pickup setting 51PP. HBL2DO may be increased to provide additional security should the second harmonic current fall below the pickup threshold before the fundamental frequency current falls below the overcurrent element pickup. Because the relay may not trip when 51PT asserts, the ER Event Report Trigger SELOGIC control equation is modified to trigger an event report. This event report can be used to evaluate the effectiveness of the harmonic blocking and determine if setting adjustments are necessary.

Changing the Pickup of a Time-Overcurrent Element

Use the second harmonic blocking elements to increase the pickup current of a time-overcurrent element during inrush conditions without changing the time delay characteristics. For example,

51PP = **6.00 A**

51AP = **15.00 A**

51BP = **15.00 A**

51CP = **15.00 A**

50P3P = **12.00 A**

51PTC = **!HBL2T + 50P3**

51ATC = **1**

51BTC = **1**

51CTC = **1**

TR = **...+ 51PT + 51AT + 51BT + 51CT +...**

In this example, the maximum-phase time-overcurrent element operates if the second harmonic blocking element is deasserted or the phase current exceeds the Level 3 Phase Instantaneous Overcurrent setting. If second harmonic blocking is asserted and the phase current is below the Level 3 Phase Instantaneous Overcurrent setting, the time-overcurrent element 51P does not operate. Thus the pickup of the maximum-phase time-overcurrent element 51P is increased from 6 A secondary to 12 A secondary during inrush. Once the maximum phase current exceeds 50P3P, the timing of the 51P element does not change, so coordination is maintained for large faults.

As shown in *Figure 3.14*, if torque-control equation 51PTC deasserts, the Level 1 phase time-overcurrent element may fully or partially reset. When second harmonic blocking elements are included in torque-control equations for time-overcurrent elements, the element will need to time from reset after the blocking element deasserts. Consider this when evaluating time-overcurrent coordination and when reviewing event reports in which harmonic blocking has operated.

Voltage Elements

Enable numerous voltage elements by making the enable setting:

EVOLT = **Y**

Voltage Values

The voltage elements operate off of various voltage values shown in *Table 3.10*.

Table 3.10 Voltage Values Used by Voltage Elements

Voltage	Description
V_A	A-phase voltage, from SEL-351 rear-panel voltage input **VA**[a]
V_B	B-phase voltage, from SEL-351 rear-panel voltage input **VB**[a]
V_C	C-phase voltage, from SEL-351 rear-panel voltage input **VC**[a]
V_{AB}	Phase-to-phase voltage[b]
V_{BC}	Phase-to-phase voltage[b]
V_{CA}	Phase-to-phase voltage
$3V_0$	Zero-sequence voltage[a, c]
V_2	Negative-sequence voltage
V_1	Positive-sequence voltage
V_S	Synchronism-check voltage, from SEL-351 rear-panel voltage input **VS**[d]

[a] Not available when delta-connected (PTCONN = DELTA).

[b] Measured directly when delta-connected.

[c] When PTCONN = WYE, the relay calculates zero-sequence voltage 3V0 from the phase voltage signals VA, VB, and VC, and uses the value to operate the zero-sequence voltage elements 59N1 and 59N2. The VSCONN setting has no effect on this calculated 3V0 quantity, even in directional SEF applications when a broken-delta connected voltage is applied to VS (with VSCONN = 3V0).

[d] Voltage VS can be used in the synchronism-check elements when Global setting VSCONN = VS (see *Synchronism-Check Elements* on page 3.36). Voltage VS can be connected to a zero-sequence voltage source (typically a broken-delta connection) when Global setting VSCONN = 3V0 (see *Broken-Delta VS Connection (Global Setting VSCONN = 3V0)* on page 2.13). Voltage VS is also used in the three voltage elements listed in *Table 3.12* and in *Figure 3.27*, **independent** of the VSCONN setting.

NOTE: Voltage VS cannot be used for 3V0 measurement and as a synchronism check input at the same time.

Voltage Element Settings

Table 3.11 through *Table 3.13* list available voltage elements and the corresponding voltage inputs and settings ranges for SEL-351 Relays. The Global setting PTCONN determines the relay voltage configuration as one of the following:

- ➤ Wye-connected (PTCONN = WYE), use *Table 3.11* and *Table 3.12*
- ➤ Delta-connected (PTCONN = DELTA), use *Table 3.12* and *Table 3.13*
- ➤ Single-phase connected (PTCONN = SINGLE) use *Table 3.11* and *Table 3.12*

The Global setting PHANTV (phantom voltage phase selection for metering) has no effect on the voltage elements. See *Settings for Voltage Input Configuration* on page 9.18.

NOTE: Voltage element pickup settings should not be set near zero, because they can assert or deassert because of noise when no signal is applied. SEL recommends a minimum setting of 2.00 V.

Table 3.11 Voltage Elements Settings and Settings Ranges (Wye-Connected or Single-Phase-Connected PTs)

Voltage Element (Relay Word Bits)	Operating Voltage	Pickup Setting/Range	See Figure
27A1	V_A	27P1P 0.00–300.00 V secondary	*Figure 3.23*
27B1	V_B		
27C1	V_C		
3P27 = 27A1 * 27B1 * 27C1			
27A2	V_A	27P2P 0.00–300.00 V secondary	
27B2	V_B		
27C2	V_C		
59A1	V_A	59P1P 0.00–300.00 V secondary	
59B1	V_B		
59C1	V_C		
3P59 = 59A1 * 59B1 * 59C1			
59A2	V_A	59P2P 0.00–300.00 V secondary	
59B2	V_B		
59C2	V_C		
27AB	V_{AB}	27PP[a] 0.00–520.00 V secondary	*Figure 3.24*
27BC	V_{BC}		
27CA	V_{CA}		
59AB	V_{AB}	59PP[a] 0.00–520.00 V secondary	
59BC	V_{BC}		
59CA	V_{CA}		
59N1	$3V_0$	59N1P[a] 0.00–300.00 V secondary	
59N2	$3V_0$	59N2P[a] 0.00–300.00 V secondary	
59Q	V_2	59QP[a] 0.00–200.00 V secondary	
59V1	V_1	59V1P[a] 0.00–300.00 V secondary	

[a] Not available when PTCONN = SINGLE.

Table 3.12 Voltage Elements Settings and Settings Ranges (VS Channel)

Voltage Element (Relay Word Bits)	Operating Voltage	Pickup Setting/Range	See Figure
27S	V_S	27SP 0.00–300.00 V secondary	*Figure 3.27*
59S1	V_S	59S1P 0.00–300.00 V secondary	
59S2	V_S	59S2P 0.00–300.00 V secondary	

Table 3.13 Voltage Elements Settings and Settings Ranges (Delta-Connected PTs)

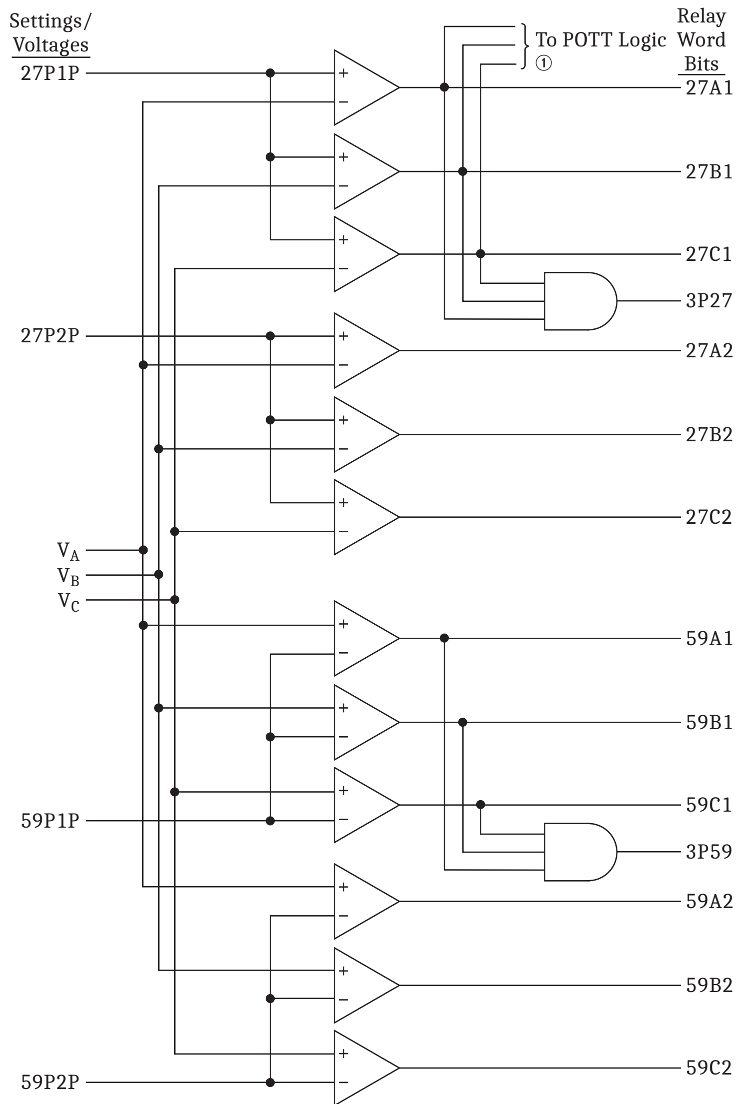
Voltage Element (Relay Word Bits)	Operating Voltage	Pickup Setting/Range	See Figure
27AB	V_{AB}	27PP 0.00–300.00 V secondary	*Figure 3.25*
27BC	V_{BC}		
27CA	V_{CA}		
3P27 = 27AB * 27BC * 27CA			
27AB2	V_{AB}	27PP2P 0.00–300.00 V secondary	
27BC2	V_{BC}		
27CA2	V_{CA}		
59AB	V_{AB}	59PP 0.00–300.00 V secondary	
59BC	V_{BC}		
59CA	V_{CA}		
3P59 = 59AB * 59BC * 59CA			
59AB2	V_{AB}	59PP2P 0.00–300.00 V secondary	
59BC2	V_{BC}		
59CA2	V_{CA}		
59Q	V_2	59QP 0.00–120.00 V secondary	*Figure 3.26*
59Q2	V_2	59Q2P 0.00–120.00 V secondary	
59V1	V_1	59V1P 0.00–170.00 V secondary	

Positive-Sequence and Negative-Sequence Calculations When PTCONN = DELTA

Use the following equations to calculate the positive-sequence and negative-sequence voltage for open-delta configurations when PTCONN = DELTA. (Calculations are shown for ABC phase rotation. Swap the results for ACB rotation.)

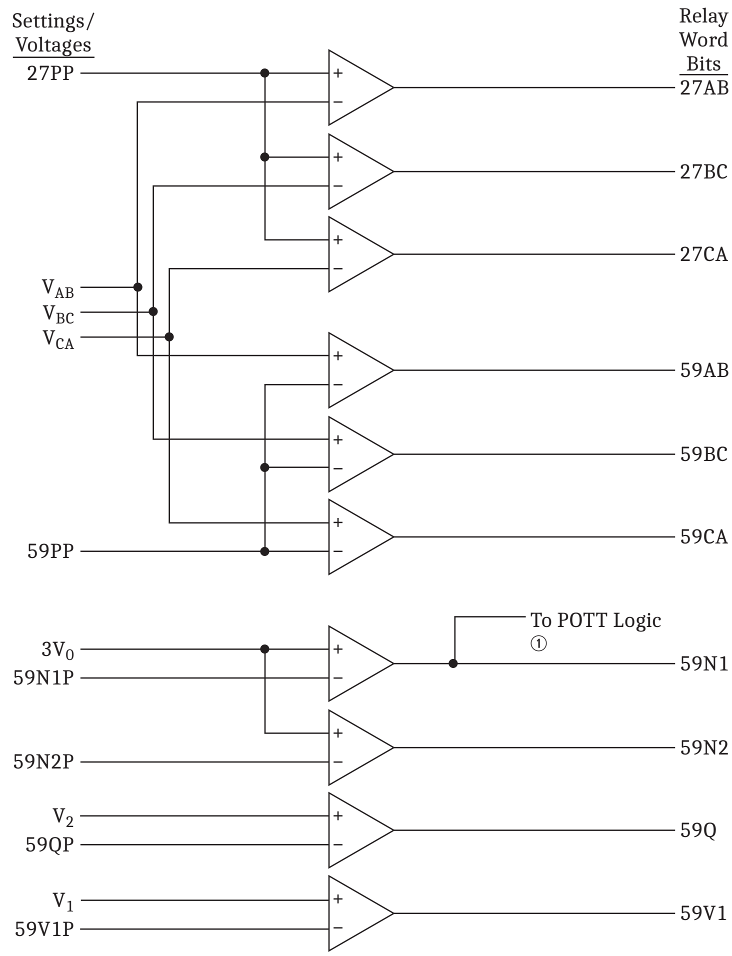
$$V_1 = \frac{1}{3} \bullet (V_{AB} - a^2 \bullet V_{BC})$$

$$V_2 = \frac{1}{3} \bullet (V_{AB} - a \bullet V_{BC})$$



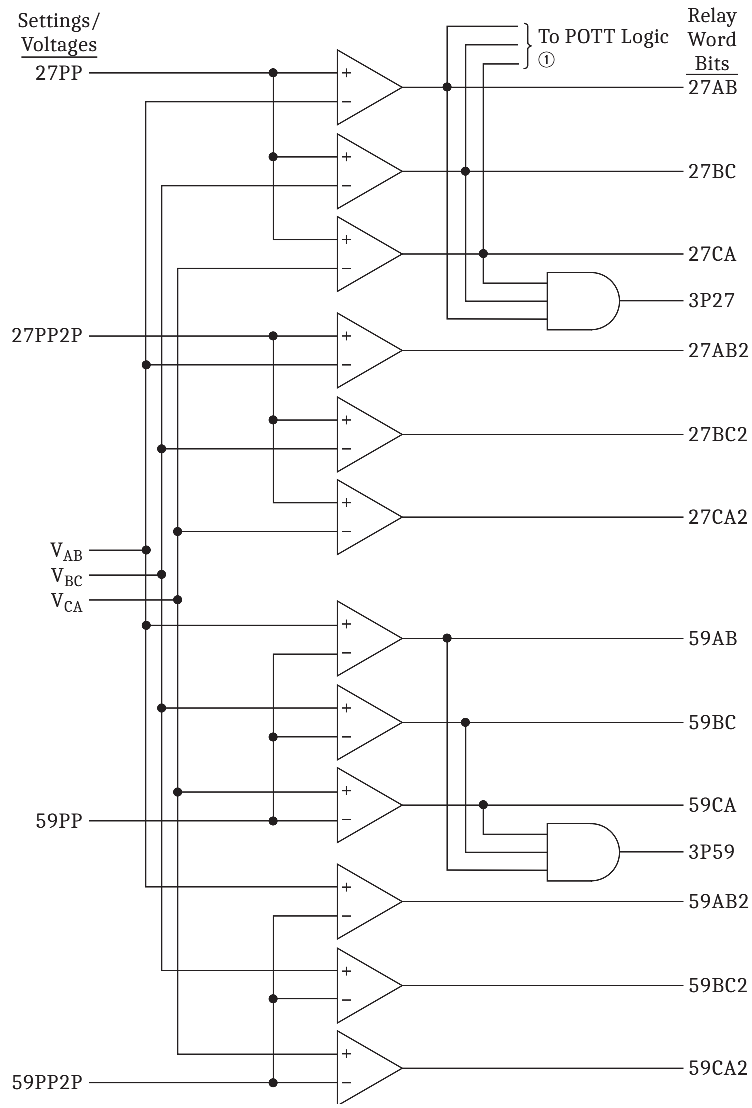
① *Figure 5.6.*

Figure 3.23 Single-Phase and Three-Phase Voltage Elements (Wye-Connected or Single-Phase-Connected PTs)



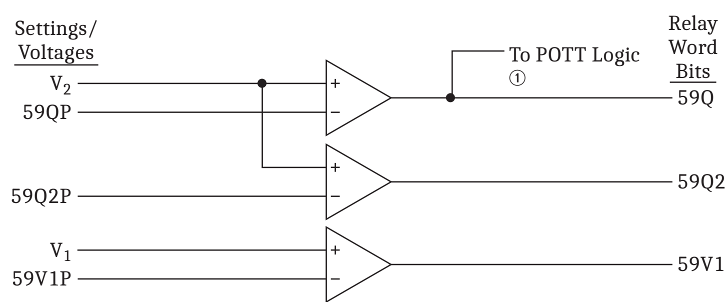
① *Figure 5.6*.

Figure 3.24 Phase-to-Phase and Sequence Voltage Elements (Wye-Connected PTs)



① *Figure 5.6.*

Figure 3.25 Phase-to-Phase Voltage Elements (Delta-Connected PTs)



① *Figure 5.6.*

Figure 3.26 Sequence Voltage Elements (Delta-Connected PTs)

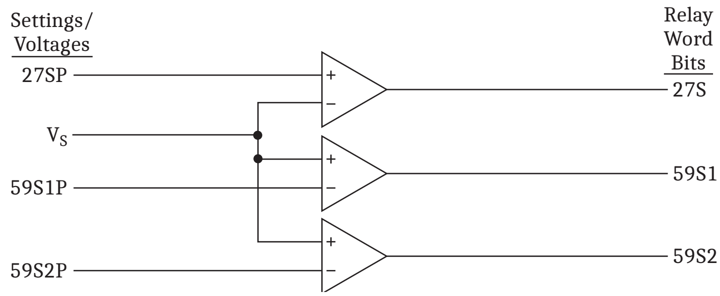


Figure 3.27 Channel VS Voltage Elements (Wye- or Delta-Connected PTs)

Voltage Element Operation

Note that the voltage elements in *Table 3.11* through *Table 3.13*, and *Figure 3.23* through *Figure 3.27* are a combination of "undervoltage" (Device 27) and "overvoltage" (Device 59) type elements. Undervoltage elements (Device 27) assert when the operating voltage goes *below* the corresponding pickup setting. Overvoltage elements (Device 59) assert when the operating voltage goes *above* the corresponding pickup setting.

Undervoltage Element Operation Example

Refer to *Figure 3.23* (top of the figure).

Pickup setting 27P1P is compared to the magnitudes of the individual phase voltages V_A, V_B, and V_C. The logic outputs in *Figure 3.23* are the following Relay Word bits:

27A1	=	1 (logical 1), if V_A < pickup setting 27P1P
	=	0 (logical 0), if $V_A \geq$ pickup setting 27P1P
27B1	=	1 (logical 1), if V_B < pickup setting 27P1P
	=	0 (logical 0), if $V_B \geq$ pickup setting 27P1P
27C1	=	1 (logical 1), if V_C < pickup setting 27P1P
	=	0 (logical 0), if $V_C \geq$ pickup setting 27P1P
3P27	=	1 (logical 1), if all three Relay Word bits 27A1, 27B1, and 27C1 are asserted (27A1 = 1, 27B1 = 1, and 27C1 = 1)
	=	0 (logical 0), if at least one of the Relay Word bits 27A1, 27B1, or 27C1 is deasserted (e.g., 27A1 = 0)

Overvoltage Element Operation Example

Refer to *Figure 3.23* (bottom of the figure).

Pickup setting 59P1P is compared to the magnitudes of the individual phase voltages V_A, V_B, and V_C. The logic outputs in *Figure 3.23* are the following Relay Word bits:

59A1	=	1 (logical 1), if V_A > pickup setting 59P1P
	=	0 (logical 0), if $V_A \leq$ pickup setting 59P1P
59B1	=	1 (logical 1), if V_B > pickup setting 59P1P
	=	0 (logical 0), if $V_B \leq$ pickup setting 59P1P
59C1	=	1 (logical 1), if V_C > pickup setting 59P1P
	=	0 (logical 0), if $V_C \leq$ pickup setting 59P1P

3P59 = 1 (logical 1), if all three Relay Word bits 59A1, 59B1, and 59C1 are asserted (59A1 = 1, 59B1 = 1, and 59C1 = 1)
= 0 (logical 0), if at least one of the Relay Word bits 59A1, 59B1, or 59C1 is deasserted (e.g., 59A1 = 0)

Voltage Elements Used in POTT Logic

Refer to *Figure 3.23* and *Figure 3.24* for wye-connected voltage inputs. Note that voltage elements 27A1, 27B1, 27C1, and 59N1 are also used in the weak-infeed portion of the POTT logic, if the weak-infeed logic is enabled (see *Figure 5.6*).

Refer to *Figure 3.25* and *Figure 3.26* for delta-connected voltage inputs. Note that voltage elements 27AB, 27BC, 27CA, and 59Q are also used in the weak-infeed portion of the POTT logic, if the weak-infeed logic is enabled (see *Figure 5.6*).

If the weak-infeed portion of the POTT logic is enabled (setting EWFC = Y) and these voltage elements are used in the logic, they can still be used in other applications (if the settings are applicable). If the weak-infeed portion of the POTT logic is not enabled, these voltage elements can be used in any desired application.

Synchronism-Check Elements

Enable the two single-phase synchronism-check elements by making the enable setting:

E25 = **Y**

NOTE: If Global setting VSCONN = 3V0, the synchronism-check elements are unavailable, and E25 = N is the only possible setting. See *Broken-Delta VS Connection (Global Setting VSCONN = 3V0)* on page 2.13 for details.

Figure 2.15–Figure 2.18, *Figure 2.27*, and *Figure 2.28* show examples where synchronism check can be applied. Synchronism-check voltage input **VS** is connected to one side of the circuit breaker, on any desired phase. The other synchronizing phase (**VA**, **VB**, or **VC** voltage inputs) on the other side of the circuit breaker is setting selected.

The two synchronism-check elements use the same voltage window (to ensure healthy voltage) and slip frequency settings (see *Figure 3.29*). They have separate angle settings (see *Figure 3.30*). A ratio correction factor setting is available to allow the voltage window settings to be used on systems that have different secondary voltage levels on the VS terminal and the VA, VB, and VC terminals.

If the voltages are static (voltages not slipping with respect to one another) or setting TCLOSD = 0.00, the two synchronism-check elements operate as shown in the top of *Figure 3.30*. The angle settings are checked for synchronism check closing.

If the voltages are not static (voltages slipping with respect to one another), the two synchronism-check elements operate as shown in the bottom of *Figure 3.30*. The angle difference is compensated by breaker close time, and the breaker is ideally closed at a zero degree phase angle difference, to minimize system shock.

These synchronism-check elements are explained in detail in the following text.

Synchronism-Check Elements Settings

Table 3.14 Synchronism-Check Elements Settings and Settings Ranges

Setting	Definition	Range
25VLO	low voltage threshold for "healthy voltage" window	0.00–300.00 V secondary
25VHI	high voltage threshold for "healthy voltage" window	0.00–300.00 V secondary
25RCF	voltage ratio correction factor	0.50–2.00, unitless
25SF	maximum slip frequency	0.005–1.0 Hz[a]
25ANG1	synchronism-check element 25A1 maximum angle	0°–80°
25ANG2	synchronism-check element 25A2 maximum angle	0°–80°
SYNCP	synchronizing phase or	VA, VB, or VC (wye-connected voltages) VAB, VBC, or VCA (delta-connected voltages)
	the number of degrees that synchronism-check voltage V_S constantly lags voltage V_A (wye-connected), **VA-N** (single-phase connected voltage), or V_{AB} (delta-connected voltages)	0°–330°, in 30° steps (any voltage connection)
TCLOSD	breaker close time for angle compensation	0.00–60.00 cycles (NFREQ = 60 HZ) 0.00–50.00 cycles (NFREQ = 50 Hz)
BSYNCH	SELOGIC control equation block synchronism-check setting	Relay Word bits referenced in *Table D.1*

[a] When TCLOSD is greater than 30 cycles (NFREQ = 60 Hz) or greater than 25 cycles (NFREQ = 50 Hz), 25SF must be set less than or equal to 0.5 Hz.

NOTE: Setting 25ANG1 = 0 or 25ANG2 = 0 disables the respective synchronism check element.

Setting SYNCP

Wye-Connected Voltages

NOTE: Settings SYNCP = 0 and SYNCP = VA are effectively the same (voltage V_S is directly synchronism checked with voltage V_A; V_S does not lag V_A). The relay will display the setting entered (SYNCP = VA or SYNCP = 0).

The angle setting choices (0, 30, …, 300, or 330 degrees) for setting SYNCP are referenced to V_A, and they indicate how many degrees V_S constantly lags V_A. In any synchronism-check application, voltage input **VA-N** always has to be connected to determine system frequency on one side of the circuit breaker (to determine the slip between V_S and V_A). V_A always has to meet the "healthy voltage" criteria (settings 25VHI, 25VLO, and 25RCF—see *Figure 3.29*). Thus, for situations where V_S cannot be in phase with V_A, V_B, or V_C, it is most straightforward to have the angle setting choices (0, 30, …, 300, or 330 degrees) referenced to V_A.

Delta-Connected Voltages

NOTE: Settings SYNCP = 0 and SYNCP = VAB are effectively the same (voltage V_S is directly synchronism checked with voltage V_{AB}; V_S does not lag V_{AB}). The relay will display the setting entered (SYNCP = VAB or SYNCP = 0).

The angle setting choices (0, 30, …, 300, or 330 degrees) for setting SYNC are referenced to V_{AB}, and they indicate how many degrees V_S constantly lags V_{AB}. In any synchronism-check application, voltage input **VA-VB** always has to be connected to determine system frequency on one side of the circuit breaker (to determine the slip between V_S and V_{AB}). V_{AB} always has to meet the "healthy voltage" criteria (settings 25VHI, 25VLO, and 25RCF—see *Figure 3.29*). Thus, for situations where V_S cannot be in phase with V_{AB}, V_{BC}, or V_{CA}, it is most straightforward to have the angle setting choices (0, 30, …, 300, or 330 degrees) referenced to V_{AB}.

Figure 2.27 shows a relay wired with delta-connected phase PTs, and a C-phase-to-ground connected **VS-NS** input. With ABC rotation, the correct SYNCP setting for this example is 270 degrees, the amount that V_C lags V_{AB}.

Single-Phase Connected Voltage

For systems with a single-phase voltage connection (Global setting PTCONN = SINGLE), the SYNCP setting can only be set to a numeric value from 0 to 330 degrees in 30 degree steps (lagging the VA terminal). In this situation, the single-phase voltage connected to the **VA-N** terminal is not necessarily V_A, but could be any system voltage (V_A, V_B, V_C, V_{AB}, V_{BC}, or V_{CA}) or the opposite polarity of any of these signals ($-V_A$, $-V_B$, $-V_C$, V_{BA}, V_{CB}, or V_{AC}).

NOTE: These "opposite polarity" connections are not compatible with phantom voltage metering. If the phantom voltage metering feature is going to be used, please read *Phantom Metering for Single-Phase Voltage Connections* on page 8.24.

The SYNCP setting prompt changes to contain "lag VA terminal" as a reminder to enter the nominal phase difference between the voltage applied to the **VS-NS** terminal and the voltage applied to the **VA-N** terminal. *Figure 3.28* shows an example where a single-phase voltage is connected to the **VA-N** terminals (PTCONN = SINGLE).

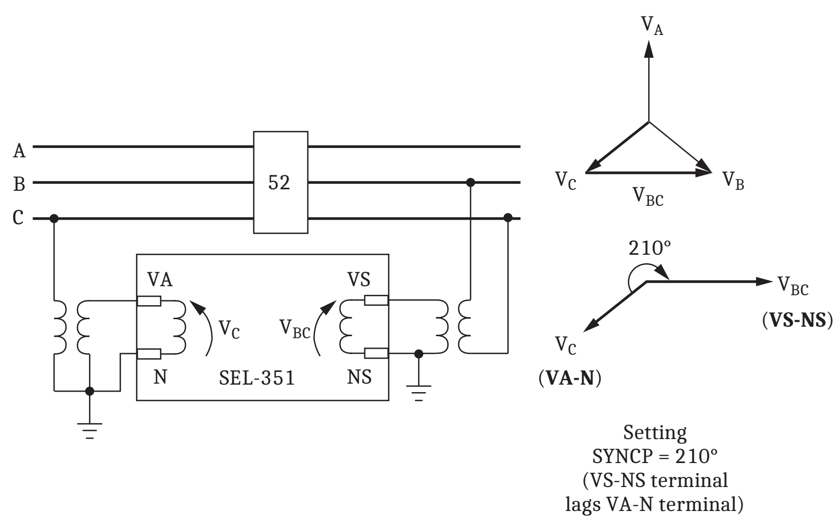


Figure 3.28 Example Single-Phase VA-N With Phase-to-Phase VS-NS Synchronism-Check Voltage

In the *Figure 3.28* example, voltage input **VA-N** is connected C-phase-to-neutral on one side of the breaker, but synchronism-check voltage input **VS-NS** is connected B-phase-to-C-phase on the other side of the breaker. For this example system, with ABC phase rotation, resultant voltage V_S constantly lags terminal voltage **VA-N** by 210°. Thus, setting SYNCP is set:

SYNCP = 210

Setting SYNCP = 210 accounts for this constant 210º phase angle difference (voltage V_S lags terminal voltage **VA-N**) in checking synchronism between voltage V_{BC} and voltage V_C.

Voltage Input VS Connected Phase-to-Phase or Beyond Delta-Wye Transformer

Sometimes synchronism-check voltage V_S cannot be in phase with voltage V_A, V_B, or V_C (wye-connected PTs); V_{AB}, V_{BC}, or V_{CA} (delta-connected PTs); or **VA** (single-phase connected voltages). This happens in applications where voltage input **VS** is connected:

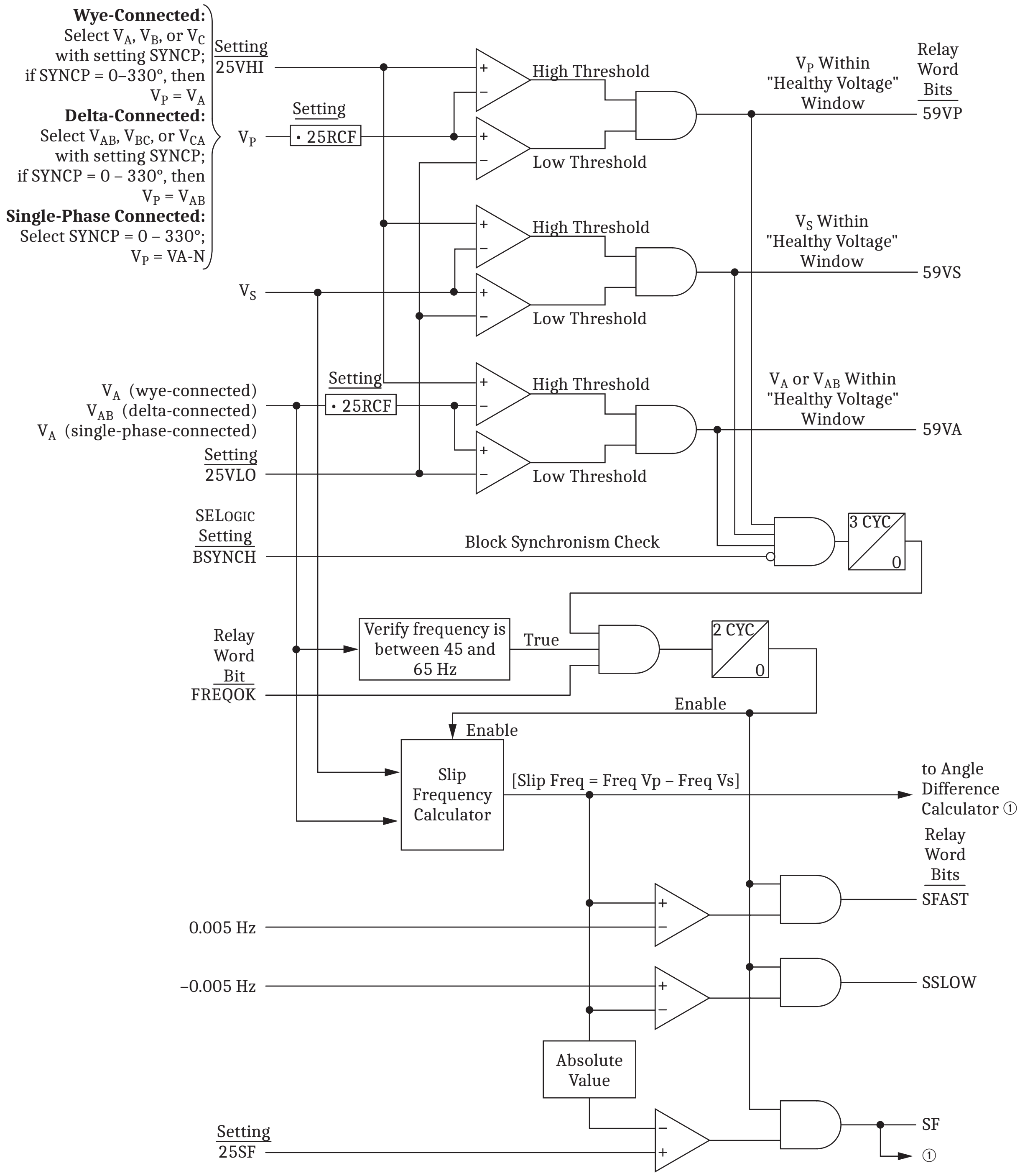
- Phase-to-phase when using a wye-connected relay
- Phase-to-neutral when using a delta-connected relay
- Beyond a delta-wye transformer

For such applications, make a numerical angle selection with the SYNCP setting (see *Table 3.14* and *Setting SYNCP* on page 3.37).

Use the voltage ratio correction factor (setting 25RCF) to compensate the magnitude of the phase voltage to match the sync voltage VS. See *Voltage Window and SYNCP Settings Example* on page 3.44 for an example application.

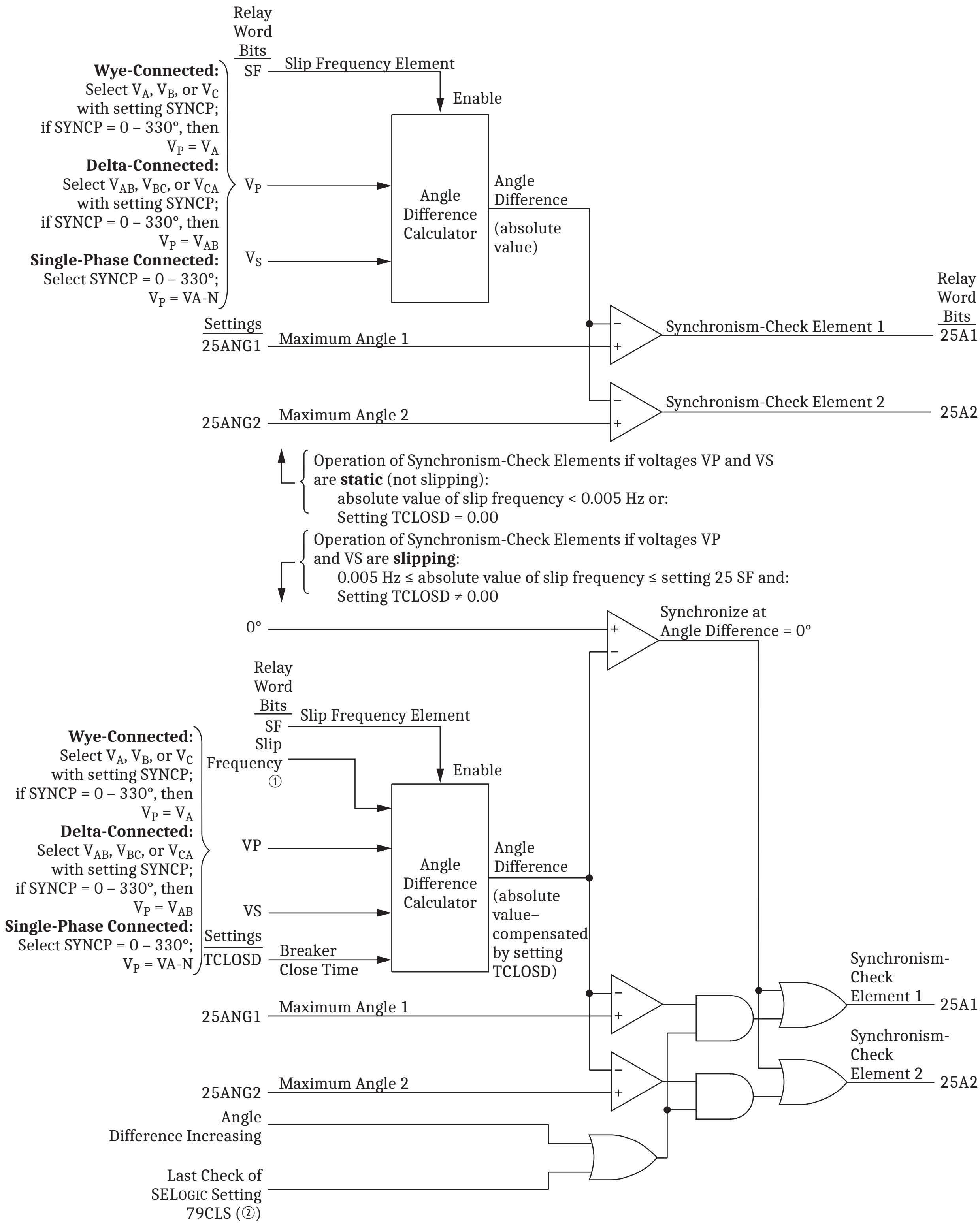
Synchronism-Check Logic Diagrams

The synchronism-check logic is shown in *Figure 3.29* and *Figure 3.30*. Make Group setting E25 = Y to access the settings and to enable this logic.



① See *Figure 3.30*.

Figure 3.29 Synchronism-Check Voltage Window and Slip Frequency Elements



① From *Figure 3.29*. ② See *Figure 6.3*.

Figure 3.30 Synchronism-Check Elements

Synchronism-Check Elements Voltage Inputs

The two synchronism-check elements are single-phase elements, with single-phase voltage inputs V_P and V_S used for both elements:

V_P Phase input voltage:

- V_A, V_B, or V_C for wye-connected voltages
- V_{AB}, V_{BC}, V_{CA} for delta-connected voltages

when designated by an alphabetic setting SYNCP (e.g., if SYNCP = VB, then V_P = VB),

or

- V_A for wye-connected voltages
- V_{AB} for delta-connected voltages
- **VA-N** for single-phase connected voltage

when designated by a numeric setting SYNCP (e.g., if SYNCP = 210 degrees, then $V_P = V_A$ when PTCONN = WYE; $V_P = V_{AB}$ when PTCONN = DELTA; V_P = **VA-N** when PTCONN = SINGLE).

V_S Synchronism-check voltage, from SEL-351 rear-panel voltage input **VS**

For example, if V_P is designated as phase input voltage V_B (setting SYNCP = VB) [or VBC (setting SYNCP = VBC) for delta], then rear-panel voltage input **VS-NS** is connected to B-phase (or BC phase-to-phase for delta) on the other side of the circuit breaker. The voltage across terminals **VB-N** (or **VB-VC** for delta) is synchronism checked with the voltage across terminals **VS-NS** (see *Figure 2.9*, *Figure 2.10*, *Figure 2.15–Figure 2.18*, *Figure 2.27*, and *Figure 2.28*).

System Frequencies Determined from Voltages V_A (or V_{AB} for Delta) and V_S

To determine slip frequency, the relay determines the system frequencies on both sides of the circuit breaker. Voltage V_S determines the frequency on one side. Voltage V_A (for wye-connected or single-phase-connected voltage inputs) or voltage V_{AB} (for delta-connected voltage inputs) determines the frequency on the other side. Thus, voltage terminals **VA-N** (or **VA-VB** for delta) have to be connected, even if another voltage (e.g., voltage V_B for wye or V_{BC} for delta) is to be synchronized with voltage V_S.

In most applications, all three voltage inputs **VA**, **VB**, and **VC** are connected to the three-phase power system and no additional connection concerns are needed for voltage connection **VA-N** (or **VA-VB** for delta). The presumption is that the frequency determined for A-phase (or AB phase-to-phase for delta) is also valid for B- and C-phase (or BC and CA phase-to-phase for delta) in a three-phase power system.

However, for example, if voltage V_B (or V_{BC} for delta) is to be synchronized with voltage V_S and plans were to connect only voltage terminals **VB-N** and **VS-NS** (or voltage terminals **VB-VC** and **VS-NS** for delta) then voltage terminals **VA-N** (or **VA-VB** for delta) will also have to be connected for frequency determination. If desired, voltage terminals **VA-N** can be connected in parallel with voltage terminals **VB-N** (or voltage terminals **VB-VA** connected in parallel with voltage terminals **VB-VC** for delta; connect voltage terminal **VA** to **VC**). In such a nonstandard parallel connection, remember that voltage terminals **VA-N** are monitoring Phase B (or voltage terminals **VB-VA** are monitoring BC phase-to-phase for delta). This understanding helps prevent confusion when observing metering and event report information or voltage element operation.

Another possible solution to this example for wye-connected relays (synchronism-check voltage input **VS-NS** connected to V_B) is to make setting SYNCP = 120 (the number of degrees that synchronism-check voltage V_S constantly lags voltage V_A) and connect voltage input **VA-N** to V_A. Voltage inputs **VB** and **VC** do not have to be connected.

For delta-connected relays (synchronism-check voltage input **VS-NS** connected to V_{BC}), make setting SYNCP = 120 (the number of degrees that synchronism-check voltage V_S constantly lags voltage V_{AB}) and connect voltage inputs **VA-VB** to V_{AB}. Voltage input **VC** does not have to be connected.

System Rotation Can Affect Setting SYNCP

The solution in the preceding paragraph:

- Voltage input **VA** connected to Phase A
- Voltage input **VS** connected to Phase B
- Setting SYNCP = 120 degrees (V_S constantly lags V_A by 120°)

presumes ABC system rotation. If voltage input connections are the same, but system rotation is ACB, then setting SYNCP = 240 degrees (V_S constantly lags V_A by 240°). See SEL Application Guide *AG2002-02, Compensate for Constant Phase Angle Difference in Synchronism Check with the SEL-351 Relay Family* for more information on setting SYNCP with an angle setting.

System Frequencies Determined From VA Terminal Voltage and Voltage V_S When PTCONN = SINGLE

When only single-phase system voltage is available, the synchronism-check elements may be configured in a straightforward manner:

- Make Global setting PTCONN = SINGLE.
- Connect the single-phase voltage to the **VA-N** terminals (see *Single-Phase Voltage Connection (Global Setting PTCONN = SINGLE)* on page 2.12
- Connect the synchronizing bus single-phase voltage (from the other side of the breaker) to the **VS-NS** terminals.
- Calculate the number of electrical degrees that terminals **VS-NS** lag terminals **VA-N**, and enter the value in the SYNCP setting.

When Global setting PTCONN = SINGLE, the relay uses the voltage connected to the **VA-N** terminals as the system frequency measurement source. The key to understanding this configuration is to realize that the frequency reference voltage connected to the **VA-N** terminals is not necessarily V_A, but can be another phase line-to-neutral or line-to-line quantity. In this configuration, the SYNCP setting only accepts the numeric settings 0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, and 330 degrees.

No voltages have to be connected to terminals **VB** and **VC**. When PTCONN = SINGLE, the synchronism-check logic ignores any voltage connected to terminals **VB** and **VC**, although these inputs may still have other relaying purposes (for example, undervoltage elements 27B1 and 27C1 can still use these inputs).

The phantom voltage feature, described in *Phantom Metering for Single-Phase Voltage Connections* on page 8.24, can be used to calculate a set of balanced, three-phase "phantom" voltage signals for metering from the single-phase signal connected to terminals **VA-N**. The Global setting PHANTV is only available when PTCONN = SINGLE. Keep in mind that the phantom voltage feature only affects metering functions, and has no effect on the actual synchronism-check logic.

NOTE: When testing the synchronism-check feature with PTCONN = SINGLE and phantom voltages enabled, be aware that the event report (**EVE** or **CEV** command) analog data do not contain the phantom meter values.

When phantom voltages are being generated, the **METER X** command can be a helpful tool for testing the synchronism-check feature, because it displays the calculated line-to-neutral, line-to-line, and VS voltage magnitudes and angles in one report. For a sample report, see **MET X k*—Extended Instantaneous Metering*** on page 10.57.

Synchronism-Check Elements Operation

Refer to *Figure 3.29* and *Figure 3.30*.

Voltage Window and SYNCP Settings Example

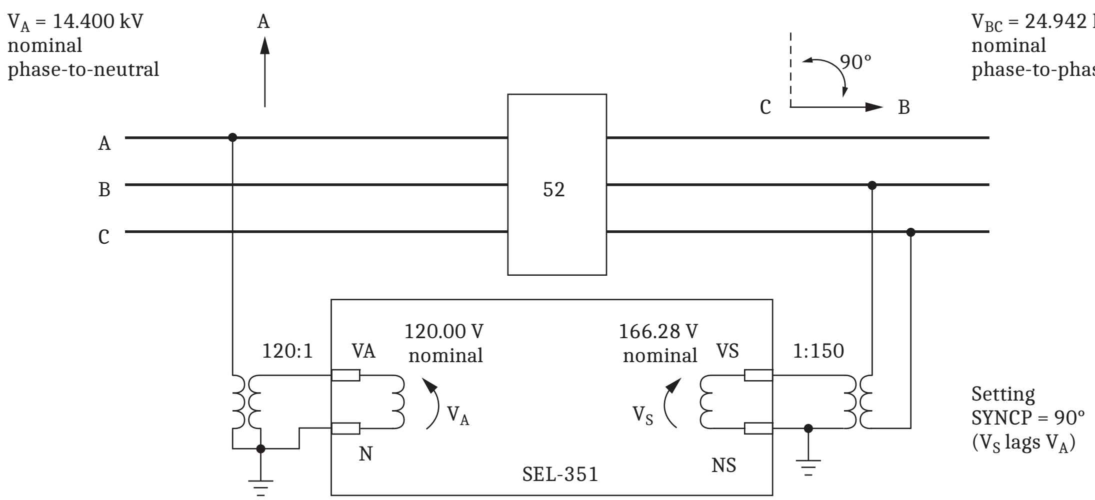


Figure 3.31 Example System With Synchronism-Check Voltage Connected Phase-To-Phase

The example system in *Figure 3.31* illustrates two problems at one time:

- ➤ There are different voltage connections between VP (= VA) and VS.
- ➤ There are different PT ratios between VP (= VA) and VS.

The SEL-351 has settings to simplify the use of synchronism-check elements on this example system.

Use SYNCP to Account for Voltage Angle Differences

In the *Figure 3.31* example, voltage input **VA-N** is connected phase-to-neutral on one side of the breaker, but synchronism-check voltage input **VS-NS** is connected phase-to-phase on the other side of the breaker. When the circuit breaker is closed (representing an ideal synchronism-check condition) the resultant voltage VS constantly lags voltage VA by 90° for a system with ABC phase rotation. Thus, setting SYNCP is set:

SYNCP = 90

The SYNCP = 90 setting accounts for this constant 90° phase angle difference (voltage VS lags voltage VA) in checking synchronism between voltage VA and voltage VS.

The SYNCP setting can bet set in 30° increments, from 0° to 330°, to handle various connection combinations. For more examples, see SEL Application Guide *AG2002-02, Compensate for Constant Phase Angle Difference in Synchronism Check with the SEL-351 Relay Family*, available on the SEL website.

Use 25RCF to Account for Voltage Magnitude Differences

In the *Figure 3.31* example, the voltage sources have different nominal magnitudes. Part of the difference is from the connection type (phase-to-neutral versus phase-to-phase), and part of the difference is from the PT ratios (120:1 vs. 150:1).

To determine the required ratio correction, it is easiest to express the voltages in secondary units:

$$\begin{aligned}\text{VA-N nominal}_{\text{secondary}} &= \frac{\text{VA-N}_{\text{primary}}}{\text{PT ratio}}\\ &= \frac{14.400\ \text{kV} \bullet\ 1000\ \text{V/kV}}{120/1}\\ &= 120.00\ \text{V sec}\end{aligned}$$

$$\begin{aligned}\text{VS-NS nominal}_{\text{secondary}} &= \frac{\text{VS-NS}_{\text{primary}}}{\text{PT ratio\_VS}}\\ &= \frac{24.942\ \text{kV} \bullet\ 1000}{150/1}\\ &= 166.28\ \text{V sec}\end{aligned}$$

NOTE: In applications where SYNCP is set to VA, VB, VC (or VAB, VBC, VCA when PTCONN = DELTA) the selected signal is routed to V_P, and V_P is also scaled by the 25RCF setting.

The SEL-351 provides a ratio-correction factor setting, 25RCF, to scale the VA voltage to the VS voltage base. The synchronism check “healthy voltage” window settings may then be represented on the common scaling base.

The required ratio correction factor setting may be calculated from the nominal voltages:

$$\begin{aligned}\text{25RCF} &= \frac{\text{VS nominal}}{\text{VA-N nominal}}\\ &= \frac{166.28}{120.00}\\ &= 1.386\end{aligned}$$

Round the value to two decimals: **1.39**

The setting range for 25RCF is 0.50 to 2.00. If the calculated correction factor falls outside the 25RCF setting range, consider changing potential transformer taps or using auxiliary PTs to bring one or both of the voltage signals to a different base. Additionally, the expected input voltages must be kept within the relay voltage input ratings, as listed in *Specifications* on page 1.4.

For this example, the desired operation range for the synchronism-check logic is the nominal voltage plus or minus 10 percent. The settings 25VHI and 25VLO must be entered for the VS-NS terminal voltage.

$$25VHI = V_S \text{ nominal} \bullet 110\%$$
$$= 166.28 \text{ V nominal} \bullet 110\%$$
$$= 182.91 \text{ V}$$

$$25VLO = V_S \text{ nominal} \bullet 90\%$$
$$= 166.28 \text{ V nominal} \bullet 90\%$$
$$= 149.65 \text{ V}$$

When V_S is between the 25VLO and 25VHI settings, the SEL-351 asserts Relay Word bit 59VS.

As shown in *Figure 3.32*, the VA signal is automatically scaled for comparison against the same 25VHI and 25VLO settings.

$$\text{25VHI equivalent for VA} = \frac{25VHI}{25RCF}$$
$$= \frac{182.91V}{1.39}$$
$$= 131.59V$$

$$\text{25VLO equivalent for VA} = \frac{25VLO}{25RCF}$$
$$= \frac{149.65V}{1.39}$$
$$= 107.66V$$

During operation, the ratio corrected VA signal will satisfy the 25VLO setting when VA > 107.66 V sec and will satisfy the 25VHI threshold when VA < 131.59 V sec. When VA is in this range, the SEL-351 will assert Relay Word bits 59VA and 59VP.

Outside the example case, when SYNCP = VB or VC (wye-connected) or VBC or VCA (delta-connected), the selected signal (VP) is also scaled by 25RCF, and the relay operates the 59VP Relay Word bit with the same thresholds as 59VA. When SYNCP is set to VA (or VAB for delta) or a numeric setting 0–330 degrees (as in the *Figure 3.31* example), VA is scaled by 25RCF and is used for both the 59VA and 59VP logic.

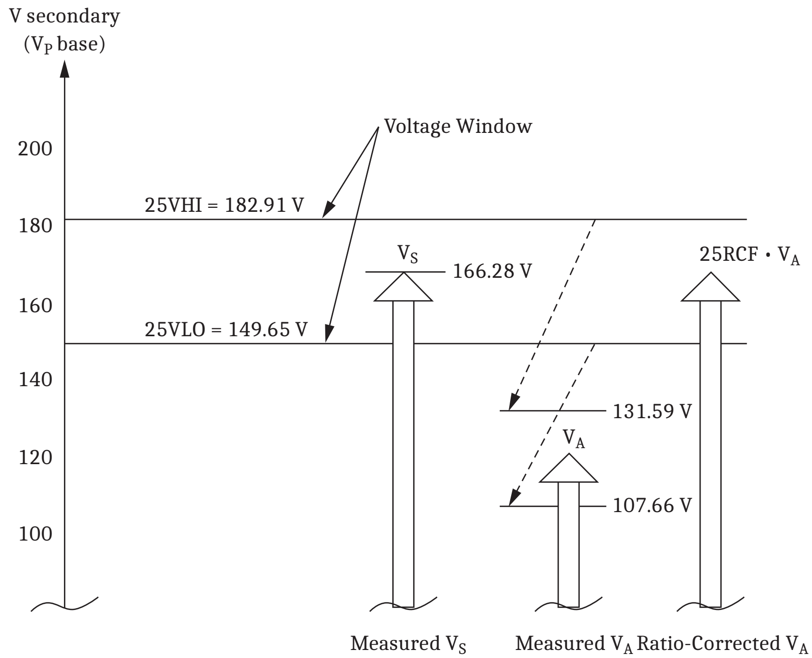


Figure 3.32 25RCF Settings Example Showing V_A Adjustment

The 25RCF setting only affects the synchronism-check logic. The SEL-351 metering and protection functions do not use the corrected value for V_A (or V_{AB}).

Here are some other settings related to the example voltage connections.

PTR = 120.00

PTRS = 150.00

VNOM = 120.00

These settings are included here for completeness; they have no effect on the synchronism-check logic.

Single-phase voltage inputs V_P (ratio corrected) and V_S are compared to a voltage window, to verify that the voltages are "healthy" and lie within settable voltage limits 25VLO and 25VHI. If both voltages are within the voltage window, the following Relay Word bits assert.

59VP indicates that voltage V_P (ratio corrected) is within voltage window setting limits 25VLO and 25VHI

59VS indicates that voltage V_S is within voltage window setting limits 25VLO and 25VHI

As discussed previously, voltage V_A (or V_{AB} for delta-connected voltage inputs) determines the frequency on the voltage V_P side of the circuit breaker. Voltage V_A (ratio corrected) is also run through voltage limits 25VLO and 25VHI to ensure "healthy voltage" for frequency determination, with corresponding Relay Word bit output 59VA.

Other Uses for Voltage Window Elements

If voltage limits 25VLO and 25VHI are applicable to other control schemes, Relay Word bits 59VP, 59VS, and 59VA can be used in other logic at the same time they are used in the synchronism-check logic.

If synchronism check is not being used, Relay Word bits 59VP, 59VS, and 59VA can still be used in other logic, with voltage limit settings 25VLO and 25VHI set as desired. Enable the synchronism-check logic (setting E25 = Y) and make settings 25VLO, 25VHI, and 25RCF. Apply Relay Word bits 59VP, 59VS, and 59VA in the desired logic scheme, using SELOGIC control equations. Even though synchronism-check logic is enabled, the synchronism-check logic outputs (Relay Word bits SF, 25A1, and 25A2) do not need to be used.

Block Synchronism-Check Conditions

Refer to *Figure 3.29*.

The synchronism-check element slip frequency calculator runs if both voltages V_P and V_S are healthy (59VP and 59VS asserted to logical 1) *and* the SELOGIC control equation setting BSYNCH (Block Synchronism Check) is deasserted (= logical 0). Setting BSYNCH is most commonly set to block synchronism-check operation when the circuit breaker is closed (synchronism check is only necessary when the circuit breaker is open):

BSYNCH = **52A** (see *Figure 6.2*)

In addition, synchronism-check operation can be blocked when the relay is tripping:

BSYNCH = **... + TRIP**

Slip Frequency Calculator

Refer to *Figure 3.29*.

The synchronism-check element Slip Frequency Calculator in *Figure 3.29* runs if voltages V_P, V_S, and V_A (or V_{AB} for delta) are healthy (59VP, 59VS, and 59VA asserted to logical 1) *and* the SELOGIC control equation setting BSYNCH (Block Synchronism Check) is deasserted (= logical 0). The Slip Frequency Calculator output is:

Slip Frequency = $f_P - f_S$ (in units of Hz = slip cycles/second)

f_P = frequency of voltage V_P (in units of Hz = cycles/second) [determined from V_A (or V_{AB} for delta)]

f_S = frequency of voltage V_S (in units of Hz = cycles/second)

A complete slip cycle is one single 360-degree revolution of one voltage (e.g., V_S) by another voltage (e.g., V_P). Both voltages are thought of as revolving phasor-wise, so the “slipping” of V_S past V_P is the *relative* revolving of V_S past V_P.

For example, in *Figure 3.29*, if voltage V_P has a frequency of 59.95 Hz and voltage V_S has a frequency of 60.05 Hz, the difference between them is the slip frequency:

Slip Frequency = 59.95 Hz – 60.05 Hz = –0.10 Hz = –0.10 slip cycles/second

The slip frequency in this example is negative, indicating that voltage V_S is not “slipping” *behind* voltage V_P, but in fact “slipping” *ahead* of voltage V_P. In a time period of one second, the angular distance between voltage V_P and voltage V_S changes by 0.10 slip cycles, which translates into:

0.10 slip cycles/second • (360°/slip cycle) • 1 second = 36°

Thus, in a time period of one second, the angular distance between voltage V_P and voltage V_S changes by 36 degrees.

The absolute value of the Slip Frequency output is run through a comparator and if the slip frequency is less than the maximum slip frequency setting, 25SF, Relay Word bit SF asserts to logical 1.

The SF Relay Word bit may not operate if the VP (= VA) frequency is changing too quickly. This will not be an issue when the synchronism-check elements are being used to verify phase alignment across breakers in transmission systems with multiple paths. However, if one side of the circuit breaker is expected to vary in frequency (perhaps it is connected to a generator bus) the best configuration for using the synchronism-check element is to connect the VA, VB, VC terminals (and thus VP) to the more stable system (e.g., the power grid), while the VS terminal (VS) is connected to the machine.

Generator Application for SSLOW and SFAST

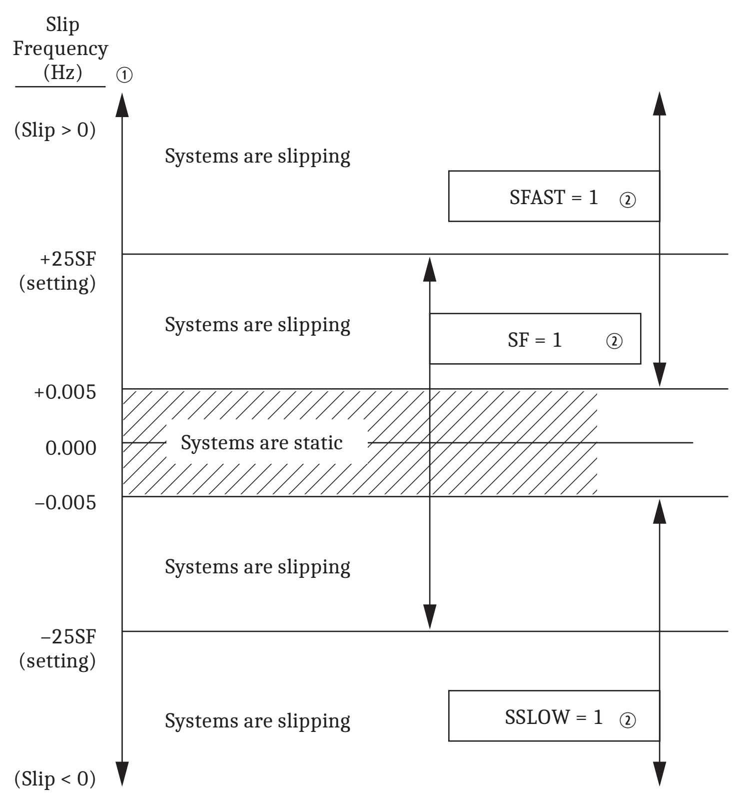
NOTE: In firmware revision R510 and earlier, the SSLOW Relay Word bit asserts when $|f_P - f_S| < 0.005$ Hz. Later firmware revisions include a deadband between SSLOW and SFAST operating zones, as shown in *Table 3.15* and *Figure 3.33*.

Relay Word bits SSLOW and SFAST in *Figure 3.29* indicate the relative slip of voltages V_P and V_S.

The SFAST, SSLOW, and SF operation over various slip frequencies is summarized in *Table 3.15* and *Figure 3.33*.

Table 3.15 SSLOW and SFAST Relay Word Bit Operating Range

Slip Frequency Range	Relay Word Bit SSLOW	Relay Word Bit SFAST
$(f_P–f_S) \le –0.005$ Hz	logical 1	logical 0
$–0.005 < (f_P–f_S) < 0.005$	logical 0	logical 0
$(f_P–f_S) \ge 0.005$ Hz	logical 0	logical 1



① Slip Frequency = Frequency of **VA-N** signal—Frequency of **VS-NS** signal, ② From *Figure 3.29*.

Figure 3.33 Graphical Depiction of SFAST, SSLOW, and SF Operation Range

An application idea for SSLOW and SFAST is a small generator installation.

> With some logic (perhaps to create pulsing signals), SSLOW and SFAST might be used as signals (via output contacts) to the generator governor. SSLOW indicates that the V_P (=V_A) frequency is lower than the V_S frequency, while SFAST indicates that the V_P (=V_A) frequency is higher than the V_S frequency. If the enable into the slip frequency calculator in *Figure 3.29* is disabled (e.g., SELOGIC setting BSYNCH asserts because the breaker closes; BSYNCH = 52A + …), then both SSLOW = logical 0 and SFAST = logical 0, regardless of slip frequency.

The SEL-351 SSLOW and SFAST outputs are available throughout a larger slip frequency range than the synchronism-check element, and are independent of the SF Relay Word bit. If the slip frequency is greater than the 25SF setting, Relay Word bit SF will be deasserted (logical 0), and one of the SSLOW or SFAST Relay Word bits may operate to indicate the polarity of the slip frequency.

The SSLOW and SFAST Relay Word bits may not operate reliably if the V_P (= V_A) frequency is changing too quickly. The best configuration for using the SSLOW and SFAST outputs is when the VA, VB, VC terminals (and thus V_P) are connected to the most stable system (e.g., the power grid), while the VS terminal (V_S) is connected to the "machine" side of the circuit breaker.

Angle Difference Calculator

The synchronism-check element Angle Difference Calculator in *Figure 3.30* runs if the slip frequency is less than the maximum slip frequency setting 25SF (Relay Word bit SF is asserted).

Voltages V_P and V_S Are "Static"

Refer to top of *Figure 3.30*.

If the absolute value of the slip frequency is less than 0.005 Hz, the Angle Difference Calculator does *not* take into account breaker close time—it presumes voltages V_P and V_S are "static" (not "slipping" with respect to one another). This would usually be the case for an open breaker with voltages V_P and V_S that are paralleled via some other electric path in the power system. The Angle Difference Calculator calculates the angle difference between voltages V_P and V_S:

$$\text{Angle Difference} = |(\angle V_P - \angle V_S)|$$

For example, if SYNCP = 90 (indicating V_S constantly lags $V_P = V_A$ by 90 degrees), but V_S actually lags V_A by 100 angular degrees on the power system at a given instant, the Angle Difference Calculator automatically accounts for the 90 degrees and:

$$\text{Angle Difference} = |(\angle V_P - \angle V_S)| = 10°$$

Also, if breaker close time setting TCLOSD = 0.00, the Angle Difference Calculator does not take into account breaker close time, even if the voltages V_P and V_S are "slipping" with respect to one another. Thus, synchronism-check elements 25A1 or 25A2 assert to logical 1 if the Angle Difference is less than corresponding maximum angle setting 25ANG1 or 25ANG2, and the slip frequency is below setting 25SF.

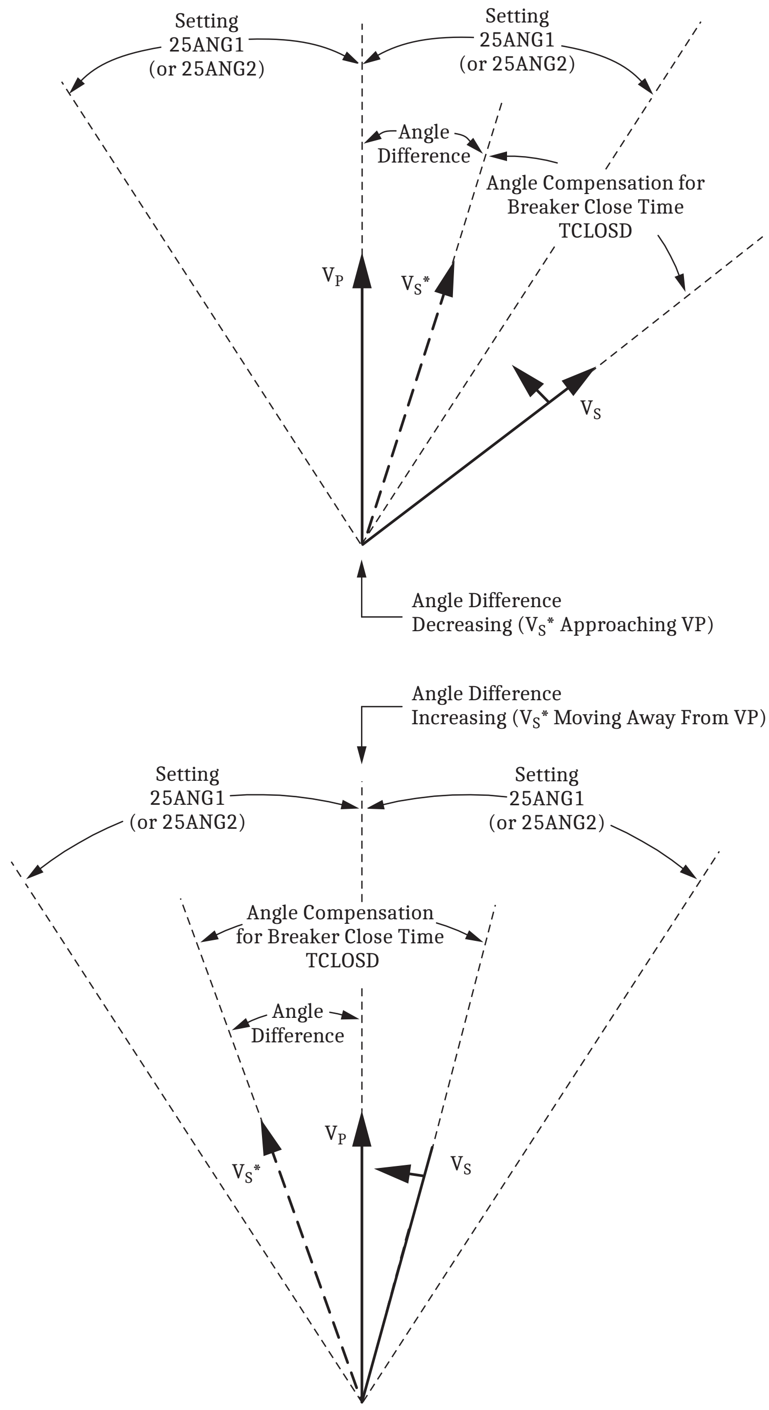


Figure 3.34 Angle Difference Between V_P and V_S Compensated by Breaker Close Time (f_P < f_S and V_P Shown as Reference in This Example)

Voltages V_P and V_S Are "Slipping"

Refer to bottom of *Figure 3.30*.

If the absolute value of the slip frequency is greater than or equal to 0.005 Hz and breaker close time setting TCLOSD ≠ 0.00, the Angle Difference Calculator takes the breaker close time into account with breaker close time setting

TCLOSD (set in cycles; see *Figure 3.34*). The Angle Difference Calculator calculates the Angle Difference between voltages V_P and V_S, compensated with the breaker close time:

$$\text{Angle Difference} = \left|(\angle V_P - \angle V_S) + \left[(f_P - f_S) \bullet \text{ TCLOSD} \bullet \left(\frac{1\text{ second}}{\text{NFREQ cycles}}\right) \bullet \left(\frac{360°}{\text{slip cycle}}\right)\right]\right|$$

NFREQ is the Global setting that defines the nominal system frequency as 50 or 60 Hz.

Angle Difference Example (Voltages V_P and V_S Are "Slipping")

Refer to bottom of *Figure 3.30*.

For example, for a 60 Hz nominal system, if the breaker close time is 10 cycles, set TCLOSD = 10 and NFREQ = 60. Presume the slip frequency is the example slip frequency calculated previously. The Angle Difference Calculator calculates the angle difference between voltages V_P and V_S, compensated with the breaker close time:

$$\text{Angle Difference} = \left|(\angle V_P - \angle V_S) + \left[(f_P - f_S) \bullet \text{ TCLOSD} \bullet \left(\frac{1\text{ second}}{60\text{ cycles}}\right) \bullet \left(\frac{360°}{\text{slip cycle}}\right)\right]\right|$$

Intermediate calculations:

$(f_P - f_S) = (59.95\text{ Hz} - 60.05\text{ Hz}) = -0.10\text{ Hz} = -0.10$ slip cycles/second
TCLOSD • (1 second/60 cycles) = 10 cycles • (1 second/60 cycles) = 0.167 second

Resulting in:

$$\text{Angle Difference} = \left|(\angle V_P - \angle V_S) + \left[(f_P - f_S) \bullet \text{ TCLOSD} \bullet \left(\frac{1\text{ second}}{60\text{ cycles}}\right) \bullet \left(\frac{360°}{\text{slip cycle}}\right)\right]\right|$$

$$= \left|(\angle V_P - \angle V_S) + [-0.10 \bullet 0.167 \bullet 360°]\right|$$

$$= \left|(\angle V_P - \angle V_S) - 6°\right|$$

NOTE: The angle compensation in *Figure 3.34* appears much greater than 6 degrees. *Figure 3.34* is for general illustrative purposes only.

During the breaker close time (TCLOSD), the voltage angle difference between voltages V_P and V_S changes by 6 degrees. This 6 degree angle compensation is applied to voltage V_S, resulting in derived voltage V_S^*, as shown in *Figure 3.34*.

The top of *Figure 3.34* shows the Angle Difference *decreasing*—V_S^* is approaching V_P. Ideally, circuit breaker closing is initiated when V_S^* is in phase with V_P (Angle Difference = 0 degrees). Then when the circuit breaker main contacts finally close, V_S is in phase with V_P, minimizing system shock.

The bottom of *Figure 3.34* shows the Angle Difference *increasing*—V_S^* is moving away from V_P. Ideally, circuit breaker closing is initiated when V_S^* is in phase with V_P (Angle Difference = 0 degrees). Then when the circuit breaker main contacts finally close, V_S is in phase with V_P. But in this case, V_S^* has already moved past V_P. In order to initiate circuit breaker closing when V_S* is in phase with V_P (Angle Difference = 0 degrees), V_S* has to slip around another revolution, relative to V_P.

Synchronism-Check Element Outputs

Synchronism-check element outputs (Relay Word bits 25A1 and 25A2 in *Figure 3.30*) assert to logical 1 for the conditions explained in the following text.

Voltages V_P and V_S Are "Static" or Setting TCLOSD = 0.00

Refer to the top of *Figure 3.30*.

If VP and VS are "static" (not "slipping" with respect to one another), the Angle Difference between them remains constant—it is not possible to close the circuit breaker at an ideal zero degree phase angle difference. Thus, synchronism-check elements 25A1 or 25A2 assert to logical 1 if the Angle Difference is less than the corresponding maximum angle setting 25ANG1 or 25ANG2.

Also, if breaker close time setting TCLOSD = 0.00, the Angle Difference Calculator does not take into account breaker close time, even if the voltages VP and VS are "slipping" with respect to one another. Thus, synchronism-check elements 25A1 or 25A2 assert to logical 1 if the Angle Difference is less than the corresponding maximum angle setting 25ANG1 or 25ANG2 and the slip frequency is below setting 25SF.

Voltages V_P and V_S Are "Slipping" and Setting TCLOSD ≠ 0.00

Refer to bottom of *Figure 3.30*. If V_P and V_S are "slipping" with respect to one another and breaker close time setting TCLOSD ≠ 0.00, the Angle Difference (compensated by breaker close time TCLOSD) changes through time. synchronism-check element 25A1 or 25A2 asserts to logical 1 for any one of the following three scenarios.

1. The top of *Figure 3.34* shows the Angle Difference *decreasing*—V_S* is approaching V_P. When V_S* is in phase with V_P (Angle Difference = 0 degrees), synchronism-check elements 25A1 and 25A2 assert to logical 1.
2. The bottom of *Figure 3.34* shows the Angle Difference *increasing*—V_S* is moving away from V_P. V_S* was in phase with V_P (Angle Difference = 0 degrees), but has now moved past V_P. If the Angle Difference is *increasing*, but the Angle Difference is still less than maximum angle settings 25ANG1 or 25ANG2, then corresponding synchronism-check elements 25A1 or 25A2 assert to logical 1.

   In this scenario of the Angle Difference increasing, but still being less than maximum angle settings 25ANG1 or 25ANG2, the operation of corresponding synchronism-check elements 25A1 and 25A2 becomes *less restrictive*. Synchronism check breaker closing does not have to wait for voltage V_S* to slip around again in phase with V_P (Angle Difference = 0 degrees). There might not be enough time to wait for this to happen. Thus, the "Angle Difference = 0 degrees" restriction is eased for this scenario.

3. Refer to *Reclose Supervision Logic* on page 6.6.

   Refer to the bottom of *Figure 6.3*. If timer 79CLSD is set greater than zero (e.g., 79CLSD = 60.00 cycles) and it times out without SELOGIC control equation setting 79CLS (Reclose Supervision) asserting to logical 1, the relay goes to the Lockout State (see top of *Figure 6.4*).

   Refer to the top of *Figure 6.3*. If timer 79CLSD is set to zero (79CLSD = 0.00), SELOGIC control equation setting 79CLS (Reclose Supervision) is checked only once to see if it is asserted to logical 1. If it is not asserted to logical 1, the relay goes to the Lockout State.

   Refer to the top of *Figure 3.34*. Ideally, circuit breaker closing is initiated when V_S* is in phase with V_P (Angle Difference = 0 degrees). Then when the circuit breaker main contacts finally close, V_S is in phase with V_P, minimizing system shock. But with time limitations imposed by timer 79CLSD, this may not be possible. To try to avoid going to the Lockout State, the following logic is employed:

   If 79CLS has not asserted to logical 1 while timer 79CLSD is timing (or timer 79CLSD is set to zero and only one check of 79CLS is made), the synchronism-check logic at the bottom of *Figure 3.30* becomes *less restrictive* at the "instant" timer 79CLSD is going to time out (or make the single check). It drops the requirement of waiting until the *decreasing* Angle Difference (V_S* approaching V_P) brings V_S* in phase with V_P (Angle Difference = 0 degrees). Instead, it just checks to see that the Angle Difference is less than angle settings 25ANG1 or 25ANG2.

   If the Angle Difference is less than angle setting 25ANG1 or 25ANG2, then the corresponding Relay Word bit, 25A1 or 25A2, asserts to logical 1 for that "instant" (asserts for 1/4 cycle).

   For example, if SELOGIC control equation setting 79CLS (Reclose Supervision) is set as follows:

   79CLS = **25A1 + ...**

   and the angle difference is less than angle setting 25ANG1 at that "instant," setting 79CLS asserts to logical 1 for 1/4 cycle, allowing the sealed-in open interval time-out to propagate on to the close logic in *Figure 6.2*. Element 25A2 operates similarly.

Synchronism-Check Applications for Automatic Reclosing and Manual Closing

Refer to *Close Logic* on page 6.2 and *Reclose Supervision Logic* on page 6.6.

For example, set 25ANG1 = 15 degrees and use the resultant synchronism-check element in the reclosing relay logic to supervise automatic reclosing, e.g.,

79CLS = **25A1 + ...** (see *Figure 6.3*)

Set 25ANG2 = 25° and use the resultant synchronism-check element in manual close logic to supervise manual closing (for example, assert **IN106** or issue the **CLO** command to initiate manual close) as shown below.

SV1 = **(/IN106 + CC) * !TRIP + SV1 * !SV1T * !TRIP * !CLOSE**

CL = **(SV1 * 25A2 + ...)** (see *Figure 6.2*)

Set SV1PU = N cycles, and SV1DO = 0.00 cycles. Choose N to represent the maximum period that a manual close can be attempted. A typical setting for N might be 50 to 600 cycles (approximately 1 to 10 seconds).

The timer effectively stretches the one processing interval CC pulse (asserted by the **CLOSE** command, or via DNP, Modbus, or SEL Fast Operate protocols—see *Section 10: Communications*) to improve the chances of closing if the synchronism-check element is not asserted at the instant the command is received. Other possible inputs to initiate manual closing include using a local bit (/LB*n*) or remote bit (/RB*n*).

The rising edge operator "/ " on IN106 prevents a maintained assertion to logical 1 from creating a standing close condition. The !TRIP terms defeat the manual close window if a relay trip is detected. The !CLOSE term cancels the timing once the close logic is activated. Other conditions could be added to defeat the manual close.

In this example, the angular difference across the circuit breaker can be greater for a manual close (25 degrees) than for an automatic reclose (15 degrees).

A single output contact (e.g., OUT102 = CLOSE) can provide the close function for both automatic reclosing and manual closing (see *Figure 6.2* logic output).

Frequency Elements

Six frequency elements are available. The desired number of frequency elements are enabled with the E81 enable setting, as shown in *Figure 3.40*.

E81 = **N** (none), 1 through 6

Frequency Element Settings and Supervision

To estimate frequency, the relay calculates an alpha voltage component (refer to *Table 3.16*) and uses the zero crossings to estimate the frequency. The Relay Word bit FRQ81OK asserts when the relay estimates the frequency is between 40–70 Hz and if the frequency slew rate is less than 20 Hz/s. If the frequency is less than 40 Hz, greater than 70 Hz, or the slew rate exceeds 20 Hz/s, the relay no longer estimates the frequency. The Relay Word bit FRQ81FZ asserts and the Relay Word bit FRQ81OK deasserts to indicate these conditions. If the frequency has not been estimated for 1 s, both FRQ81OK and FRQ81FZ will deassert.

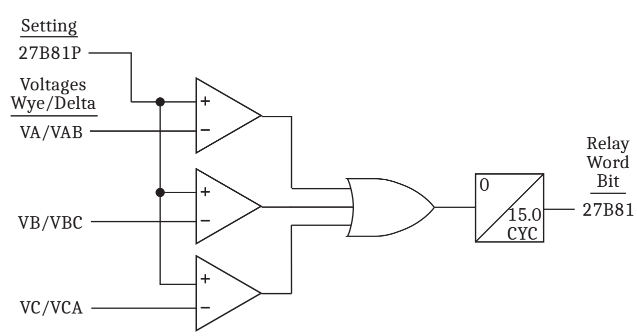


Figure 3.35 Undervoltage Block for Frequency Elements (Group Setting VNOM ≠ OFF)

NOTE: Group setting VNOM is not accessible when Global setting PTCONN = SINGLE. In this situation, the VNOM setting is internally set to OFF, and the 27B81 function operates as shown in *Figure 3.36*.

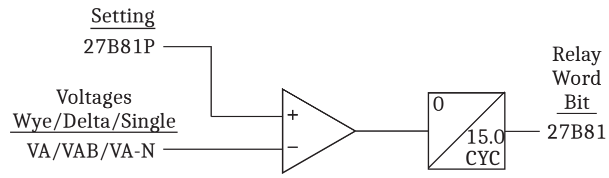
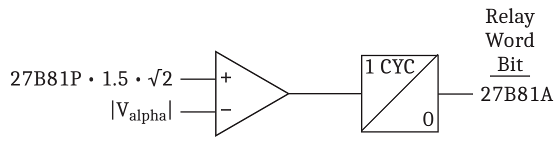


Figure 3.36 Undervoltage Block for Frequency Elements (Group Setting VNOM = OFF or Global Setting PTCONN = SINGLE)



NOTE: The comparator threshold for 27B81A is different between R518-V0 and R518-V1 for PTCONN = DELTA applications. In R518-V0, the threshold for 27B81A was 27B81P • 1.5 • √2. In R518-V1 the threshold is 27B81P • 1.5• √2 / √3.

Verify your 27B81P setting if upgrading from R518-V0 to R518-V1 or higher. Examples are given in *Examples for Calculating 27B81P Setting Values* on page 3.61.

Figure 3.37 Undervoltage Block Element for 81 Supervision (Global Setting PTCONN = WYE)

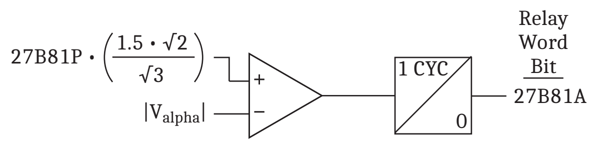


Figure 3.38 Undervoltage Block Element for 81 Supervision (Global Setting PTCONN = DELTA)

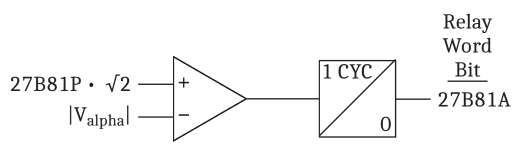


Figure 3.39 Undervoltage Block Element for 81 Supervision (Global Setting PTCONN = SINGLE)

NOTE: The V_{alpha} quantity is calculated using instantaneous samples of the voltage waveforms shown in *Table 3.16*. V_{alpha} is different than most quantities in the relay, which are typically based on rms magnitudes. If the power system voltages are in a steady-state balanced condition, the V_{alpha} waveform will be a sinusoidal combination of the phase voltages based on the equations in *Table 3.16*.

Table 3.16 System Frequency Estimation Based on V_{alpha} Zero-Crossing Method

Global Setting	Frequency Estimation
PTCONN = WYE	$V_{alpha} = V_A - \frac{V_B}{2} - \frac{V_C}{2}$
PTCONN = DELTA	$V_{alpha} = V_{AB} - \frac{V_{CB}}{2}$
PTCONN = SINGLE	$V_{alpha} = V_A$

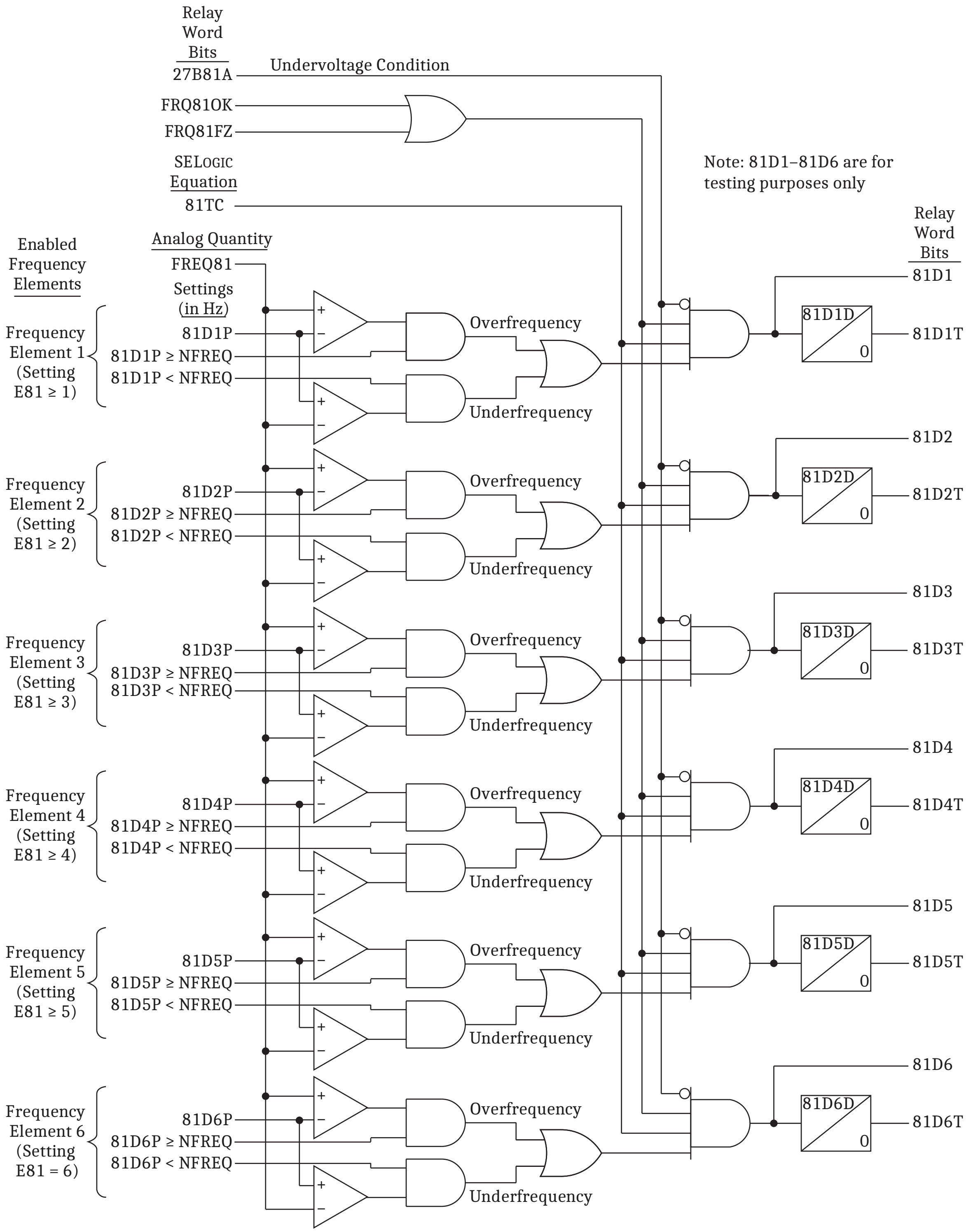


Figure 3.40 Levels 1–6 Frequency Elements

NOTE: In firmware versions R510 and earlier, the default setting for 81D1D–81D6D is 2.00 cycles. In later firmware, the default is 60.00 cycles.

NOTE: Frequency element time delays are best set no less than 5 cycles. Frequency is determined by a zero-crossing technique on V_{alpha}. If voltage waveform offset occurs (e.g., due to a fault), then frequency can be off for a few cycles. A 5-cycle or greater time delay (e.g., 81D1D = 6.00 cycles) overrides this occurrence.

NOTE: In firmware versions prior to R517, 27B81 supervised Levels 1–6 frequency elements. In firmware versions R517 and later, 27B81A supervises Levels 1–6 frequency elements. The 81TC SELOGIC setting provides additional supervision of Levels 1-6 frequency elements. For consistent operation, the default setting for 81TC is !27B81.

Table 3.17 Frequency Elements Settings and Settings Ranges

Setting	Definition	Range
27B81P	Undervoltage frequency element block (Responds to V_{LN} when Global setting PTCONN = WYE, responds to V_{LL} when Global setting PTCONN = DELTA, and responds to VA-N when PTCONN = SINGLE)	25.00–300.00 V secondary
81D1P	Frequency Element 1 pickup	40.10–65.00 Hz
81D1D	Frequency Element 1 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D2P	Frequency Element 2 pickup	40.10–65.00 Hz
81D2D	Frequency Element 2 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D3P	Frequency Element 3 pickup	40.10–65.00 Hz
81D3D	Frequency Element 3 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D4P	Frequency Element 4 pickup	40.10–65.00 Hz
81D4D	Frequency Element 4 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D5P	Frequency Element 5 pickup	40.10–65.00 Hz
81D5D	Frequency Element 5 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D6P	Frequency Element 6 pickup	40.10–65.00 Hz
81D6D	Frequency Element 6 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81TC	Frequency element torque control	SELOGIC control equation

Create Over- and Underfrequency Elements

Refer to *Figure 3.40*.

Note that pickup settings 81D1P–81D6P are compared to setting NFREQ. NFREQ is the nominal frequency setting (a Global setting), set to 50 or 60 Hz.

Overfrequency Element

For example, make settings:

NFREQ = **60 Hz** (nominal system frequency is 60 Hz)

E81 ≥ **1** (enable frequency element 1)

81D1P = **61.25 Hz** (frequency element 1 pickup)

With these settings (81D1P ≥ NFREQ) the overfrequency part of frequency element 1 logic is enabled. 81D1 and 81D1T operate as overfrequency elements. 81D1 is used in *testing only*.

Underfrequency Element

For example, make settings:

NFREQ = **60 Hz** (nominal system frequency is 60 Hz)

E81 ≥ **2** (enable frequency element 2)

81D2P = **59.65 Hz** (frequency element 2 pickup)

With these settings (81D2P < NFREQ) the underfrequency part of frequency element 2 logic is enabled. 81D2 and 81D2T operate as underfrequency elements. 81D2 is used in *testing only*.

Frequency Element Operation

Refer to *Figure 3.40*.

Overfrequency Element Operation

With the previous overfrequency element example settings, if system frequency is *less than or equal to* 61.25 Hz (81D1P = 61.25 Hz), frequency element 1 outputs:

81D1	= logical 0	(instantaneous element)
81D1T	= logical 0	(time-delayed element)

If system frequency is *greater than* 61.25 Hz (81D1P = 61.25 Hz), frequency element 1 outputs:

81D1	= logical 1	(instantaneous element)
81D1T	= logical 1	(time-delayed element)

Relay Word bit 81D1T asserts to logical 1 only after time delay 81D1D.

Underfrequency Element Operation

With the previous underfrequency element example settings, if system frequency is *less than or equal to* 59.65 Hz (81D2P = 59.65 Hz), frequency element 2 outputs:

81D2	= logical 1	(instantaneous element)
81D2T	= logical 1	(time-delayed element)

Relay Word bit 81D2T asserts to logical 1 only after time delay 81D2D.

If system frequency is *greater than* 59.65 Hz (81D2P = 59.65 Hz), frequency element 2 outputs:

81D2	= logical 0	(instantaneous element)
81D2T	= logical 0	(time-delayed element)

Instantaneous Frequency Element Response Time

The SEL-351 uses a zero-crossing period measurement technique on V_{alpha} to determine the power system frequency (refer to *Table 3.16*). There is an intrinsic delay in the instantaneous frequency elements 81D1–81D6 that depends on the pickup setting, the applied signal, and the conditions prior to the change in signal.

The 81D1–81D6 response time to a valid frequency change is typically 1 to 3 cycles, but could be as long as 4.5 cycles. This detail is usually of little consequence when longer time delay settings 81D1D–81D6D are used. However, understanding this built-in delay may help during testing, and in certain applications.

System disturbances that do not cause the undervoltage block element 27B81A to assert can affect the voltage signals and cause the instantaneous frequency elements to briefly assert when there is no actual frequency deviation. For this reason, time-delayed elements 81D1T–81D6T are the only Relay Word bits intended for use in protection, and the recommended minimum time-delay setting is 5 cycles.

Frequency Element Time Delay Considerations

The SEL-351 frequency element time delay settings are specified in cycles, as shown in *Table 3.17*. When determining the time delay settings appropriate for an application, keep in mind that the power system frequency will not be at the nominal value (50 Hz or 60 Hz) when an overfrequency or underfrequency element times out. The relay adjusts the processing algorithms to track the system frequency, and this can make the time delay seem shorter or longer than anticipated.

For pickup settings that are close to the nominal frequency, or with short duration delays, the nominal frequency may be used to convert the desired time delay from seconds into cycles with negligible error.

However, for elements that have pickup settings (81D*n*P) set farther from the nominal frequency, or elements set with long time delays (81D*n*D), the over- or underfrequency pickup setting may be used for the time-base conversion instead.

The observed time delay will depend on the frequency of the power system or test set during the excursion, and whether the frequency change is applied as step-change, a ramp, or some other function.

Overfrequency Element Settings Example

On a 60 Hz nominal system, the planner requires an overfrequency trip to occur if the frequency exceeds 60.60 Hz for 30 seconds.

Convert the time delay from seconds to cycles using the pickup setting.

$$\begin{aligned}\text{Delay} &= 30\ \text{s} \bullet 60.60\ \text{Hz} \\ &= 30\ \text{s} \bullet 60.60\ \text{cycles/s} \\ &= 1818\ \text{cycles}\end{aligned}$$

Required settings.

81D1P = **60.60 Hz**

81D1D = **1818.00 cycles**

Using the example settings, if a 60.80 Hz signal is applied for testing, the SEL-351 would be expected to assert 81D1T approximately

1818 cycles / 60.80 cycles/s = 29.90 s

after the instantaneous element (81D1) pickup.

If the nominal frequency 60 Hz conversion factor has been used instead, the time delay setting would have been 1800 cycles, and the same 60.80 Hz test signal would be expected to assert 81D1T approximately 1800 cycles / 60.80 cycles/s = 29.61 s after the instantaneous element (81D1) pickup.

In this test example, the time delay settings adjustment improves the timing accuracy by about 1 percent.

Frequency Element Voltage Control

NOTE: When the group setting VNOM = OFF, the group setting 27B81P becomes hidden and is set to the default of 40.00 V.

NOTE: The comparator threshold for 27B81A is different between R518-V0 and R518-V1 for PTCONN = DELTA applications. In R518-V0 the threshold for 27B81A was 27B81P • 1.5 • √2. In R518-V1 the threshold is 27B81P • 1.5 • √2 / √3.

Verify your 27B81P setting if upgrading from R518-V0 to R518-V1 or higher. Examples are given in *Examples for Calculating 27B81P Setting Values*.

Refer to *Figure 3.35*, *Figure 3.36*, *Figure 3.37*, *Figure 3.38*, and *Figure 3.39*.

Note that all six frequency elements are supervised by the same undervoltage element (Relay Word bit 27B81A). For example, when group setting VNOM ≠ OFF, and Global setting PTCONN = WYE, Relay Word bit 27B81A asserts to logical 1 and blocks the frequency element operation if V_{alpha} is less than the derived voltage pickup threshold based on 27B81P (see *Figure 3.37*). This control prevents erroneous frequency element operation following fault inception.

However, if group setting VNOM = OFF, Relay Word bit 27B81A is only affected by the voltage applied to the **VA-N** terminals. This is useful in applications where there is only single-phase voltage available to the relay. This also applies when Global setting PTCONN = SINGLE and the VNOM setting is hidden and set to OFF internally.

Examples for Calculating 27B81P Setting Values

The following section discusses how V_{alpha} is calculated and how to set 27B81P for PTCONN = WYE, DELTA and SINGLE. The following examples use the average (60 percent) of the 50–70 percent undervoltage range that IEEE C37.117 recommends. The following examples are based on ABC rotation, but will also work with ACB rotation. It is important to consider the difference between Relay Word bits 27B81 (shown in *Figure 3.35*) and 27B81A (shown in *Figure 3.37*, *Figure 3.38*, and *Figure 3.39*). In *Figure 3.35*, the undervoltage blocking element 27B81 is based on the comparing the filtered rms phase/phase-phase voltages directly to the 27B81P setting. In *Figure 3.37*, *Figure 3.38*, and *Figure 3.39*, the undervoltage blocking element 27B81A is based on the comparison of a unfiltered peak alpha voltage to a derived threshold. The derived threshold in *Figure 3.37*, *Figure 3.38*, and *Figure 3.39* takes into account the peak voltage comparison, the alpha voltage calculation, and the PTCONN setting.

Example 3.1 Case 1: Wye-Connected PT

For the logic in *Figure 3.35*, if a nominal phase to neutral voltage of 67 V is expected, then 60 percent of this nominal voltage will result in 27B81P = 40 V. As per *Figure 3.35*, if VA, VB or VC drop lower than 40 V rms, 27B81 asserts.

For the logic in *Figure 3.37*, the 27B81P setting is scaled by a factor of 1.5 and √2. This is because the logic in *Figure 3.37* is based on a peak alpha voltage comparison to the derived threshold of 27B81P • 1.5 • √2. The calculations below show an example of calculating the V_{alpha} quantity and how to calculate 27B81P based on the result. Note that the V_{alpha} quantity is calculated using instantaneous samples of the voltage waveforms shown in *Table 3.16*. V_{alpha} is different than most quantities in the relay, which are typically based on rms magnitudes. If the power system voltages are in a steady-state balanced condition, the V_{alpha} waveform will be a sinusoidal combination of the phase voltages based on the equations in *Table 3.16*. The following equations for the 27B81P pickup setting will be in a form similar to phasor notation. We consider the power system as balanced and the peak of the voltage waveforms as 67 • √2.

Given that:

$$V_{Apeak} = 67\sqrt{2}\angle 0°$$

$$V_{Bpeak} = 67\sqrt{2}\angle -120°$$

$$V_{Cpeak} = 67\sqrt{2}\angle 120°$$

From *Table 3.16*, V_{alpha} is given by:

$$V_{alpha} = V_{Apeak} - \frac{V_{Bpeak}}{2} - \frac{V_{Cpeak}}{2} = 67\sqrt{2}\angle 0 - \frac{67\sqrt{2}\angle -120}{2} - \frac{67\sqrt{2}\angle 120}{2} = 142 \text{ Vpk}$$

If we wish to pickup at 60 percent of V_{alpha}, then we must consider the factors of 1.5 and √2 with regards to setting 27B81P.

$$60\% \bullet 142 \text{ Vpk} = 85 \text{ Vpk}$$
$$27B81P \bullet 1.5 \bullet \sqrt{2} = 85 \text{ Vpk}$$

Solving for 27B81P:

$$27B81P = 40 \text{ V}$$

Note that the result of setting the 27B81P setting for a pickup of 60 percent of the phase voltages or the alpha voltage comes out to the same setting of 40 Volts. The internal scaling of 27B81P for use with the alpha voltage was designed for 27B81 and 27B81A to behave in a similar manner.

Example 3.2 Case 2: DELTA Connected PTs

For the logic in *Figure 3.35*, if a nominal phase-to-phase voltage of 116 V is expected, then 60 percent of this nominal voltage will result in 27B81P = 70 V. As per *Figure 3.35*, if VAB, VBC, or VCA drop lower than 70 V rms, 27B81 asserts.

For the logic in *Figure 3.38*, the 27B81P setting is scaled by a factor of 1.5 • √2 / √3. This is because the logic in *Figure 3.38* is based on a peak alpha voltage comparison to the derived threshold of 27B81P • 1.5 • √2 / √3. The calculations below show an example of calculating the V_{alpha} quantity and how to calculate 27B81P based on the result. Note that the V_{alpha} quantity is calculated using instantaneous samples of the voltage waveforms shown in *Table 3.16*. V_{alpha} is different than most quantities in the relay, which are typically based on rms magnitudes. If the power system voltages are in a steady-state balanced condition, the V_{alpha} waveform will be a sinusoidal combination of the phase voltages based on the equations in *Table 3.16*. The following equations for the 27B81P pickup setting will be in a form similar to phasor notation. We consider the power system as balanced and the peak of the voltage waveforms as 116 • √2.

Given that:

$$V_{ABpeak} = 116\sqrt{2}\angle 30°$$
$$V_{BCpeak} = 116\sqrt{2}\angle -90°$$
$$V_{CApeak} = 116\sqrt{2}\angle 150°$$

From *Table 3.16*, V_{alpha} is given by:

$$V_{alpha} = V_{ABpeak} - \frac{V_{CBpeak}}{2} = 116\sqrt{2}\angle 30 - \frac{116\sqrt{2}\angle 90}{2} = 142 \text{ Vpk}$$

If we wish to pickup at 60 percent of V_{alpha}, then we must consider the factors of 1.5 and √2 / √3 with regards to setting 27B81P.

$$60\% \bullet 142 \text{ Vpk} = 85 \text{ Vpk}$$

$$27B81P \bullet 1.5 \bullet \frac{\sqrt{2}}{\sqrt{3}} = 85 \text{ Vpk}$$

Solving for 27B81P:

$$27B81P = 70 \text{ V}$$

Note that the result of setting the 27B81P setting for a pickup of 60 percent of the phase-phase voltages or the alpha voltage comes out to the same setting of 70 V. The internal scaling of 27B81P for use with the alpha voltage was designed for 27B81 and 27B81A to behave in a similar manner.

Example 3.3 Case 3: PTCONN = SINGLE

For *Figure 3.36*, if a nominal A-phase-to-neutral voltage of 67 V is expected, then 60 percent of this nominal voltage will result in 27B81P = 40 V. As shown in *Figure 3.36*, if VA drops below 40 V rms, 27B81 asserts.

For the logic in *Figure 3.39*, the 27B81P setting is scaled by a factor of √2. This is because the logic in *Figure 3.39* is based on a peak alpha voltage comparison to the derived threshold of 27B81P • √2. The calculations below show an example of calculating the V_{alpha} quantity and how to calculate 27B81P based on the result. Note that the V_{alpha} quantity is calculated using instantaneous samples of the voltage waveforms shown in *Table 3.16*. V_{alpha} is different than most quantities in the relay, which are typically based on rms magnitudes. If the power system voltages are in a steady-state balanced condition, the V_{alpha} waveform will be a sinusoidal combination of the phase voltages based on the equations in *Table 3.16*. The following equations for the 27B81P pickup setting will be in a form similar to phasor notation. We consider the power system as balanced and the peak of the voltage waveform as 67 • √2.

Given that:

$$V_{Apeak} = 67\sqrt{2}\angle 0°$$

Then V_{alpha} is given by:

$$V_{alpha} = V_{Apeak} = 67\sqrt{2}\angle 0° = 95 \text{ Vpk}$$

If we wish to pickup at 60 percent of V_{alpha}, then we must consider the factor of √2 with regards to setting 27B81P.

$$60\% \bullet 95 \text{ Vpk} = 57 \text{ Vpk}$$

$$27B81P \bullet \sqrt{2} = 57 \text{ Vpk}$$

Solving for 27B81P:

$$27B81P = 40 \text{ V}$$

Note that the result of setting the 27B81P setting for a pickup of 60 percent of the phase voltages or the alpha voltage comes out to the same setting of 40 V. The internal scaling of 27B81P for use with the alpha voltage was designed for 27B81 and 27B81A to behave in a similar manner.

Other Uses for Undervoltage Element 27B81

If voltage pickup setting 27B81P is applicable to other control schemes, Relay Word bit 27B81 can be used in other logic at the same time it is used in the frequency element logic.

For example, in the SEL-351 default settings, the torque-control equation 81RTC uses the logical inverse of 27B81, as described in *Rate-of-Change-of-Frequency (81R) Protection*.

If frequency elements are not being used, Relay Word bit 27B81 can still be used in other logic, with voltage setting 27B81P set as desired. Enable the frequency elements (setting E81 ≥ 1) and make setting 27B81P. Apply Relay Word bit 27B81 in the specified logic scheme, using SELOGIC control equations. Even though frequency elements are enabled, the frequency element outputs (Relay Word bits 81D1T–81D6T) do not have to be used.

Frequency Element Uses

The instantaneous frequency elements (81D1–81D6) are used in *testing only*.

The time-delayed frequency elements (81D1T–81D6T) are used for underfrequency load shedding, frequency restoration, and other schemes.

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

Frequency changes occur in power systems when there is an unbalance between load and active power generated. Typically, generator control action adjusts the generated active power and restores the frequency to nominal value. Failure of such control action can lead to system instability unless remedial action, such as load shedding, is taken. You can use the rate-of-change-of-frequency element to detect and initiate a remedial action. The SEL-351 provides four rate-of-change-of-frequency elements. *Table 3.18* shows the settings available for the elements.

Table 3.18 Rate-of-Change-of-Frequency Settings (Sheet 1 of 2)

Setting	Definition	Setting Range
E81R	Enable Rate-of-Change-of-Frequency Elements	N, 1–4
81RTC	Torque Control	Relay Word bits referenced in *Table D.1* or set directly to logical 1 (= 1)[a]
81R1P	Element 1 Pickup	OFF, 0.10–15.00 Hz/s
81R1TRND	Element 1 Trend	INC, DEC, ABS
81R1PU	Element 1 Timer Pickup	0.10–60.00 s
81R1DO	Element 1 Timer Dropout	0.00–60.00 s
81R2P	Element 2 Pickup	OFF, 0.10–15.00 Hz/s
81R2TRND	Element 2 Trend	INC, DEC, ABS
81R2PU	Element 2 Timer Pickup	0.10–60.00 s
81R2DO	Element 2 Timer Dropout	0.00–60.00 s
81R3P	Element 3 Pickup	OFF, 0.10–15.00 Hz/s
81R3TRND	Element 3 Trend	INC, DEC, ABS
81R3PU	Element 3 Timer Pickup	0.10–60.00 s

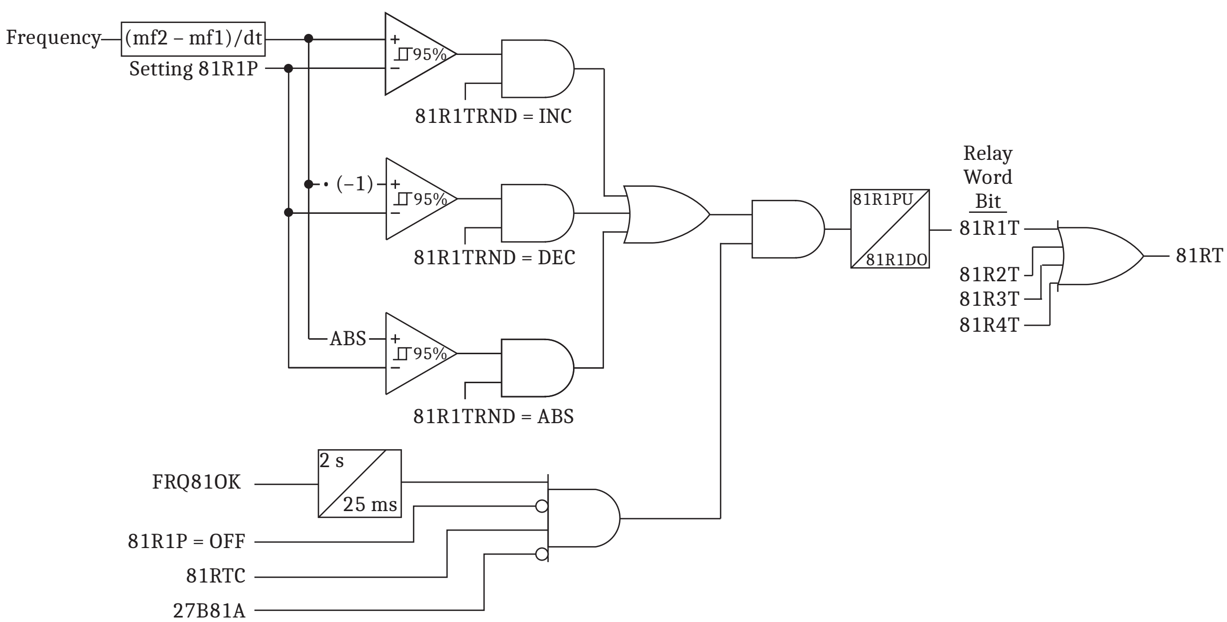
Table 3.18 Rate-of-Change-of-Frequency Settings (Sheet 2 of 2)

Setting	Definition	Setting Range
81R3DO	Element 3 Timer Dropout	0.00–60.00 s
81R4P	Element 4 Pickup	OFF, 0.10–15.00 Hz/s
81R4TRND	Element 4 Trend	INC, DEC, ABS
81R4PU	Element 4 Timer Pickup	0.10–60.00 s
81R4DO	Element 4 Timer Dropout	0.00–60.00 s

[a] SELOGIC control equation torque-control settings (e.g., 81RTC) cannot be set directly to logical 0.

Use E81R setting to enable the number of elements desired, *Figure 3.41* shows the element logic. The SEL-351 measures frequency (mf1), and then measures a second frequency (mf2) after a time window (dt) determined by Trip Level setting (81R*n*P). The element has hysteresis, such that pickup is 100 percent of the 81R*n*P setting and dropout is 95 percent. *Table 3.19* shows the time windows for different trip level settings. The Relay Word bit 81RT = 81R1T + 81R2T + 81R3T + 81R4T.

The SEL-351 does not track the system frequency when the frequency changes faster than 20 Hz/second, and the 81R elements will not respond.



Logic shown for 81R1T. Logic for 81R2T–81R4T is similar.

Figure 3.41 81R Frequency Rate-of-Change Scheme Logic

Table 3.19 Time Window Versus 81RnP Setting (Sheet 1 of 2)

81RnP Setting (Hz/s)	Time Window (ms)
0.10–0.14	1000
0.15–0.19	666
0.20–0.29	500
0.30–0.39	333
0.40–0.59	250
0.60–1.19	166

Table 3.19 Time Window Versus 81RnP Setting (Sheet 2 of 2)

81RnP Setting (Hz/s)	Time Window (ms)
1.20–2.39	83
2.40–15.00	41

For testing purposes, the expected pickup time can be calculated using *Equation 3.1*, the 81R*n*P pickup setting, the corresponding time window from *Table 3.19*, and the rate-of-change-of-frequency of the applied signal. For a given 81R*n*P pickup setting, the pickup time of the element decreases as the rate of frequency change increases. Use *Equation 3.1* to select the time delay setting 81R*n*PU so that the element responds as desired.

$$81\text{R}n\text{T Minimum Pickup Time} = \frac{81\text{R}n\text{P} \bullet \text{ Time Window}}{\text{Rate of Frequency Change}} + 81\text{R}n\text{PU}$$

Equation 3.1

Set 81R*n* Trend to INC or DEC to limit operation of the element to increasing or decreasing frequency respectively. Set the trend to ABS if you want the element to disregard the frequency trend.

FRQ81OK ensures that the estimated frequency is between 40–70 Hz and that the frequency slew rate is less than 20 Hz/s.

Set 81RTC to limit when the 81R elements are active. The default setting for 81RTC is !27B81. The 27B81 Relay Word bit asserts when any of the phase voltages is less than the 27B81P threshold. By default, 27B81P is set to 40.00 V. As a result, when configured with default settings, the 81RTC SELOGIC control equation operates as an undervoltage supervision check for the 81R elements.

The 27B81A Relay Word bit asserts when V_{alpha} is less than the derived threshold based on 27B81P, as shown in *Figure 3.37*, *Figure 3.38*, and *Figure 3.39*. The 27B81A Relay Word bit supervises the rate-of-change-of-frequency elements, as shown in *Figure 3.41*. The supervision of the 81R elements with 27B81 and 27B81A is important because it prevents the rate-of-change-of-frequency elements from operating during a fault condition. Set the 27B81P pickup setting so that it asserts for fault conditions. To modify 27B81P, enable the frequency elements; if no frequency elements are enabled, 27B81P defaults to the value of 40.00 V.

Use the Relay Word bit 81R*n*T or 81RT in the SELOGIC trip equations to open appropriate breaker(s) as necessary for your load-shedding scheme.

Voltage Sag, Swell, and Interruption Elements

NOTE: Voltage sag, swell, and interruption elements are only available in firmware version 7 for the SEL-351.

The SEL-351-7 has three types of elements to detect voltage disturbances. These elements detect voltage sags, swells, and interruptions (abbreviated as “VSSI” or “SSI”). These elements are enabled by group setting ESSI = Y and controlled by the VINT, VSWELL, and VSAG settings.

Enter the VSSI element threshold settings VSAG, VSWELL, and VINT in percentage units, which relate to the Positive-Sequence Reference Voltage: Vbase. The use of percentage settings instead of absolute voltage limits allows the SSI elements to perform better in systems that have a range of nominal voltages, with no need to adjust settings for seasonal loading or to set them far apart to accommodate the action of a tap-changing transformer. The SSI elements respond to phase-to-neutral voltages when the relay is wye-connected, and phase-to-phase voltages when the relay is delta-connected, as determined by Global setting PTCONN.

NOTE: The VSSI elements are not available when Global setting PTCONN = SINGLE.

The Positive-Sequence Reference Voltage is discussed in its own subsection.

The Voltage Sag, Swell, Interruption Recorder automatically uses the SSI elements. These elements are also available as Relay Word bits, so they can be used in any SELOGIC control equation. See *Sag/Swell/Interruption (SSI) Report (Available in Firmware Version 7)* on page 12.42.

Voltage Sag Elements

As shown in *Figure 3.42*, if the magnitude of a voltage drops below the voltage sag pickup threshold for one cycle, the corresponding SAG Relay Word bit for that phase (or phase-to-phase pair) asserts (SAGA, SAGB, or SAGC, wye-connected; SAGAB, SAGBC, SAGCA, delta-connected). If all three SAG*p* elements assert, an additional Relay Word bit asserts—SAG3P. The SAG elements remain asserted until the magnitude of the corresponding voltage rises and remains above the sag dropout threshold for one cycle.

The sag pickup and dropout thresholds depend on Vbase and the VSAG setting.

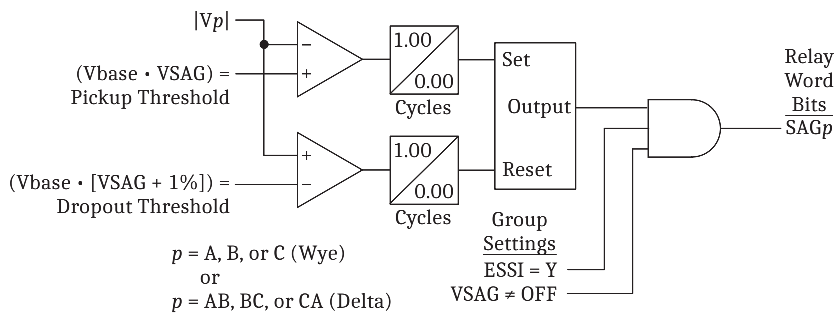


Figure 3.42 Voltage Sag Elements

Voltage Swell Elements

As shown in *Figure 3.43*, if the magnitude of a voltage rises above the voltage swell pickup threshold for one cycle, the corresponding SW Relay Word bit for that phase (or phase-to-phase pair) asserts (SWA, SWB, or SWC, wye-connected; SWAB, SWBC, SWCA, delta-connected). If all three SW*p* elements assert, an additional Relay Word bit asserts—SW3P. The SW elements remain asserted until the magnitude of the corresponding voltage drops and remains below the swell dropout threshold for one cycle.

The swell pickup and dropout thresholds depend on Vbase and the VSWELL setting.

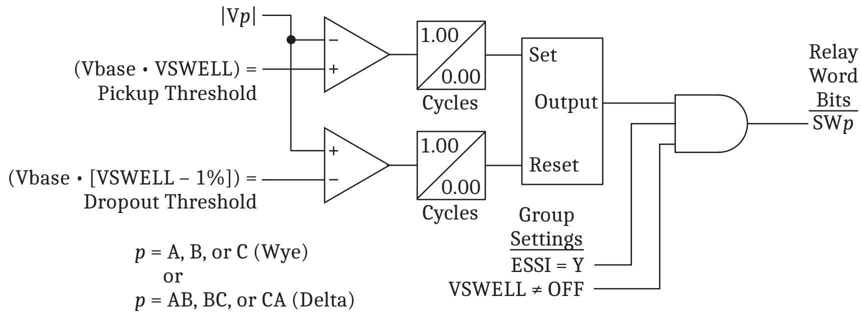


Figure 3.43 Voltage Swell Elements

Voltage Interruption Elements

As shown in *Figure 3.44*, if the magnitude of a voltage drops below the voltage interruption pickup threshold for one cycle, the corresponding INT Relay Word bit for that phase (or phase-to-phase pair) asserts (INTA, INTB, or INTC, wye-connected; INTAB, INTBC, INTCA, delta-connected). If all three INT*x* elements assert, an additional Relay Word bit asserts—INT3P. The INT elements remain asserted until the magnitude of the corresponding voltage rises and remains above the interruption dropout threshold for one cycle.

The interruption pickup and dropout thresholds depend on Vbase and the VINT setting.

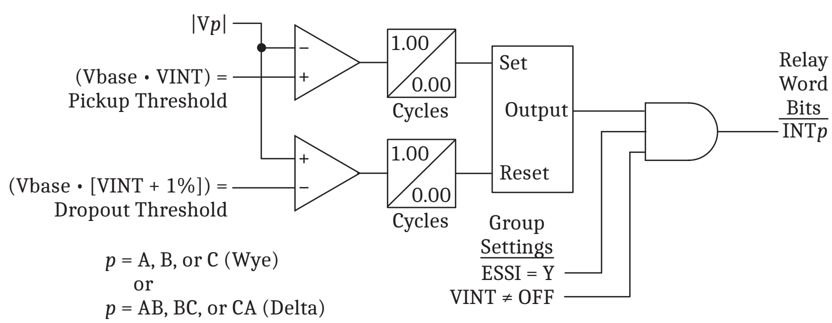


Figure 3.44 Voltage Interruption Elements

Voltage Sag, Swell, and Interruption Elements Settings

The settings ranges for the SSI thresholds are shown in *Table 3.20*.

The factory default settings match the Interruption, Sag, and Swell definitions in IEEE Standard 1159-1995 “Classifications of RMS Variations.”

Table 3.20 Sag/Swell/Interruption Elements Settings (Must First Set ESSI = Y)

Settings	Definition	Range	Default
VINT[a]	Percentage of memory voltage compared to phase-to-neutral or phase-to-phase voltage to assert INT elements	OFF, 5 to 95% of reference voltage, Vbase	10.00%
VSAG	Percentage of memory voltage compared to phase-to-neutral or phase-to-phase voltage to assert SAG elements	OFF, 10 to 95% of reference voltage, Vbase	90.00%
VSWELL	Percentage of memory voltage compared to phase-to-neutral or phase-to-phase voltage to assert SW elements	OFF, 105 to 180% of reference voltage, Vbase (300 V secondary maximum upper limit)	110.00%

[a] VINT cannot be set higher than VSAG.

Positive-Sequence Reference Voltage, Vbase

The relay converts the positive-sequence voltage quantity, |V1|, to a reference voltage, Vbase, that has a thermal demand characteristic with a time constant of 100 seconds. This allows the Vbase quantity to slowly track normal system voltage variations (tap changer operations and load effects), but not follow fast system voltage changes (unless the change is held for several seconds).

In a balanced three-phase system, |V1| is the average of the three phase-to-neutral voltages.

For wye-connected systems, Vbase tracks |V1|, and represents the average phase-to-neutral voltage.

For delta-connected systems, Vbase tracks √ 3 • |V1|, and represents the average phase-to-phase voltage.

The present value of Vbase can be viewed by issuing the **MET X** command. See **MET *(Metering Data)*** on page 10.55.

Vbase Thermal Element Block

To prevent the Vbase quantity from tracking during transient voltage conditions, the calculation of the Vbase thermal element is blocked during the assertion of any of the SAG*p*, SW*p*, or INT*p* Relay Word bits or the FAULT SELOGIC control equation setting. When blocked, the Vbase quantity will not change. This allows the SAG, SWELL, and INT elements voltage comparisons to be made with the reference Vbase locked at a "healthy" system voltage level. Once the disturbance is over and all of the SAG*p*, SW*p*, and INT*p* Relay Word bits deassert, and the FAULT SELOGIC control equation setting deasserts, the thermal element for Vbase is unblocked.

Figure 3.45 shows an example of how Vbase tracking is suspended during a voltage disturbance (wye-connected). The example voltage disturbance is the result of an overload condition (three-phase sag), followed by a source-side breaker operation (three-phase interruption). To illustrate the dynamic nature of the VSSI thresholds, the Interrupt, Sag, and Swell pickup levels are also plotted, using the factory default settings for VINT, VSAG, and VSWELL. For this hypothetical three-phase disturbance, V1 has the same magnitude as V_A, V_B, and V_C (as shown). Single-phase disturbances are handled in a similar fashion, except that the phases and V1 will have different voltage magnitudes.

The use of a VSAG setting higher than 90 percent, at the same time as a VSWELL setting lower than 110 percent, should be carefully considered. Moving these thresholds too close together increases the probability that an end-of-disturbance condition is missed. This could create a false sag or swell condition that may not clear itself until the next disturbance, thus causing the Vbase thermal element to remain blocked.

Vbase thermal element blocking by the FAULT Relay Word bit is programmable via SELOGIC setting FAULT. SELOGIC control equation setting FAULT also controls other relay functions, see SELOGIC *Control Equation Setting FAULT* on page 5.39.

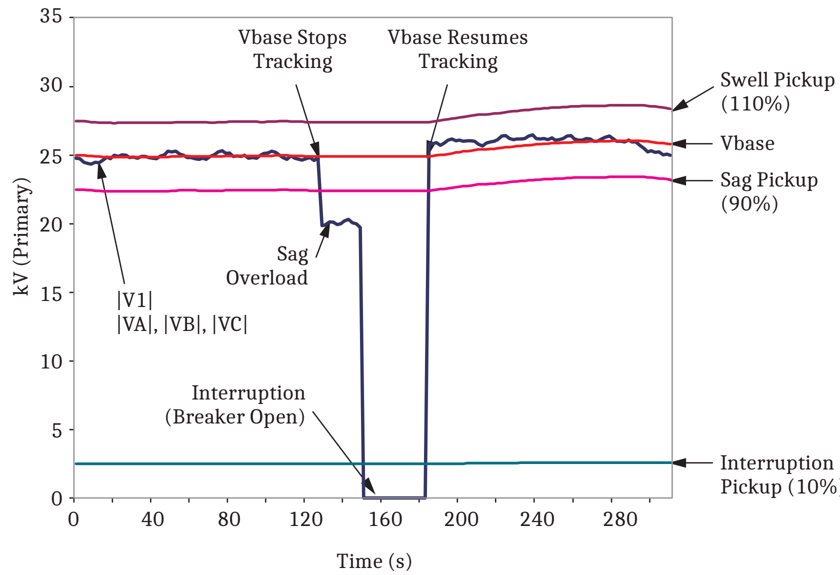


Figure 3.45 Vbase Tracking Example (Three-Phase Disturbance, Wye-connected)

Vbase Initialization

The Vbase thermal element is automatically initialized when the relay is powered up, and also after a settings change or group change that results in a new ESSI = Y condition.

Vbase can also be forced to initialize by issuing the **SSI R** command (Access Level 1).

During initialization, the SSI elements are deasserted and the SSI Recorder is disabled until all of the following conditions are met:

- |V1| > |3V2| (correct phase rotation check)
- |V1| > |3V0| (correct phase connection check) (wye-connected only)
- V_A, V_B, and V_C are all greater than 25 V secondary (wye-connected)
- V_{AB}, V_{BC}, V_{CA} are all greater than 43.3 V secondary (delta connected)
- SELOGIC control equation setting FAULT is deasserted
- |V1| is within three percent of the calculated Vbase value (wye-connected)
- |V1| is within three percent of the calculated Vbase value/√ 3 (delta connected)
- At least 12 seconds have elapsed

As soon as the above Vbase initialization conditions are satisfied, the SSI Relay Word bits will be allowed to change state according to their settings and the present voltage conditions, and the SSI Recorder will be enabled.

Vbase Tracking Range

The Vbase quantity will track the positive-sequence voltage over a large range of system voltages. The tracking limits are explained below. In normal relay use, these limits are not likely to be reached, because one of the Sag, Swell, or Interruption Relay Word bits would most likely assert for a large voltage deviation, thus blocking the Vbase thermal element from tracking to one of the range limits.

The minimum value that Vbase can achieve is equivalent to a positive-sequence (V1) value of 25 volts secondary. In primary units, the lowest value depends on the Global setting PTCONN:

When PTCONN = WYE: minimum Vbase =

$$\frac{25\text{ V} \bullet \text{ PTR}}{1000}\text{kV}$$

When PTCONN = DELTA: minimum Vbase =

$$\frac{43.3\text{V} \bullet \text{ PTR}}{1000}\text{kV}$$

The maximum value that Vbase can achieve is equivalent to 300 volts secondary divided by VSWELL, so the maximum Vbase in primary kV is

$$\frac{300\text{ V} \bullet \text{ PTR} \bullet \text{ 100}}{\text{VSWELL} \bullet \text{ 1000}} = \frac{30\text{ V} \bullet \text{ PTR}}{\text{VSWELL}}$$

The upper limit for Vbase is not affected by the PTCONN Global setting.

If the expected higher end of the "normal" system voltage range is close to 300 V, secondary, then the VSWELL setting may need to be reduced, or turned "OFF," in order to allow Vbase to track the actual system voltage and not run into the maximum value limit. For example, if connecting to an industrial service rated at 277 V_{LN}/480 V_{LL}, using the wye-connection (with no PTs), and the normal operating range goes to as much as 285 V_{LN}, then the maximum VSWELL setting that will allow for proper Vbase tracking is 105 percent.

SSI Reset Command

After commissioning tests or other maintenance activities that have applied test voltages to the SEL-351, the Vbase element may have locked onto a test voltage. Use the **SSI R** (reset) command once normal system voltages are restored on the voltage terminals. Powering up the relay automatically performs this reset.

See *Resetting the SSI Recorder Logic* on page 12.48 for more details.

Power Elements

NOTE: Power elements are only available in firmware version 7.

Four independent power elements are available. The Global setting PTCONN = WYE, DELTA, or SINGLE controls which power elements are available. The Group setting EPWR determines how many (and what type of) power elements are enabled:

NOTE: Although the power elements may be enabled when PTCONN = SINGLE, the specific system connections may not give the elements meaningful operating quantities. See *Special Considerations for Using Power Elements When PTCONN = SINGLE* on page 3.74 before attempting to use the power elements with a single-phase voltage connection.

When PTCONN = WYE (wye-connected voltages):

EPWR = **N** (none), **1**, **2**, **3**, **4** (single-phase); **3P1**, **3P2**, **3P3**, **3P4** (three-phase)

When PTCONN = DELTA (delta-connected voltages):

EPWR = **N** (none), **3P1**, **3P2**, **3P3**, **3P4** (three-phase)

When PTCONN = SINGLE (wye-connected voltages):

EPWR = **N** (none), **1**, **2**, **3**, **4** (single-phase)

Each enabled power element can be set to detect real power or reactive power. With SELOGIC control equations, the power elements provide a wide variety of protection and control applications. Typical applications are:

- ➤ Overpower and/or underpower protection/control
- ➤ Reverse power protection/control
- ➤ VAR control for capacitor banks

Power Elements Settings

Table 3.21 Single-Phase Power Element Settings and Setting Ranges (EPWR = 1, 2, 3, or 4)

Settings	Definition	Range
PWR1P, PWR2P, PWR3P, PWR4P	Power element pickup	OFF, 0.33–13000.00 VA secondary, single-phase (5 A nominal phase current inputs, IA, IB, IC) OFF, 0.07–2600.00 VA secondary, single-phase (1 A nominal phase current inputs, IA, IB, IC)
PWR1T, PWR2T, PWR3T, PWR4T	Power element type	+WATTS, –WATTS, +VARS, –VARS
PWR1D, PWR2D, PWR3D, PWR4D	Power element time delay	0.00–16000 cycles, in 0.25-cycle steps

Table 3.22 Three-Phase Power Element Settings and Setting Ranges (EPWR = 3P1, 3P2, 3P3, or 3P4)

Settings	Definition	Range
3PWR1P, 3PWR2P, 3PWR3P, 3PWR4P	Power element pickup	OFF, 1.00–39000.00 VA secondary, three-phase (5 A nominal phase current inputs, IA, IB, IC) OFF, 0.20–7800.00 VA secondary, three-phase (1 A nominal phase current inputs, IA, IB, IC)
PWR1T, PWR2T, PWR3T, PWR4T	Power element type	+WATTS, –WATTS, +VARS, –VARS
PWR1D, PWR2D, PWR3D, PWR4D	Power element time delay	0.00–16000 cycles, in 0.25-cycle steps

The power element type settings are made in reference to the *load* convention:

- ➤ +WATTS: positive or forward real power
- ➤ –WATTS: negative or reverse real power
- ➤ +VARS: positive or forward reactive power (lagging)
- ➤ –VARS: negative or reverse reactive power (leading)

Power Element Time Delay Setting Considerations

The four power element time delay settings (PWR1D–PWR4D) can be set to have no intentional delay for testing purposes. For protection applications involving the power element Relay Word bits, SEL recommends a minimum time delay setting of 5.00 cycles for general applications. The classical power calculation is a product of voltage and current, to determine the real and reactive power quantities. During a system disturbance, because of the high sensitivity of the power elements, the changing system phase angles and/or frequency shifts may cause transient errors in the power calculation.

Using Power Elements in the Relay Trip Equation

The power elements are not supervised by any relay elements other than the minimum voltage checks shown in *Figure 3.46* and *Figure 3.47*. If the protection application requires overcurrent protection in addition to the power elements, there may be a race condition, during a fault, between the overcurrent element(s) and the power element(s) if the power element(s) are still receiving sufficient operating quantities. In some protection schemes this may jeopardize coordination. One method of accommodating this is to increase the power element time delay settings. Another method is to supervise the power element Relay Word bit(s) with the overcurrent element pickup. For example, if the application requires that the relay trip the attached circuit breaker when a forward power flow threshold is exceeded, and a phase definite-time overcurrent element is also in the relay trip equation, extra security can be achieved with these SELOGIC control equation settings:

TR = **... + ... + SV1T + 67P1T**

SV1 = **3PWR1 * !67P1**

And group settings:

E50P = **1**

ESV = **1**

EPWR = **3P1**

50P1P = **5.00 A**

67P1D = **10.00 cycles**

SV1PU = **1.00 cycle**

SV1DO = **0.00 cycles**

3PWR1P = **360.00 VA**

PWR1T = **+WATTS**

PWR1D = **5.00 cycles**

During a fault that can pick up both the power element and the overcurrent element, these settings will ensure that the definite-time overcurrent element (67P1T) will trip the relay for the fault, even if the PWR1D setting is set to a smaller time delay than the 67P1D setting. Relay Word bit 3PWR1 is ANDed with Relay Word bit NOT(67P1), which effectively blocks 3PWR1 when 67P1 is asserted. The SELOGIC variable timer SV1T is employed in this example to avoid another race condition that could occur if the fault was cleared by another device before the definite-time element time-out, which could potentially deassert 67P1 a few quarter-cycles before 3PWR1 deasserts. Without this timer, an incorrect trip operation may occur.

See *Instantaneous/Definite-Time Overcurrent Elements* on page 3.1, and SELOGIC *Control Equation Variables/Timers* on page 7.26 for details on the operation of these functions and their settings.

Single-Phase Power Element Calculations

The numeric method used in the single-phase power elements uses line-to-neutral voltage and phase current quantities. Each phase is calculated separately, with the resulting power quantities subject to the minimum voltage tests shown in the lower half of *Figure 3.46*.

Special Considerations for Using Power Elements When PTCONN = SINGLE

For meaningful operation of a single-phase power element, the calculation path requires that the element be connected to like-phase current and voltage signals.

For example, if the **VA/N** terminal is connected to the distribution system C-phase line-to neutral PT, and the current transformers are connected in the usual fashion (A-phase to **IA•**, B-phase to **IB•**, C-phase to **IC•**), the A-phase power element logic is attempting to calculate power using V_C and I_A, and outputs PWRA1, PWRA2, PWRA3, PWRA4 are not valid. The other power elements PWRB1-4 and PWRC1-4 are inactive because there are no voltages being applied to the VB and VC terminals.

Continuing with this example, a possible solution is to jumper the single-phase voltage from the **VA** to the **VC** terminal, supplying the relay V_C input with the same signal as the VA input. In this situation, the power elements PWRC1-PWRC4 may be used, because the power element logic is seeing the same -phase signals on V_C and I_C. It is important to leave the **VA** terminal connected for proper relay operation, because other functions such as frequency tracking, frequency measurement, and phantom metering require a **VA** terminal signal. See *Settings for Voltage Input Configuration* on page 9.18.

If the single-phase voltage is connected line-to-line, the power elements are not valid because the current and voltage operating quantities are not from the same phase. There is no wiring solution for this, other than changing the voltage source to a line-to-neutral connection.

Three-Phase Power Element Calculations

The numeric method used in the three-phase power elements uses line-to-line voltage and phase current quantities, corrected with zero-sequence voltage and current when unbalanced. The following discussion assumes that all three phase currents (I_A, I_B, and I_C) are connected to the relay.

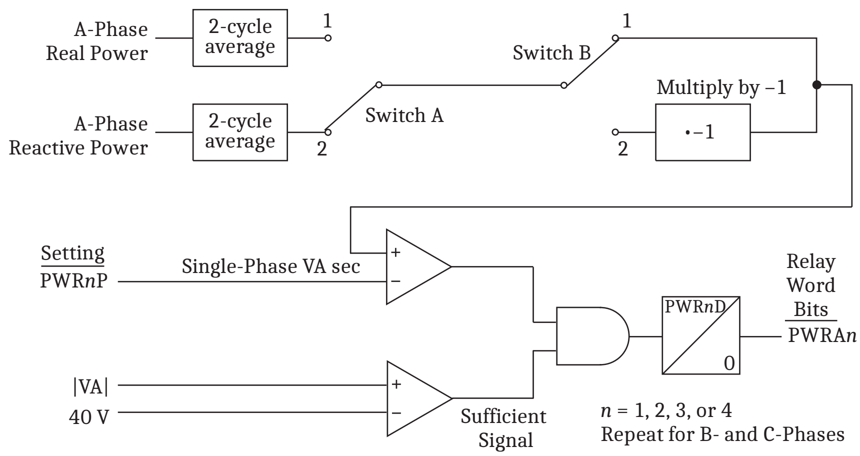
The resulting power quantities are subject to the minimum voltage tests shown in the lower half of *Figure 3.47*.

For wye-connected relays (Global setting PTCONN = WYE), the three-phase power is the same as the sum of the single-phase powers under any conditions of unbalance, because the zero-sequence voltage (and current) is available.

For delta-connected relays (Global setting PTCONN = DELTA) with a broken delta 3V0 connection (Global setting VSCONN = 3V0), the three-phase power is the same as the sum of the theoretical single-phase powers under any conditions of unbalance, because the zero-sequence voltage is available via the **VS-NS** terminals (provided the 3V0 source is on the same bus section as the three-phase voltage inputs, the two signal sources cannot be isolated by switching action, and the PTR and PTRS settings are properly entered).

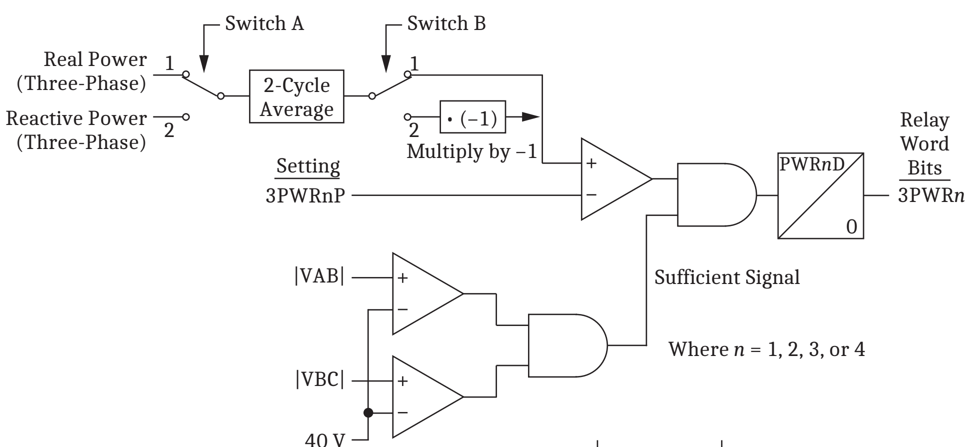
For delta-connected relays (Global setting PTCONN = DELTA) with no broken delta 3V0 connection (Global setting VSCONN = VS), the three-phase power is the same as the sum of the theoretical single-phase powers only in balanced conditions (either |3V0| = 0, or |3I0| = 0, or both). For unbalanced conditions, the three-phase power element value will include an error term that is proportional to the amount of unbalance.

Power Elements Logic Operation



Setting PWRnT	Switch A Position	Switch B Position
+WATTS	1	1
−WATTS	1	2
+VARS	2	1
−VARS	2	2

Figure 3.46 Single-Phase Power Elements Logic (+VARS Example Shown)



Setting PWRnT	Switch A Position	Switch B Position
+WATTS	1	1
−WATTS	1	2
+VARS	2	1
−VARS	2	2

Figure 3.47 Three-Phase Power Elements Logic

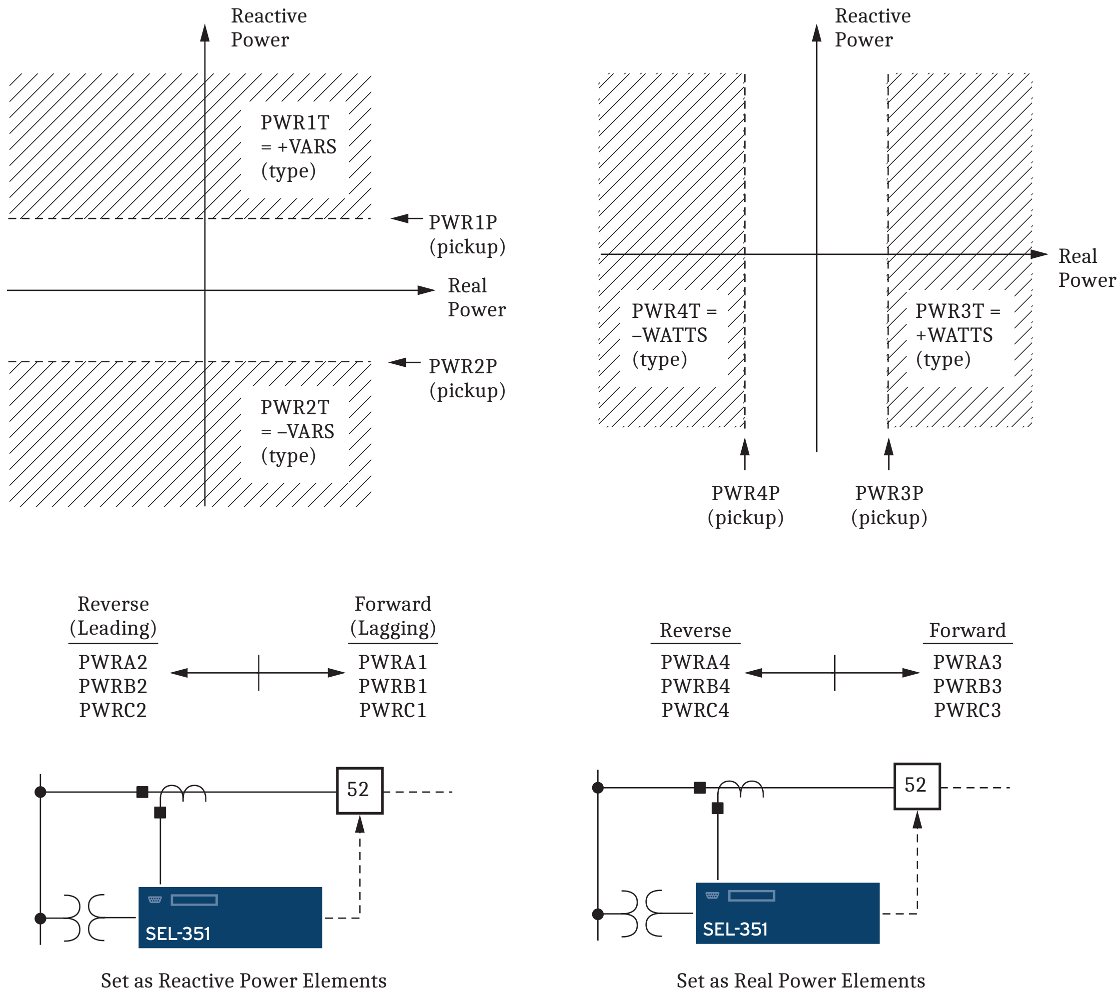


Figure 3.48 Power Elements Operation in the Real/Reactive Power Plane

In *Figure 3.46*, an example is shown with setting PWR*n*T = +VARS. This corresponds to the settings PWR1P (pickup) and PWR1T (type) in *Figure 3.48*.

In *Figure 3.48*, if the A-Phase reactive power level is above pickup setting PWR*n*P, Relay Word bit PWRA*n* asserts (PWRA*n* = logical 1) after time delay setting PWR*n*D (*n* = 1 through 4), subject to the “sufficient signal” conditions.

Pickup setting PWR*n*P is always a positive number value (see *Table 3.21*). Thus, if –WATTS or –VARS are chosen with setting PWR*n*T, the corresponding real or reactive power values have to be multiplied by –1 so that element PWRA*n* asserts for negative real or reactive power.

Power Elements Application—VAR Control for a Capacitor Bank

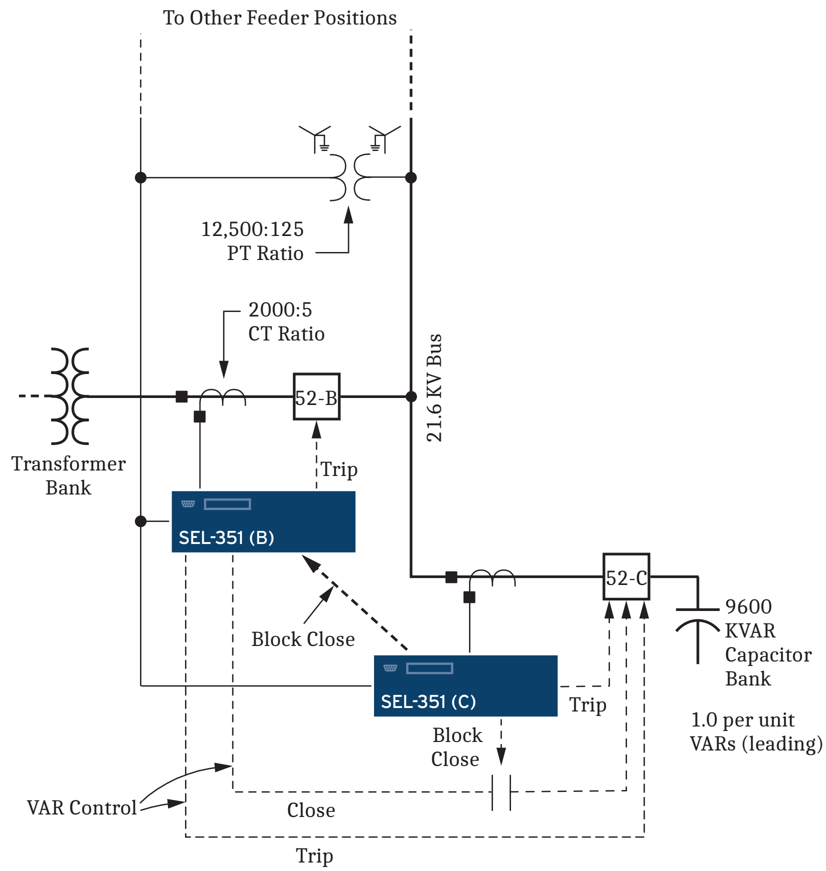


Figure 3.49 SEL-351(B) Provides VAR Control for 9600 kVAR Capacitor Bank

The 9600 kVAR capacitor bank in *Figure 3.49* is put on-line and taken off-line according to the VAR loading on the transformer bank feeding the 21.6 kV bus. The VAR loading is measured with the SEL-351(B) located at bus circuit breaker 52-B.

Two SEL-351 Relays control the capacitor bank. Both relays are connected to capacitor bank circuit breaker 52-C. The SEL-351(C) provides capacitor overcurrent protection and trips circuit breaker 52-C for a fault in the capacitor bank. The SEL-351(B) provides VAR control and automatically puts the capacitor bank on-line (closes circuit breaker 52-C) or takes it off-line (trips circuit breaker 52-C) according to the measured VAR level. The SEL-351(B) also provides bus overcurrent protection and trips circuit breaker 52-B for a fault on the 21.6 kV bus.

In *Figure 3.49*, if the SEL-351(C) trips circuit breaker 52-C for a fault in the capacitor bank, then a block close signal is sent from the SEL-351(C) to the SEL-351(B). This prevents the SEL-351(B) from issuing an automatic close to circuit breaker 52-C.

For additional security, the close circuit from the SEL-351(B) to circuit breaker 52-C is supervised by a block close output contact from the SEL-351(C). This block close output contact opens if the SEL-351(C) trips circuit breaker 52-C for a fault in the capacitor bank—no automatic closing can then take place.

These block close signals seal in when the SEL-351(C) trips circuit breaker 52-C for a fault in the capacitor bank. Automatic closing of circuit breaker 52-C with the SEL-351(B) can then take place only after the block close signals are reset. The exact implementation of this block close logic requires an application note beyond the scope of this discussion.

The rest of this discussion focuses on the determination of VAR levels (and corresponding power element settings) for automatic tripping and closing of circuit breaker 52-C with the SEL-351(B).

Convert three-phase 9600 kVAR (kVA) to single-phase VA (volt-amperes) secondary:

9600 kVA/(21.6 kV • $\sqrt{3}$) = 256.6 A primary

256.6 A primary • (5/2000) = 0.64 A secondary

0.64 A secondary • 125 V secondary = 80.0 VA secondary (single-phase)

The three-phase 9600 kVAR capacitor is converted to 1.0 per unit VARs (leading) for demonstration convenience in *Figure 3.49*. *Figure 3.50* shows the per unit VAR levels for putting on-line (closing circuit breaker 52-C) or taking off-line (tripping circuit breaker 52-C) the capacitor bank.

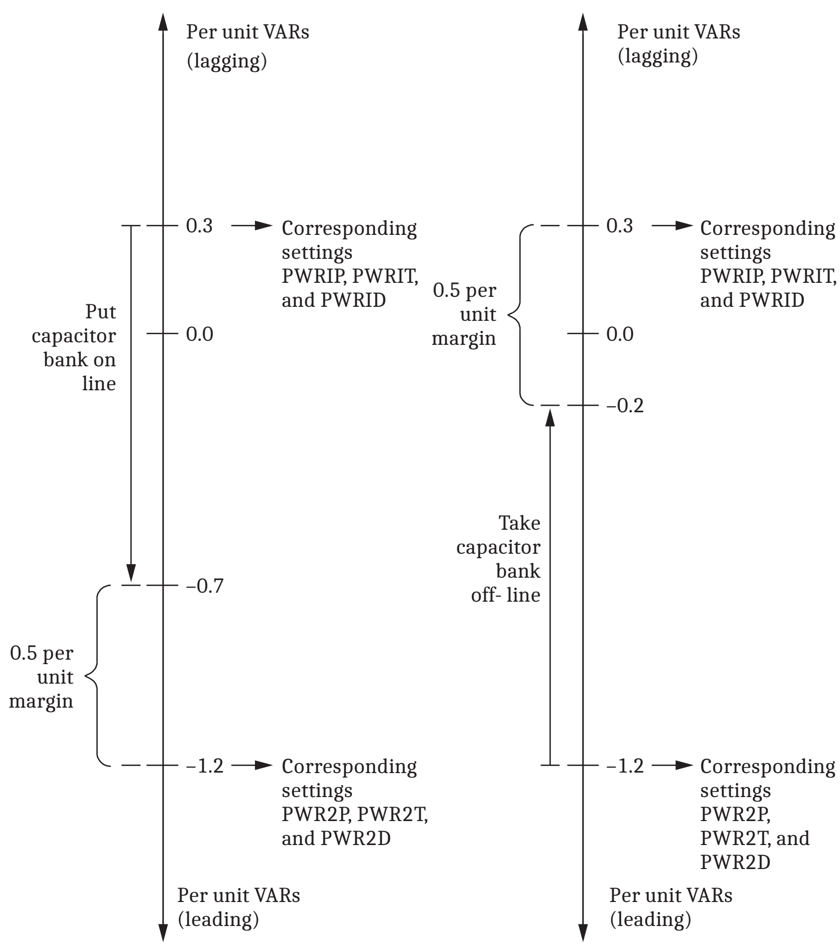


Figure 3.50 Per Unit Setting Limits for Switching 9600 kVAR Capacitor Bank On- and Off-Line

The capacitor bank is put on-line at the 0.3 per unit VAR level (lagging) on the bus. The per unit VAR level immediately changes to the –0.7 per unit VAR level (leading) when the capacitor bank is put on-line (0.3 – 1.0 = –0.7). There is a margin of 0.5 per unit VARs until the capacitor bank is then taken off-line (–0.7 – 0.5 = –1.2).

The capacitor bank is taken off-line at the –1.2 per unit VAR level (leading) on the bus. The per unit VAR level immediately changes to –0.2 per unit VAR level (leading) when the capacitor bank is taken off-line (–1.2 + 1.0 = –0.2). There is a margin of 0.5 per unit VARs until the capacitor bank is put on-line again (–0.2 + 0.5 = 0.3).

Settings for Single-Phase Power Elements

From preceding calculations and figures:

9600 kVAR ≈ 1.0 per unit VARs ≈ 80.0 VA secondary (single-phase)

Convert the per unit VAR levels 0.3 and –1.2 to single-phase VA (volt-amperes) secondary:

0.3 • 80.0 VA secondary (single-phase) = 24.0 VA secondary (single-phase)

–1.2 • 80.0 VA secondary (single-phase) = –96.0 VA secondary (single-phase)

Make the following power element settings for the SEL-351(B):

EPWR = **2** (enable two power elements)

PWR1P = **24.0** (power element pickup; VA secondary [single-phase])

PWR1T = **+VARS** (power element type; lagging VARs)

PWR1D = ___ (power element time delay; cycles)

PWR2P = **96.0** (power element pickup; VA secondary [single-phase])

PWR2T = **-VARS** (power element type; leading VARs)

PWR2D = ___ (power element time delay; cycles)

To override transient reactive power conditions, set the above power element time-delay settings equivalent to several seconds (or perhaps minutes).

Resulting single-phase power elements PWRA1, PWRB1, and PWRC1 assert when the lagging VAR level exceeds the 0.3 per unit VAR level (lagging) for each respective phase (see *Figure 3.50* and left-hand side of *Figure 3.48*). These elements are used in close logic in the SEL-351(B) to automatically put the 9600 kVAR capacitor bank on-line.

Resulting single-phase power elements PWRA2, PWRB2, and PWRC2 assert when the leading VAR level exceeds the –1.2 per unit VAR level (leading) for each respective phase (see *Figure 3.50* and left-hand side of *Figure 3.48*). These elements are used in trip logic in the SEL-351(B) to automatically take the 9600 kVAR capacitor bank off-line.

Settings for Three-Phase Power Elements

Following the single-phase derivation, the resulting power element setting values need to be multiplied by three.

EPWR = **3P2**

3PWR1P = **72.0**

PWR1T = **+VARS**

PWR1D = ____

3PWR2P = **288.0**

PWR1T = **-VARS**

PWR1D = ____

The exact implementation of this capacitor close and trip logic in SELOGIC control equations in the SEL-351(B) is not shown.

SECTION 4

Loss-of-Potential, Load-Encroachment, and Directional Element Logic

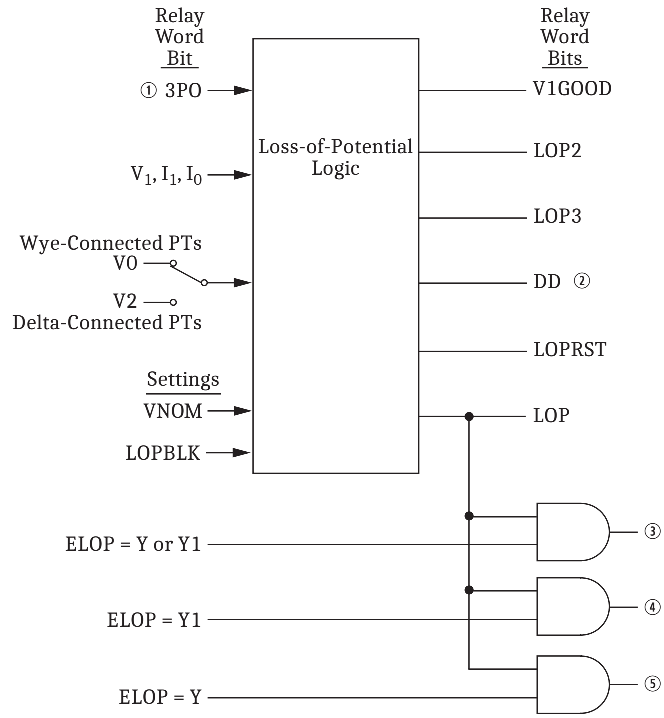
Overview

This section gives a detailed description of the operation and settings for the loss-of-potential logic, load-encroachment logic, and directional control logic for overcurrent elements.

The following functions are discussed in this section:

Loss-of-Potential Logic

The loss-of-potential (LOP) logic operates as shown in *Figure 4.1*.



① From *Figure 5.3*. ② To *Figure 5.1*. ③ To *Figure 4.11*, *Figure 4.12*, *Figure 4.13*, and *Figure 4.26*. ④ To *Figure 5.6*. ⑤ To *Figure 4.20*, *Figure 4.21*, and *Figure 4.27*.

Figure 4.1 Loss-of-Potential Logic

Inputs into the LOP logic are described in *Table 4.1*.

Table 4.1 LOP Logic Inputs

Inputs	Description
3PO	three-pole open condition (indicates circuit breaker open condition see *Figure 5.3*)
V_1	positive-sequence voltage (V secondary)
I_1	positive-sequence current (A secondary)
I_0	zero-sequence current (A secondary)
V_0	zero-sequence voltage (V secondary; wye-connected PTs)
V_2	negative-sequence voltage (V secondary; delta-connected PTs)
VNOM	PT nominal voltage setting (line-to-neutral, [wye-connected PTs] or line-to-line [delta-connected PTs], secondary)
ELOP	Loss-of-potential enable setting
LOPBLK	SELogic control equation to block loss-of-potential logic

LOP asserts immediately when LOP2 asserts. LOP latches if LOP2 stays asserted for 15 cycles (indicated by LOP3). LOP deasserts (or is prevented from asserting) if voltages are restored and remain healthy for one cycle (indicated by LOPRST).

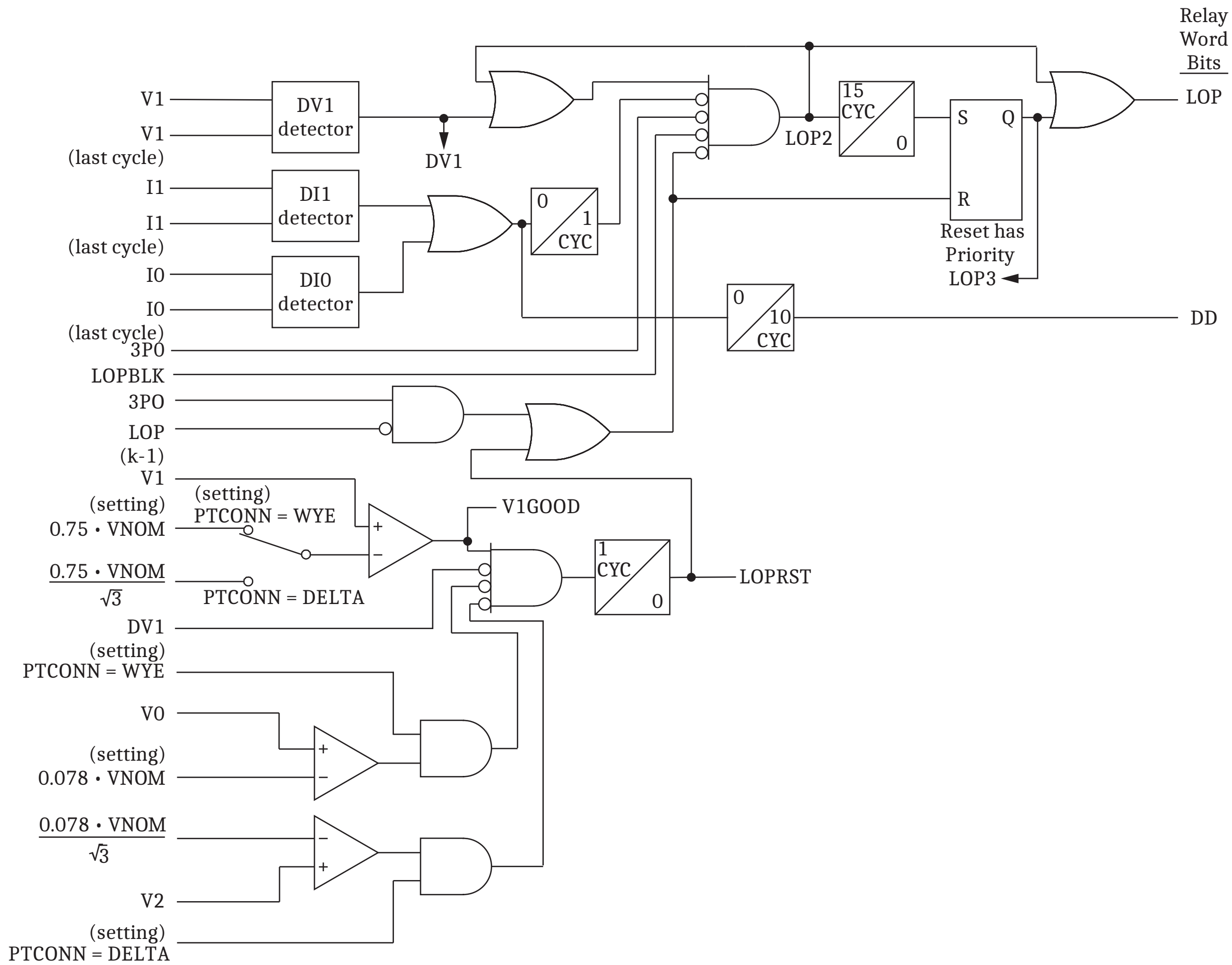


Figure 4.2 Overall LOP

Table 4.2 Loss-of-Potential Logic Outputs

Relay Word Bit	Full Name	Description
LOP	Loss-of-potential	Loss-of-potential status. This output is always available, regardless of ELOP setting.
LOP2	Loss-of-potential point 2	Drop in voltage without change in current LOP logic asserted
LOP3	Loss-of-potential point 3	LOP latched
DD	Disturbance Detector	Change in current detected during last 10 cycle period. Used for enhancing protection security through TRQUAL setting and EDDSOTF setting. See *Trip Logic* on page 5.1.
LOPRST	LOP Reset	LOP Reset condition based on detection of healthy voltages

To provide a better understanding of the logic, the following subsections describe the purpose of each part of the logic.

Relay Word Bit LOP2: Drop In Voltage With No Change in Current

Refer to the top of *Figure 4.1*.

The main LOP logic (LOP2) is based upon measuring a decrease in the magnitude of positive-sequence voltage without a simultaneous change (magnitude or angle) in either the positive-sequence or the zero-sequence currents. *Figure 4.3* shows a processing flow chart of the logic.

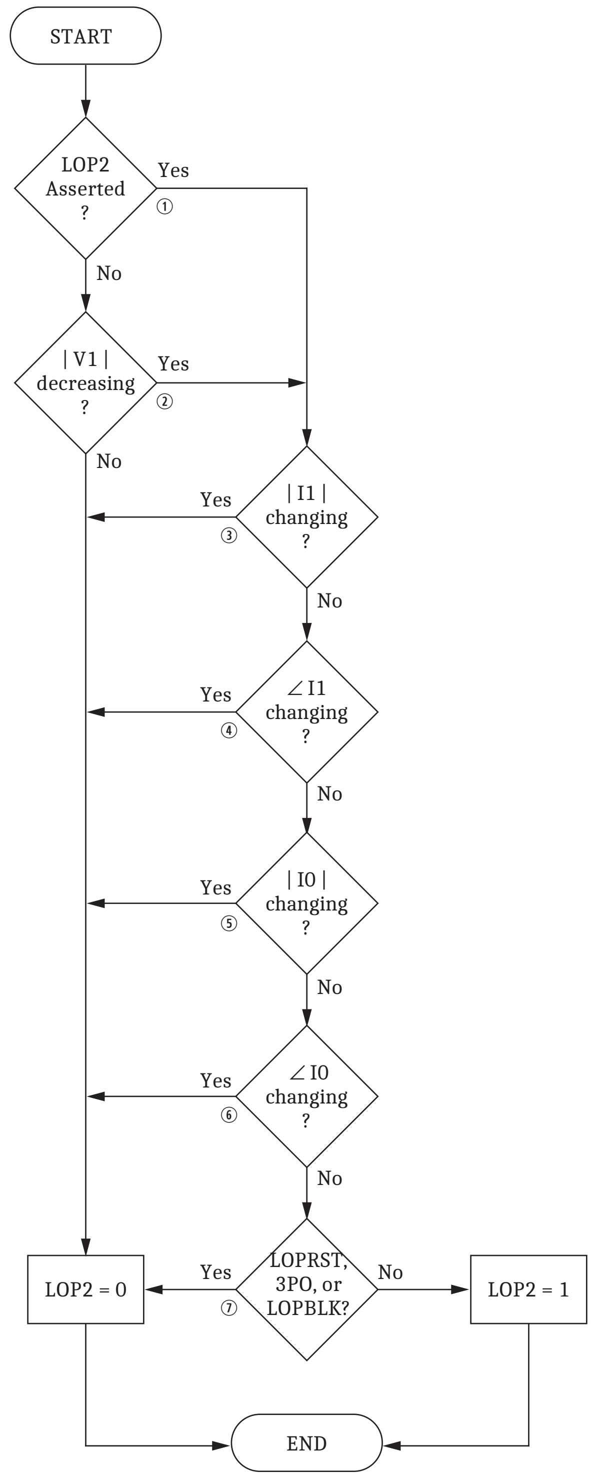


Figure 4.3 LOP2 Logic Processing Overview (Relay Word Bit LOP2)

The following text gives additional description of the steps in *Figure 4.3*:

Step 1. Is LOP2 asserted?

NO. Go to *Step 2*.

YES. Keep LOP2 asserted until one of *Step 3–Step 7* yields a true result. This "seal-in" function memorizes the change in positive-sequence voltage.

Step 2. Magnitude of positive-sequence voltage is decreasing.

Measure positive-sequence voltage magnitude (called $|V_{1(k)}|$, where k represents the present processing interval result) and compare it to $|V_1|$ from one power system cycle earlier (called $|V_{1(k-1\ \mathrm{cycle})}|$).

If $|V_{1(k)}| < 0.9 \bullet |V_{1(k-1\ \mathrm{cycle})}|$, then assert LOP2 if all of the conditions in the next steps (*Step 3–Step 7*) are satisfied.

Otherwise, jump to the end (LOP2 remains deasserted).

Step 3. Positive-sequence current magnitude not changing, and has not changed in the last two cycles.

Measure positive-sequence current magnitude ($|I_{1(k)}|$) and compare it to $|I_{1(k-1\ \mathrm{cycle})}|$ from one cycle earlier. If this difference is greater than 10 percent of nominal current, deassert LOP2.

Otherwise, continue with *Step 4*.

This condition is memorized for one cycle.

Step 4. Positive-sequence current angle is not changing, and has not changed in the last two cycles.

Measure positive-sequence current angle ($\angle I_{1k}$) and compare it to $\angle I_{1(k-1\ \mathrm{cycle})}$ from one cycle earlier. If this difference is greater than 5°, deassert LOP2.

Otherwise, continue with *Step 5*.

This condition is memorized for one cycle. If $|I1| < 0.05 \bullet I_{NOM}$, this angle check does not block LOP2.

Step 5. Zero-sequence current magnitude is not changing, and has not changed in the last two cycles.

Measure zero-sequence current magnitude ($|I_{0k}|$) and compare it to $|I_{0(k-1\ \mathrm{cycle})}|$ from one cycle earlier. If this difference is greater than 10 percent of nominal, deassert LOP2.

Otherwise, continue with *Step 6*.

This condition is memorized for one cycle.

Step 6. Zero-sequence current angle is not changing, and has not changed in the last two cycles.

Measure zero-sequence current angle ($\angle I_{0k}$) and compare it to $\angle I_{0(k-1\ \mathrm{cycle})}$. If this difference is greater than 5°, deassert LOP2.

Otherwise, continue with *Step 7*.

This condition is memorized for one cycle. For security, this declaration requires that |I0| be greater than 1.6 percent of INOM to override the LOP2 declaration.

Step 7. Is LOPRST, 3PO, or LOPBLK asserted?

NO. Assert LOP2.

YES. Deassert LOP2 (LOPRST is described below).

If LOP2 is asserted, we declare a loss-of-potential condition (LOP asserts) as shown in *Figure 4.2*.

Relay Word Bit LOP3: LOP Latch Conditions

LOP asserts immediately when LOP2 asserts. However, we delay latching LOP for 15 cycles to allow LOP2 transient conditions to settle. Once voltages are healthy, we reset the latch. *Figure 4.4* shows the LOP Latch logic.

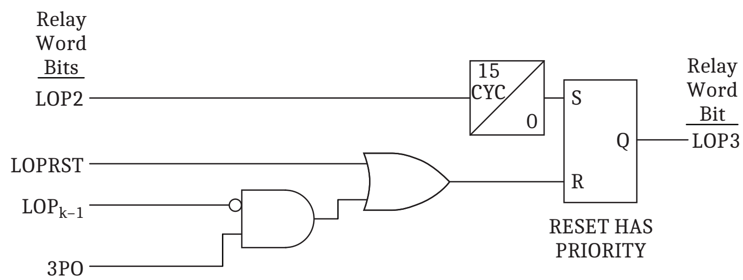


Figure 4.4 LOP Latch Logic (Relay Word Bit LOP3)

Relay Word Bit LOPRST: LOP Reset Conditions

Once LOP is declared or LOP is latched, the logic can be reset. When PTCONN = WYE, LOP resets when V1 is greater than 75 percent of setting VNOM (Relay Word bit V1GOOD = logical 1) and V0 is less than 7.8 percent of setting VNOM. When PTCONN = DELTA, LOP resets when V1 is greater than 43 percent of setting VNOM (Relay Word bit V1GOOD = logical 1) and V2 is less than 4.5 percent of setting VNOM.

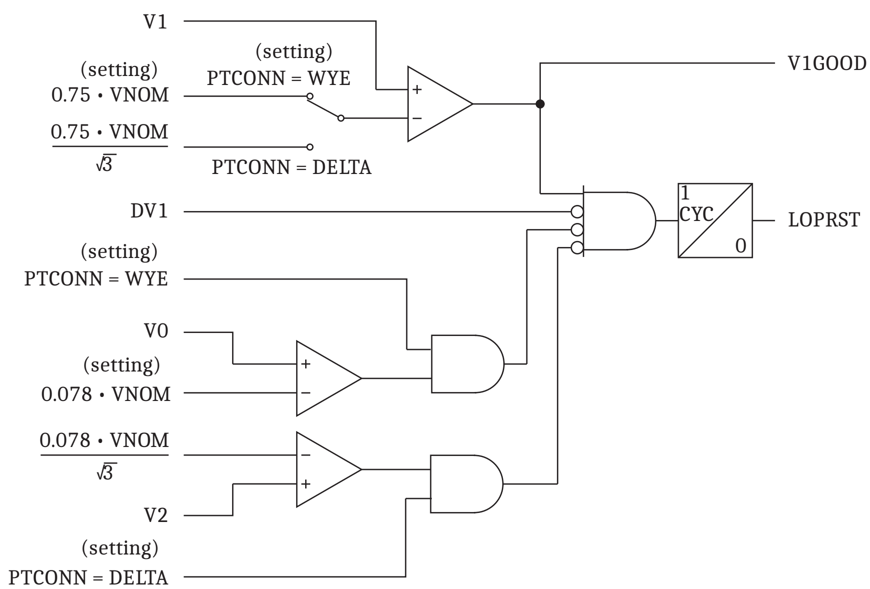


Figure 4.5 LOP Reset Logic (Relay Word Bit LOPRST)

Setting VNOM = OFF

NOTE: The disturbance detector (DD) logic continues to operate when the loss-of-potential logic is disabled.

If setting VNOM = OFF, the loss-of-potential logic is disabled (Relay Word bits LOP and V1GOOD are forced to logical 0), and setting ELOP can only be set to "N." See *Potential Transformer Ratios and PT Nominal Secondary Voltage Settings* on page 9.22 for more details on the VNOM setting.

Setting ELOP = Y or Y1

NOTE: When Global setting PTCONN = SINGLE, the ELOP setting is hidden and internally set to N.

If setting ELOP = Y or Y1 and a loss-of-potential condition occurs (Relay Word bit LOP asserts to logical 1), directional element enable Relay Word bits 32QE, 32QGE, 32VE, and 32NE, plus the positive-sequence voltage-polarized directional element, are disabled, except as discussed in NOTE 1 (see *Figure 4.11*, *Figure 4.12*, *Figure 4.13*, and *Figure 4.26*). The loss-of-potential condition makes the voltage-polarized directional elements controlled by these internal enables unreliable. The overcurrent elements controlled by these voltage-polarized directional elements are also disabled unless overridden by conditions explained in *Setting ELOP = Y* on page 4.7.

The channel IN current-polarized directional element (*Figure 4.16*) is controlled by internal enable 32IE (*Figure 4.12*). This directional element is not voltage-polarized and thus a loss-of-potential condition does not disable the element.

In *Figure 5.6*, if setting ELOP = Y1 and LOP asserts, keying and echo keying in the permissive overreaching transfer trip (POTT) logic are blocked.

> NOTE 1: When Global setting VSCONN = 3V0, the various ground-directional elements that rely on zero-sequence voltage quantities (ORDER settings V, S, P, and U) are not disabled by a loss-of-potential condition on relay inputs **VA**, **VB**, and **VC**, because these directional elements use the $3V_0$ zero-sequence voltage that comes directly from voltage input **VS**, rather than the zero-sequence voltage calculated from voltage inputs **VA**, **VB**, and **VC** (wye-connected PTs). This difference is shown in *Figure 4.12* and *Figure 4.13*, where Relay Word bit 3V0 is used as a block signal for the loss-of-potential signal. Relay Word bit 3V0 is asserted (= logical 1) whenever Global setting VSCONN = 3V0. Refer to *Settings for Voltage Input Configuration* on page 9.18.

Setting ELOP = Y

Additionally, if setting ELOP = Y and a loss-of-potential condition occurs (Relay Word bit LOP asserts to logical 1), overcurrent elements set direction forward are enabled, except as discussed in NOTE 2 (see *Figure 4.20*, *Figure 4.21*, and *Figure 4.27*). These direction forward overcurrent elements effectively become nondirectional and provide overcurrent protection during a loss-of-potential condition.

As detailed previously, voltage-based directional elements are disabled during a loss-of-potential condition. Thus, the overcurrent elements controlled by these voltage-based directional elements are also disabled. However, this disable condition is overridden for the overcurrent elements set direction forward if setting ELOP = Y.

> NOTE 2: When Global setting VSCONN = 3V0, the ground-directional elements that rely on zero-sequence voltage quantities (ORDER settings V, S, P, and U) are not affected by a loss-of-potential condition on relay inputs **VA**, **VB**, and **VC**, because these elements use the $3V_0$ zero-sequence voltage that comes directly from voltage input **VS**, rather than the zero-sequence voltage calculated from voltage inputs **VA**, **VB**, and **VC** (wye-connected PTs). Therefore, even if LOP is asserted and setting ELOP = Y when Relay Word bit 3V0 is asserted (= logical 1), the relay will not force an enable of ground elements set direction forward when one of the zero-sequence voltage-polarized ground directional element enables (32VE or 32NE) is asserted. This difference is shown in *Figure 4.20* and *Figure 4.21*, where Relay Word bit 3V0 is

combined with Relay Word bits 32NE and 32VE to create a block signal for the loss-of-potential signal. Refer to *Settings for Voltage Input Configuration* on page 9.18.

Setting ELOP = N

If setting ELOP = N, the loss-of-potential logic still operates (Relay Word bit LOP asserts to logical 1 for a loss-of-potential condition) but does not disable any voltage-based directional elements (as occurs with ELOP = Y or Y1) or enable overcurrent elements set direction forward (as occurs with ELOP = Y).

SELOGIC Setting LOPBLK

The loss-of-potential logic detects changes in positive- and zero-sequence current magnitude and angle to differentiate actual loss-of-potential conditions from voltage changes because of faults. This logic prevents Relay Word bit LOP from asserting during the majority of faults. Program SELOGIC control equation LOPBLK with fault-detecting elements to provide additional security during faults. Use the Level 5 or Level 6 instantaneous overcurrent elements (50P5, 50P6, 50Q5, 50Q6, 50G5, 50G6, 50N5, or 50N6) to ensure that the blocking elements are processed before the LOP logic (see *Appendix F: Setting SELOGIC Control Equations*).

When LOPBLK is asserted, a change in voltage cannot cause LOP to newly assert. However, if LOP was already asserted and had been asserted for at least 15 cycles when LOPBLK asserts, the loss-of-potential condition is latched (LOP3 = logical 1) and LOP remains asserted regardless of the state of equation LOPBLK.

Consider using LOPBLK when positive-sequence current may be low during a fault, such as when the relay is protecting a grounded-wye transformer winding or other source of zero-sequence current. To ensure that LOP asserts during an actual loss-of-potential condition, set blocking elements such that LOPBLK cannot assert because of load.

Using LOP to Supervise Undervoltage Elements

The LOP logic is intended to supervise directional and load-encroachment elements. Exercise caution when using the Loss-of-Potential logic to supervise undervoltage elements. Under certain low load conditions, undervoltage can cause LOP to assert and block undervoltage elements unexpectedly. If it is necessary to use Relay Word bit LOP to supervise an undervoltage element (27A1, for example) when positive-sequence secondary current may be less than 0.05 • Phase Channel Nominal Rating, consider using logic similar to the following:

... + 27A1 * (!LOP + !50P32) + ...

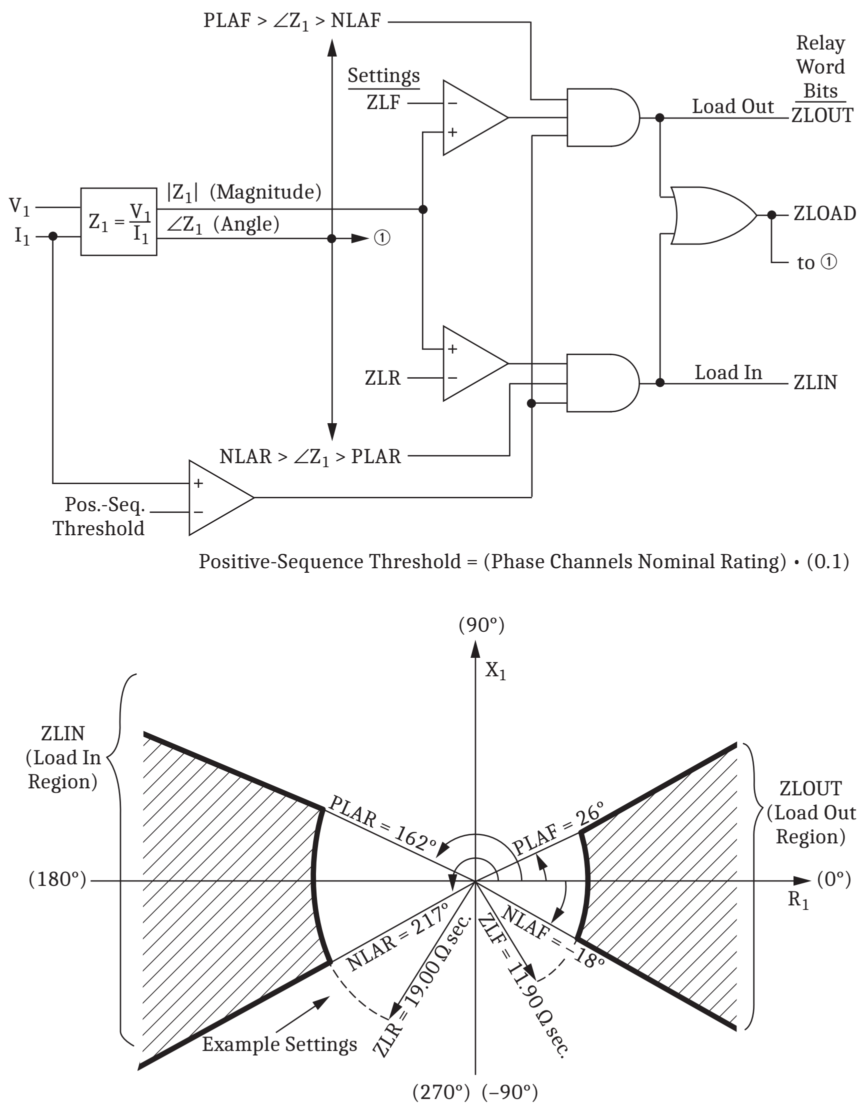
where 50P32P = 0.1 • Phase Channel Nominal Rating (the minimum setting). With this logic, if all three phase-to-phase currents are less than 50P32P • $\sqrt{3}$ A when a loss of voltage occurs, Relay Word bit LOP may assert, but Relay Word bit 50P32 will be deasserted and the undervoltage trip will be allowed. Keep in mind that if a true Loss-of-Potential event occurs because of a blown fuse when the current is less than 50P32P amperes, the undervoltage element will not be blocked. Note that E32 must be set to Y or AUTO to set 50P32P. If 50P32P must be set to a different value for directional element security, a phase overcurrent element can be used as a current detector.

Load-Encroachment Logic

NOTE: When Global setting PTCONN = SINGLE, the ELOAD setting is hidden and internally set to N.

The load-encroachment logic (see *Figure 4.6*) and settings are enabled/disabled with setting ELOAD. If Group setting VNOM = OFF, then ELOAD can only be set to “N.” See *Potential Transformer Ratios and PT Nominal Secondary Voltage Settings* on page 9.22 for more details on the VNOM setting.

The load-encroachment feature allows phase overcurrent elements to be set without regard for load levels. This is especially helpful in bus overcurrent applications. A bus relay sees the cumulative currents of all the feeders but still has to provide overcurrent backup protection for all these feeders. If the phase elements in the bus relay are set to provide adequate backup, they often are set close to maximum bus load current levels. This runs the risk of tripping on bus load current. The load-encroachment feature prevents this from happening as shown in the example that follows in this subsection.



① To *Figure 4.26*.

Figure 4.6 Load-Encroachment Logic

Note that a positive-sequence impedance calculation (Z_1) is made in the load-encroachment logic in *Figure 4.6*. Load is largely a balanced condition; so apparent positive-sequence impedance is a good load measure. The load-encroachment logic only operates if the positive-sequence current (I_1) is greater than the Positive-Sequence Threshold defined in *Figure 4.6*. For a balanced load condition, I_1 = phase current magnitude.

Forward load (load flowing out) lies within the hatched region labeled ZLOUT. Relay Word bit ZLOUT asserts to logical 1 when the load lies within this hatched region.

Reverse load (load flowing in) lies within the hatched region labeled ZLIN. Relay Word bit ZLIN asserts to logical 1 when the load lies within this hatched region.

Relay Word bit ZLOAD is the OR-combination of ZLOUT and ZLIN:

ZLOAD = **ZLOUT + ZLIN**

Settings Ranges

Refer to *Figure 4.6*.

Table 4.3 Load-Encroachment Settings Ranges

Setting	Description and Range
ZLF	Forward Minimum Load Impedance—corresponding to maximum load flowing out
ZLR	Reverse Minimum Load Impedance—corresponding to maximum load flowing in
	0.09–128.00 Ω secondary (5 A nominal phase current inputs, IA, IB, IC)
	0.45–640.00 Ω secondary (1 A nominal phase current inputs, IA, IB, IC)
PLAF	Maximum Positive Load Angle Forward (–90° to +90°)
NLAF	Maximum Negative Load Angle Forward (–90° to +90°)
PLAR	Maximum Positive Load Angle Reverse (+90° to +270°)
NLAR	Maximum Negative Load Angle Reverse (+90° to +270°)

Load-Encroachment Setting Example

Example system conditions:

Nominal Line-to-Line Voltage:	230 kV
Maximum Forward Load:	800 MVA
Maximum Reverse Load:	500 MVA
Power Factor (Forward Load):	0.90 lag to 0.95 lead
Power Factor (Reverse Load):	0.80 lag to 0.95 lead
CT ratio:	2000/5 = 400
PT ratio:	134000/67 = 2000

The PTs are connected line-to-neutral.

Convert Maximum Loads to Equivalent Secondary Impedances

Start with maximum forward load:

800 MVA • (1/3)	267 MVA per phase
230 kV • (1/√ 3) =	132.8 kV line-to-neutral
267 MVA • (1/132.8 kV) • (1000kV/MV) =	2010 A primary
2010 A primary • (1/CT ratio) =	2010 A primary • (1 A secondary/400 A primary)
=	5.03 A secondary
132.8 kV • (1000 V/kV) =	132800 V primary
132800 V primary • (1/PT ratio) =	132800 V primary • (1 V secondary/2000 V primary)
=	66.4 V secondary

Now, calculate the equivalent secondary impedance:

$$\frac{66.4 \text{ V secondary}}{5.03 \text{ A secondary}} = 13.2\ \Omega \text{ secondary}$$

This secondary value can be calculated more expediently with the following equation:

$$\frac{(\text{line-line voltage in kV})^2 \bullet \text{ CT ratio}}{\text{3-phase load in MVA} \bullet \text{ PT ratio}}$$

Again, for the maximum forward load:

$$\frac{230^2 \bullet 400}{800 \bullet 2000} = 13.2\ \Omega \text{ secondary}$$

To provide a margin for setting ZLF, multiply by a factor of 0.9:

$$\begin{aligned} \text{ZLF} &= 13.2\ \Omega \text{ secondary} \bullet 0.9 \\ &= 11.90\ \Omega \text{ secondary} \end{aligned}$$

For the maximum reverse load:

$$\frac{230^2 \bullet 400}{500 \bullet 2000} = 21.1\ \Omega \text{ secondary}$$

Again, to provide a margin for setting ZLR:

$$\begin{aligned} \text{ZLR} &= 21.1 \text{ secondary} \bullet 0.9 \\ &= 19.00\ \Omega \text{ secondary} \end{aligned}$$

Convert Power Factors to Equivalent Load Angles

The power factor (forward load) can vary from 0.90 lag to 0.95 lead.

Setting PLAF = $\cos^{-1}$ (0.90) = 26°

Setting NLAF = $\cos^{-1}$ (0.95) = –18°

The power factor (reverse load) can vary from 0.80 lag to 0.95 lead.

Setting PLAR = 180° – $\cos^{-1}$ (0.95) = 180° – 18° = 162°

Setting NLAR = 180° + $\cos^{-1}$ (0.80) = 180° + 37° = 217°

Apply Load-Encroachment Logic to a Nondirectional Phase Time-Overcurrent

Again, from *Figure 4.6*:

ZLOAD = **ZLOUT + ZLIN**

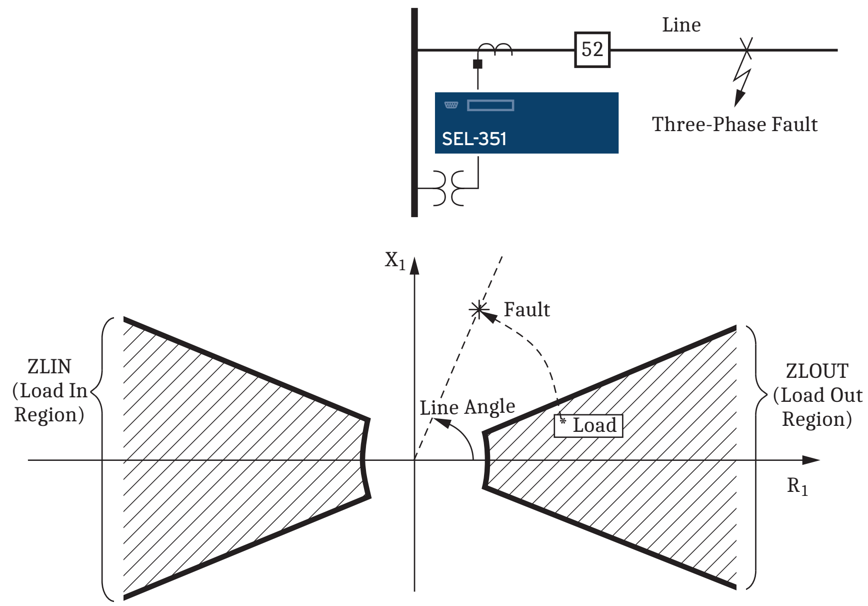


Figure 4.7 Migration of Apparent Positive-Sequence Impedance for a Fault Condition

Refer to *Figure 4.7*. In a load condition, the apparent positive-sequence impedance is *within* the ZLOUT area, resulting in:

ZLOAD = **ZLOUT + ZLIN** = logical 1 + ZLIN = logical 1

If a fault occurs, the apparent positive-sequence impedance moves *outside* the ZLOUT area (and stays outside the ZLIN area, too), resulting in:

ZLOAD = **ZLOUT + ZLIN** = logical 0 + logical 0 = logical 0

Load Encroachment for Directionally Controlled Elements

Embedded logic handles load-encroachment concerns for directional phase overcurrent elements. Directional control for phase overcurrent elements comes from *Figure 4.29*, which refers back to *Figure 4.27*, which in turn refers back to *Figure 4.25* and *Figure 4.26*. In *Figure 4.26*, notice that the “!ZLOAD” condition is embedded in the positive-sequence voltage-polarized directional element logic. This logic prevents a directional overcurrent element from operating when the measured positive-sequence impedance is within the Load In or Load Out regions.

Load Encroachment for Nondirectional Elements

It is possible to use SELOGIC control equation torque-control settings to apply load-encroachment supervision for nondirectional overcurrent elements. However, keep in mind that load encroachment is not a valid representation of the positive-sequence impedance during unbalanced faults, and ZLOAD may assert during certain unbalanced faults. This means that a torque-control equation intended to prevent operation of a phase overcurrent element for load conditions may also prevent operation of the element for unbalanced faults. Therefore, when using load encroachment to control phase overcurrent elements, residual or neutral-ground overcurrent elements must be used to detect phase-ground faults. Similarly negative-sequence overcurrent elements must be used to detect phase-to-phase faults (see *Appendix G: Setting Negative-Sequence Overcurrent Elements*). These phase-ground and phase-to-phase elements must be at least as sensitive as the phase overcurrent elements.

Example 1

If it is acceptable for the phase overcurrent element to operate for some unbalanced fault conditions, refer to *Figure 3.14* and make the following SELOGIC control equation torque-control setting:

51PTC = **!ZLOAD * !LOP + 50P6** (= NOT[ZLOAD] * NOT[LOP] + 50P6)

As shown in *Figure 4.6*, load-encroachment logic is a positive-sequence calculation. During LOP conditions (loss-of-potential; see *Figure 4.1*), positive-sequence voltage (V_1) can be substantially depressed in magnitude or changed in angle. This change in V_1 can possibly cause ZLOAD to deassert (= logical 0), erroneously indicating that a “fault condition” exists. Thus, !ZLOAD should be supervised by !LOP in a torque-control setting. This also effectively happens in the directional element in *Figure 4.26*, where ZLOAD and LOP are part of the logic.

In the above setting example, phase instantaneous overcurrent element 50P6 is set above any maximum load current level—if 50P6 picks up, there is assuredly a fault. For faults below the pickup level of 50P6, but above the pickup of phase time-overcurrent element 51PT, the !ZLOAD * !LOP logic discriminates between high load and fault current. If an LOP condition occurs (LOP = logical 1), the pickup level of 50P6 becomes the effective pickup of phase time-overcurrent element 51PT. In other words, 51PT loses its sensitivity when an LOP condition occurs:

51PTC = **!ZLOAD * !LOP + 50P6** = !ZLOAD * NOT[LOP] + 50P6 = !ZLOAD * NOT[logical 1] + 50P6 = 50P6

Example 2

If it is *not* acceptable for the phase-overcurrent element to operate for any unbalanced fault current less than 50P6P or for load conditions, enable load encroachment, refer to *Figure 3.14*, and make the following SELOGIC control equation torque-control setting:

51PTC = **F32P + R32P + 50P6**

This uses the directional control logic (*Figure 4.26*) to cause the phase-overcurrent element to be sensitive only to three-phase fault conditions. Residual or neutral ground-overcurrent elements must be used to detect phase-ground faults, and negative-sequence overcurrent elements must be used to detect phase-to-phase faults (see *Appendix G: Setting Negative-Sequence Overcurrent Elements*). These phase-ground and phase-to-phase elements must be at least as sensitive as the phase-overcurrent elements.

Because the directional control logic is defeated when a Loss-of-Potential occurs, phase instantaneous overcurrent element 50P6 is set above any maximum load current level—if 50P6 picks up, there is assuredly a fault. If a LOP condition occurs (LOP = logical 1), the pickup level of 50P6 becomes the effective pickup of phase time-overcurrent element 51PT. In other words, 51PT loses its sensitivity when an LOP condition occurs.

The directional elements must be enabled by setting E32 to Y or AUTO. See *Directional Control Settings* on page 4.43 for a discussion of other settings that may be necessary for directional control to function properly.

See SEL Application Guide *AG2005-07, Guidelines for Applying Load-Encroachment Element for Overcurrent Supervision*, available on the SEL website, for more information.

If phase time-overcurrent element 51PT is used in a directional application, then this special torque-control logic is not used and the corresponding torque-control setting is set directly to logical 1 (51PT = 1), unless additional control is desired.

Use SEL-321 Relay Application Guide for the SEL-351 Relay

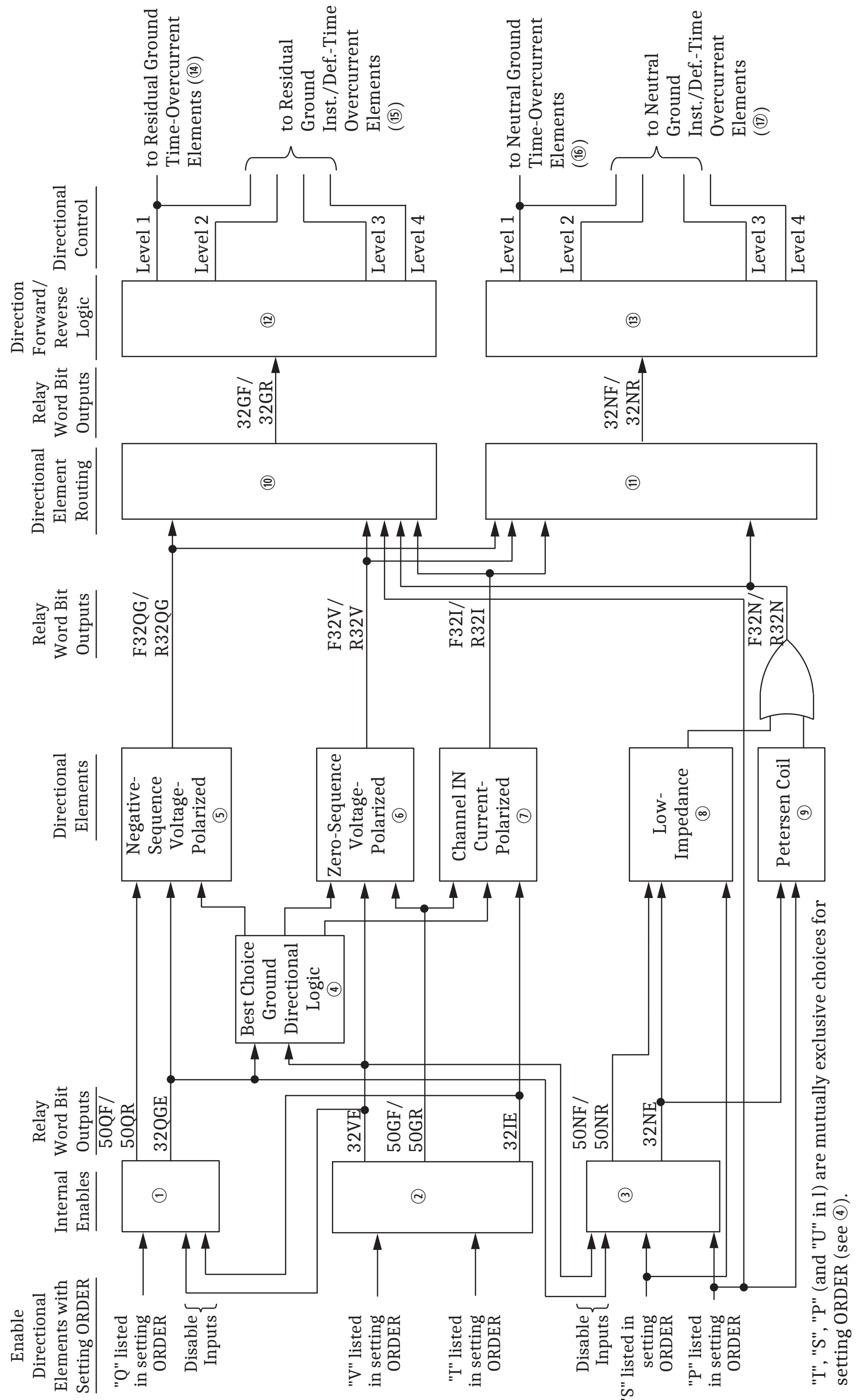
The load-encroachment logic and settings in the SEL-351 are the same as those in the SEL-321. Refer to SEL Application Guide *AG93-10, SEL-321 Relay Load-Encroachment Function Setting Guidelines* for applying the load-encroachment logic in the SEL-351. Note that Application Guide AG93-10 discusses applying the load-encroachment feature to phase distance elements in the SEL-321. The SEL-351 does not have phase distance elements, but the principles and settings example are still applicable to the SEL-351.

Directional Control for Neutral-Ground and Residual-Ground Overcurrent Elements

The directional control for overcurrent elements is enabled by making directional control enable setting E32. Setting E32 and other directional control settings are described in *Directional Control Settings* on page 4.43.

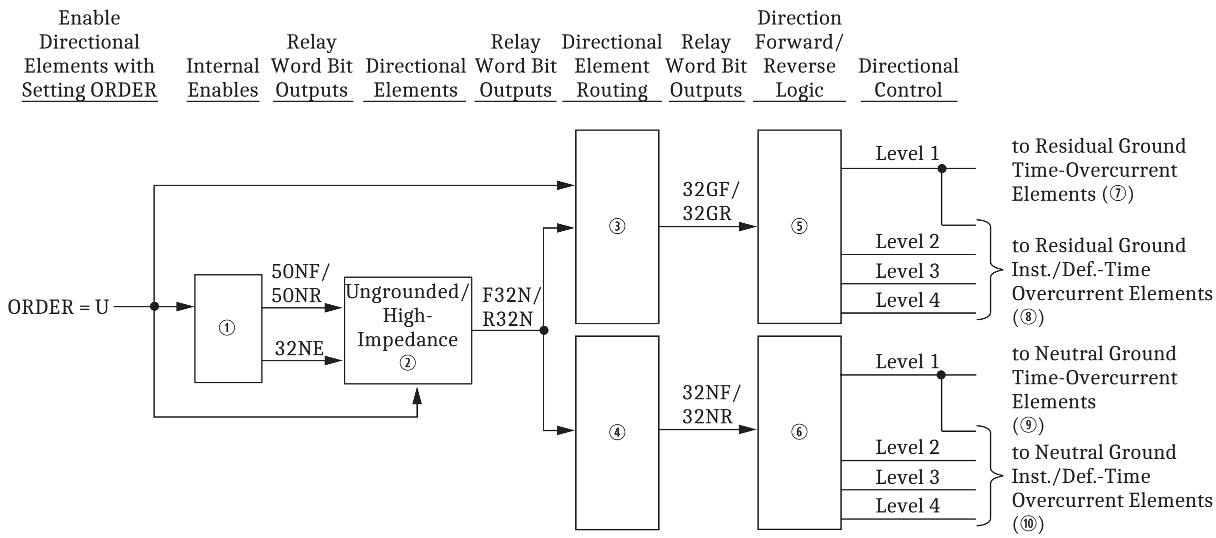
Six directional elements are available to control the neutral ground and residual ground overcurrent elements. Not all are available simultaneously. These six directional elements are:

- Negative-sequence voltage-polarized directional element
- Zero-sequence voltage-polarized directional element
- Channel IN current-polarized directional element
- Zero-sequence voltage-polarized directional element (low-impedance grounded system)
- Wattmetric and incremental conductance directional elements (Petersen Coil-grounded system)
- Zero-sequence voltage-polarized directional element (ungrounded/high-impedance grounded system)



① *Figure 4.11*. ② *Figure 4.12*. ③ *Figure 4.13*. ④ *Table 4.4* and *Table 4.5*. ⑤ *Figure 4.14*. ⑥ *Figure 4.15*. ⑦ *Figure 4.16*. ⑧ *Figure 4.17*. ⑨ *Figure 4.18*. ⑩ *Figure 4.20*. ⑪ *Figure 4.21*. ⑫ *Figure 4.22*. ⑬ *Figure 4.23*. ⑭ *Figure 3.19*. ⑮ *Figure 3.10*. ⑯ *Figure 3.18*. ⑰ *Figure 3.8*. ⑱ *Figure 4.9*.

Figure 4.8 General Logic Flow of Directional Control for Neutral Ground and Residual Ground Overcurrent Elements (Excluding Ungrounded/High-Impedance Grounded Systems)



① *Figure 4.13*. ② *Figure 4.19*. ③ *Figure 4.20*. ④ *Figure 4.21*. ⑤ *Figure 4.22*. ⑥ *Figure 4.23*. ⑦ *Figure 3.19*. ⑧ *Figure 3.10*. ⑨ *Figure 3.18*. ⑩ *Figure 3.8*.

Figure 4.9 General Logic Flow of Directional Control for Neutral Ground and Residual Ground Overcurrent Elements (Ungrounded/High-Impedance Grounded Systems; ORDER = U)

Table 4.4 Available Ground Directional Elements

ORDER Setting Choices	Corresponding Ground Directional Element (and System Grounding)	Corresponding Internal Enables (and System Grounding)	Corresponding Figures	Availability
Q	Negative-sequence voltage-polarized	32QGE	*Figure 4.11*, *Figure 4.14*	All models (not dependent on neutral channel [IN])
V	Zero-sequence voltage-polarized	32VE	*Figure 4.12*, *Figure 4.15*	
I	Channel IN current-polarized	32IE	*Figure 2.18*, *Figure 4.12*, *Figure 4.16*	Models with a 1 A or 5 A nominal neutral channel (IN)
S[a]	Zero-sequence voltage-polarized (Low-impedance)	32NE (Low-impedance)	*Figure 2.23*, *Figure 4.13*, *Figure 4.17*	Models with a 0.2 A nominal neutral channel (IN)
P[a]	Wattmetric and incremental conductance (Petersen Coil)	32NE (Petersen Coil)	*Figure 2.24*, *Figure 4.13*, *Figure 4.18*	
U[a]	Zero-sequence voltage-polarized (Ungrounded/ High-Impedance)	32NE (Ungrounded/ High-Impedance)	*Figure 2.23*, *Figure 2.25*, *Figure 2.26*, *Figure 4.13*, *Figure 4.19*	

[a] S, P, and U are mutually exclusive—they cannot be listed together in the ORDER setting.

NOTE: The neutral channel (IN) can also be ordered as a 0.05 A nominal neutral channel. This neutral channel provides no special directional element options, unlike those listed above. The 0.05 A nominal neutral channel is a legacy nondirectional sensitive earth fault (SEF) option (a 0.2 A nominal neutral channel can provide the same SEF function and more). See *Figure 3.8*, *Figure 3.9*, and *Figure 3.18* and accompanying setting ranges explanation.

Table 4.5 Best Choice Ground Directional Element Logic

ORDER Setting Combinations	Resultant ground directional element preference (indicated below with corresponding internal enables; run element that corresponds to highest choice internal enable that is asserted; system grounding in parentheses)			ORDER Setting Combination Availability
	1st Choice	2nd Choice	3rd Choice	
OFF	No ground directional elements enabled			All models (not dependent on neutral channel [IN])
Q	32QGE			
QV	32QGE	32VE		
V	32VE			
VQ	32VE	32QGE		
I	32IE			Additional setting combinations for models with a 1 A or 5 A nominal neutral channel (IN)
IQ	32IE	32QGE		
IQV	32IE	32QGE	32VE	
IV	32IE	32VE		
IVQ	32IE	32VE	32QGE	
QI	32QGE	32IE		
QIV	32QGE	32IE	32VE	
QVI	32QGE	32VE	32IE	
VI	32VE	32IE		
VIQ	32VE	32IE	32QGE	
VQI	32VE	32QGE	32IE	
VS	32VE	32NE (Low-impedance)		Additional setting combinations for models with a 0.2 A nominal neutral channel (IN)[a]
VQS	32VE	32QGE	32NE (Low-impedance)	
QVS	32QGE	32VE	32NE (Low-impedance)	
P	32NE (Petersen Coil)			
QP	32QGE	32NE (Petersen Coil)		
QVP	32QGE	32VE	32NE (Petersen Coil)	
VP	32VE	32NE (Petersen Coil)		
VQP	32VE	32QGE	32NE (Petersen Coil)	
U	32NE (Ungrounded/High-Impedance)			

[a] S, P, and U are mutually exclusive and are the last (or only) listed choice for the order setting.

Table 4.6 Ground Directional Element Availability by Voltage Connection Settings

Element Designation in ORDER Setting	Availability[a] When VNOM ≠ OFF VSCONN = VS		Availability[a] When VNOM ≠ OFF VSCONN = 3V0	Availability[a] When VNOM = OFF VSCONN = VS	Availability[a] When VNOM = OFF VSCONN = 3V0
	PTCONN = WYE	PTCONN = DELTA	PTCONN = WYE or PTCONN = DELTA	PTCONN = WYE, PTCONN = DELTA, or PTCONN = SINGLE	PTCONN = WYE, PTCONN = DELTA, or PTCONN = SINGLE
Q	Yes	Yes	Yes	No[b]	No[b]
V	Yes	No	Yes	No[b]	Yes
I	Yes	Yes	Yes	Yes	Yes
S	Yes	No	Yes	No[b]	Yes
P	Yes	No	Yes	No[b]	Yes
U	Yes	No	Yes	No[b]	Yes

[a] Subject to availability of elements by relay model shown in *Table 4.4* and *Table 4.5*.

[b] The displayed setting range for the ORDER setting may show these element choices, but the relay will not accept these choices when a settings save is attempted.

NOTE: If Global setting PTCONN = SINGLE, setting VNOM is set to OFF.

Figure 4.8 and *Figure 4.9* give an overview of how these directional elements are enabled and routed to control the neutral ground and residual ground overcurrent elements.

Note in *Figure 4.8* and *Figure 4.9* that setting ORDER enables the directional elements. Setting ORDER can be set with the elements listed and defined in *Table 4.4*, subject to the setting combination constraints in *Table 4.5*. Note that *Table 4.4* and *Table 4.5* also list the directional element availability, per model (according to the neutral channel [IN] rating).

NOTE: When Global settings PTCONN = SINGLE and VSCONN = 3V0, E32 cannot be set to AUTO.

Table 4.6 details the availability of the ground directional elements for the various combinations of the PTCONN, VSCONN, and VNOM settings. Make the E32 setting when Global setting PTCONN = WYE or DELTA, when PTCONN = SINGLE and the relay has a 1 A or 5 A nominal neutral rating, or when PTCONN = SINGLE and VSCONN = 3V0. If none of the ground directional elements are available (per *Table 4.4* through *Table 4.6*), group setting E32 (directional control enable) can only be set to N. Refer to *Settings for Voltage Input Configuration* on page 9.18 for information on these settings.

NOTE: When VNOM = OFF, Global setting VSCONN = VS and the relay has a 0.2 A or 0.05 A nominal neutral rating, E32 can only be set to N.

Also, note that *Table 4.4* through *Table 4.6* (and lower left-hand corner of *Figure 4.8*) detail the mutual exclusivity of ORDER setting choices I, S, P, and U. If particular directional elements are not available (because of model type) or are not listed in setting ORDER, these elements are *defeated* and *nonoperational*.

For example, suppose that setting choice S is listed in setting ORDER. By virtue of not being available or not being listed in setting ORDER, the directional elements corresponding to setting choices I, P, and U (see *Table 4.4*, *Figure 4.8*, and *Figure 4.9*) are *defeated* and *nonoperational*. So, for nonavailable setting choice I, corresponding internal enable 32IE = logical 0 and directional outputs F32I = logical 0 and R32I = logical 0. Similarly, for the directional elements corresponding to nonlisted setting choices P and U, the logic outputs are at a logical 0 state.

The order in which these directional elements are listed in setting ORDER determines the priority in which they operate to provide Best Choice Ground Directional Element logic control. See the discussion on setting ORDER in *Directional Control Settings* on page 4.43.

Internal Enables

Refer to *Figure 4.8*, *Figure 4.9*, *Figure 4.11*, *Figure 4.12*, and *Figure 4.13*.

Table 4.4 lists the internal enables and their correspondence to the ground directional elements.

Note that *Figure 4.11* has extra internal enable 32QE, which is used in the directional element logic that controls negative-sequence and phase overcurrent elements (see *Figure 4.24*).

Also, note that if enable setting ELOP = Y or Y1 and a loss-of-potential condition occurs (Relay Word bit LOP asserts), all the internal directional enables (except for 32IE) are disabled (see *Figure 4.11*, *Figure 4.12*, and *Figure 4.13*), unless VSCONN = 3V0. In that case, the directional element enables in *Figure 4.12* and *Figure 4.13* are not affected by LOP. This is explained in *Loss-of-Potential Logic* on page 4.1.

The channel IN current-polarized directional element (with corresponding internal enable 32IE; *Figure 4.12*) does not use voltage in making direction decisions, thus a loss-of-potential condition does not disable the element. Refer to *Figure 4.1* and accompanying text for more information on loss-of-potential.

The settings involved with the internal enables (e.g., settings a2, k2, a0, a0N) are explained in *Directional Control Settings* on page 4.43.

Switch Between I_N and I_G for Low-Impedance Grounded and Ungrounded/High-Impedance Grounded Systems

If an ungrounded or high-impedance grounded system (setting ORDER = U) has appreciable circuit length, the capacitance levels can be such that appreciable current flows for a ground fault. A low-impedance grounded system (setting ORDER contains S) can also have appreciable current flow for a ground fault.

The 0.2 A nominal neutral channel (**IN**) can discriminate to as much as 5 A secondary. Under certain conditions, the logic in *Figure 4.13* (and *Figure 4.17* and *Figure 4.19*) switches from monitoring neutral channel current I_N to monitoring residual ground current I_G. Residual ground current I_G is derived internally from phase current channels **IA**, **IB**, and **IC**; I_G is effectively $3I_0$ and has a much higher upper range than neutral channel current I_N. As shown in *Figure 4.10*, the relay uses the settings CTR and CTRN, along with the magnitudes of I_G and I_N, to determine when current I_N might exceed 5 A. When such a condition is detected, the relay switches to I_G. The switching logic is designed such that the switch may occur when neutral current is less than 5 A.

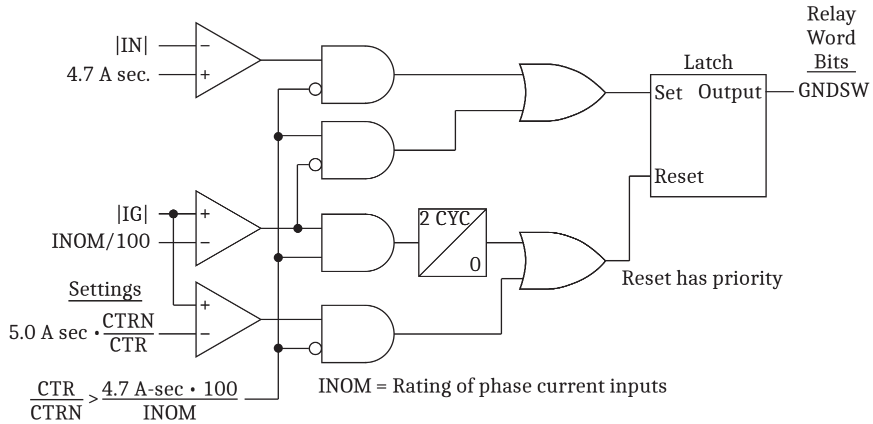


Figure 4.10 Logic for Relay Word bit GNDSW

Relay Word bit GNDSW indicates whether the directional element for low-impedance grounded or ungrounded/high-impedance grounded systems is operating on neutral channel (**IN**) current I_N (GNDSW = logical 1) or on residual ground current I_G instead (GNDSW = logical 0).

Of course, this switching of currents (from I_N to I_G) requires the 50NFP/50NRP settings (based on current I_N) in the *Figure 4.13* logic to be effectively changed to the new I_G base. This is done internally with CT ratio settings:

50NFP • CTRN/CTR (I_G base)

50NRP • CTRN/CTR (I_G base)

If the logic in *Figure 4.13* (and *Figure 4.17* and *Figure 4.19*) operates on neutral current I_N, then settings 50NFP and 50NRP are not adjusted, and just operate as:

50NFP (I_N base)

50NRP (I_N base)

This transition is "seamless" if the lower detection threshold of the residual ground current I_G (0.05 A secondary for 5 A nominal phase; 0.01 A secondary for 1 A nominal) effectively overlaps with the upper detection threshold of neutral channel current I_N (5 A secondary):

CTR/CTRN ≤ (5 A/0.05 A) = 100 (5 A nominal phase inputs)

CTR/CTRN ≤ (5 A/0.01 A) = 500 (1 A nominal phase inputs)

There is no effective overlap if:

CTR/CTRN > 100 (5 A nominal phase inputs)

CTR/CTRN > 500 (1 A nominal phase inputs)

With no effective overlap, when the neutral channel current I_N exceeds the upper detection threshold of neutral channel IN (5 A secondary), the unit still operates on the neutral channel current I_N until the lower detection threshold of the residual ground current I_G (0.05 A secondary for 5 A nominal phase; 0.01 A secondary for 1 A nominal) is reached. It is better to have effective overlap:

CTR/CTRN ≤ 100 (5 A nominal phase inputs)

CTR/CTRN ≤ 500 (1 A nominal phase inputs)

This I_N to I_G (or I_G to I_N) current switching discussed for *Figure 4.13* (and *Figure 4.17* and *Figure 4.19*) also has an effect on zero-sequence impedance settings Z0F and Z0R (see *Figure 4.17* and *Figure 4.19*). Z0F and Z0R (Ω secondary) are set in reference to the phase current inputs (**IA**, **IB**, and **IC**; residual current I_G is derived internally from these phase currents). However, settings Z0F and Z0R are applied to *Figure 4.17* and *Figure 4.19*, where neutral current I_N (from neutral current channel IN) is also applied when GNDSW is asserted. Settings Z0F and Z0R are adjusted internally (with CT ratio settings) to operate on this I_N current base:

Z0F • CTRN/CTR (I_N base)

Z0R • CTRN/CTR (I_N base)

If the logic in *Figure 4.13* (and *Figure 4.17*, and *Figure 4.19*) operates on residual current I_G, as a result of current switching, then settings Z0F and Z0R are not adjusted, and just operate as:

Z0F (I_G base)

Z0R (I_G base)

Zero-Sequence Voltage Sources

The directional elements that rely on zero-sequence voltage $3V_0$ (ORDER setting choices “V,” “S,” “P,” and “U,” shown in *Figure 4.15* and *Figure 4.17* through *Figure 4.19*) may use either a calculated $3V_0$ from the wye-connected voltages V_A, V_B, and V_C, or a measured $3V_0$ from the VS channel, which is typically connected to a broken-delta PT secondary. The Global setting VSCONN selects the zero-sequence voltage source to be used by the affected directional elements.

When VSCONN = 3V0, the measured voltage on terminals **VS-NS** is scaled by the ratio of Group settings PTRS/PTR to convert it to the same voltage base as the **VA**, **VB**, and **VC** terminals, and the resulting signal is applied to the directional element “$3V_0$” inputs.

When VSCONN = VS, the calculated zero-sequence voltage from terminals **VA**, **VB**, and **VC** is applied to the directional element “$3V_0$” inputs, provided that the relay is connected to wye-connected PTs (Global setting PTCONN = WYE). If the relay is connected to open-delta PTs (Global setting PTCONN = DELTA), $3V_0$ cannot be calculated from the **VA**, **VB**, and **VC** terminals, and the directional elements that require zero-sequence voltage are unavailable.

When testing the relay, it is important to note that the **METER** command 3V0 quantity, when available, is always the calculated value from the wye-connected PT inputs, even when VSCONN = 3V0. The **METER** command VS quantity is always the measured value from the **VS-NS** terminals.

See *Broken-Delta VS Connection (Global Setting VSCONN = 3V0)* on page 2.13, and *Settings for Voltage Input Configuration* on page 9.18.

Best Choice Ground Directional Element Logic

The Best Choice Ground Directional Element logic determines which directional element should be enabled to operate. The neutral ground and residual ground overcurrent elements set for directional control are then controlled by this enabled directional element.

Table 4.5 is the embodiment of the Best Choice Ground Directional Element logic. Note in *Table 4.5* that any of the directional elements corresponding to S, P, or U that operate on 0.2 A nominal neutral channel (IN) are listed last (or by themselves) in any of the available setting combinations for the ORDER setting.

This is because preference is given to selected directional elements that operate off of bigger signals (i.e., directional elements corresponding to Q and V). Setting choice "I" cannot be listed with S, P, or U.

Figure 4.8 shows no control emanating from the Best Choice Ground Directional Element logic to the directional elements corresponding to S or P (*Figure 4.17*, and *Figure 4.18*, respectively). This Best Choice Ground Directional Element logic for the directional elements corresponding to S or P is effectively handled with the "disable inputs" (internal enables 32QGE and 32VE) running into the internal enable logic of *Figure 4.13*. If neither 32QGE nor 32VE are asserted (and thus their corresponding directional elements are not enabled), then the internal enable logic of *Figure 4.13* is free to run for the last directional element selected in setting ORDER (if S or P is the last element listed in setting ORDER).

Setting choice U (ungrounded/high-impedance grounded) can only be listed by itself (ORDER = U), so Best Choice Ground Directional Element logic is irrelevant in this case just as it is also irrelevant when Q, V, I, or P are listed by themselves in setting ORDER.

Directional Elements

Refer to *Figure 4.8*, *Figure 4.9*, and *Figure 4.14* through *Figure 4.19*.

The Best Choice Ground Directional Element logic in *Table 4.5* determines which directional element will run.

Note in *Figure 4.18* that the incremental conductance directional element outputs F32C/R32C do not propagate to directional outputs F32N/R32N, respectively, as do the wattmetric directional element outputs F32W/R32W. Incremental conductance elements are used more for alarming purposes than for controlling overcurrent elements for tripping. Incremental conductance elements provide more sensitivity for detecting high-resistance faults on Petersen Coil-grounded systems (as compared to the wattmetric elements). For more information on the operation and application of incremental conductance elements for Petersen Coil- (resonant) grounded systems, see the paper: "Review of Ground Fault Protection Methods for Grounded, Ungrounded, and Compensated Distribution System," by Jeff Roberts, Hector Altuve, and Daqing Hou, presented at the 28th Annual Western Protective Relay Conference, Spokane, Washington, October 22–24, 2001.

Directional Element Routing

Refer to *Figure 4.8*, *Figure 4.9*, *Figure 4.20*, and *Figure 4.21*.

The directional element outputs are routed to the forward (Relay Word bits 32GF and 32NF) and reverse (Relay Word bits 32GR and 32NR) logic points and then on to the direction forward/reverse logic in *Figure 4.22* and *Figure 4.23*.

Loss of Potential

Note if *all* the following are true:

- Enable setting ELOP = Y,
- Global setting VSCONN = VS,
- A loss-of-potential condition occurs (Relay Word bit LOP asserts),
- And internal enable 32IE (for channel IN current-polarized directional element) is not asserted

then the forward logic point (Relay Word bit 32GF in *Figure 4.20* and 32NF in *Figure 4.21*) asserts to logical 1, thus, enabling the residual ground (*Figure 4.22*) and neutral ground (*Figure 4.23*) overcurrent elements that are set direction forward (with settings DIR1 = F, DIR2 = F, etc.). These direction forward overcurrent elements effectively become nondirectional and provide overcurrent protection during a loss-of-potential condition.

If Global setting VSCONN = 3V0 and Group setting ELOP = Y, the LOP condition will not cause the forward directional outputs to assert when either directional element enable 32VE or 32NE is asserted, as shown at the top of *Figure 4.20* and *Figure 4.21*. In this situation, the elements that are enabled by signals 32VE and 32NE are still able to operate reliably during a loss-of-potential condition, so there is no need to force the forward outputs to assert. However, when 32VE or 32NE are not asserted, a standing LOP condition will force the forward outputs to assert continuously. Consider this when determining residual- and neutral-ground overcurrent element pickup settings and time delay settings, so that “load conditions” do not cause a forward-set ground directional overcurrent element to pick up and start timing.

As detailed previously in *Internal Enables* on page 4.19, some or all of the voltage-based directional elements are disabled during a loss-of-potential condition. Thus, the overcurrent elements controlled by these voltage-based directional elements are also disabled. However, this disable condition is overridden for these overcurrent elements set direction forward if setting ELOP = Y.

Refer to *Figure 4.1* and accompanying text for more information on loss-of-potential.

Direction Forward/Reverse Logic

Refer to *Figure 4.8*, *Figure 4.9*, *Figure 4.22*, and *Figure 4.23*.

The forward (Relay Word bit 32GF in *Figure 4.22* and 32NF in *Figure 4.23*) and reverse (Relay Word bit 32GR in *Figure 4.22* and 32NR in *Figure 4.23*) logic points are routed to the different levels of overcurrent protection by the level direction settings DIR1 through DIR4.

Table 4.9 shows the overcurrent elements that are controlled by each level direction setting. Note in *Table 4.9* that all the time-overcurrent elements (51_T elements) are controlled by the DIR1 level direction setting.

In most communications-assisted trip schemes, the levels are set as follows (see *Figure 5.4*):

- Level 1 overcurrent elements set direction forward (DIR1 = F)
- Level 2 overcurrent elements set direction forward (DIR2 = F)
- Level 3 overcurrent elements set direction reverse (DIR3 = R)

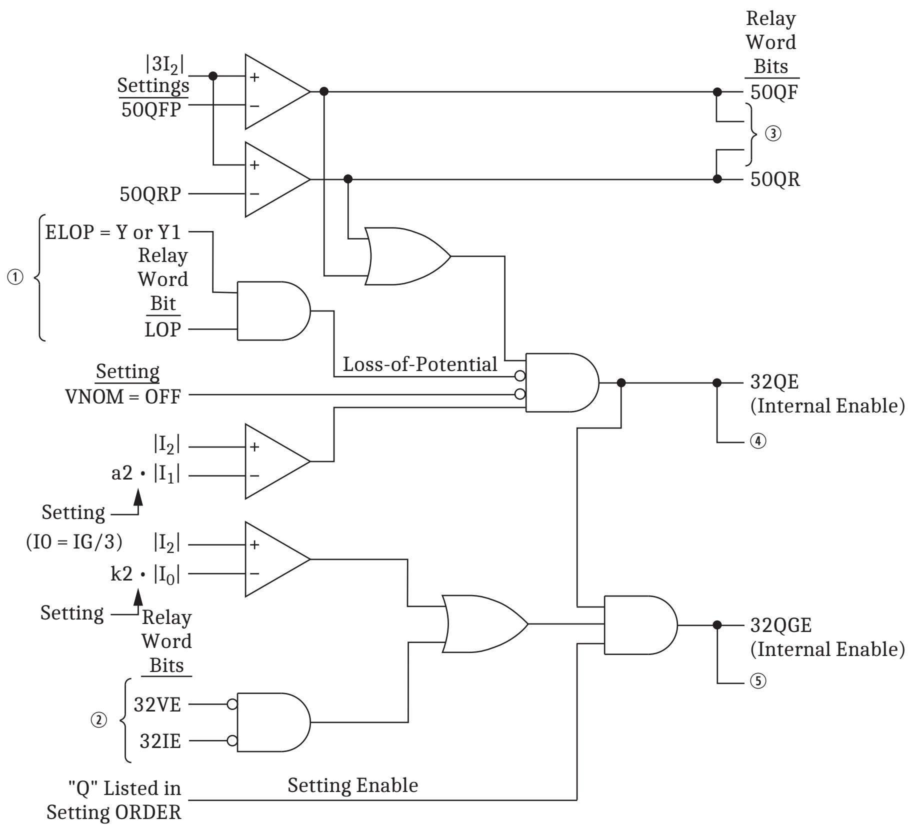
If a level direction setting (e.g., DIR1) is set:

DIR1 = **N** (nondirectional)

then the corresponding Level 1 directional control outputs in *Figure 4.22* and *Figure 4.23* assert to logical 1. The referenced Level 1 overcurrent elements in *Figure 4.22* and *Figure 4.23* are then not controlled by the directional control logic.

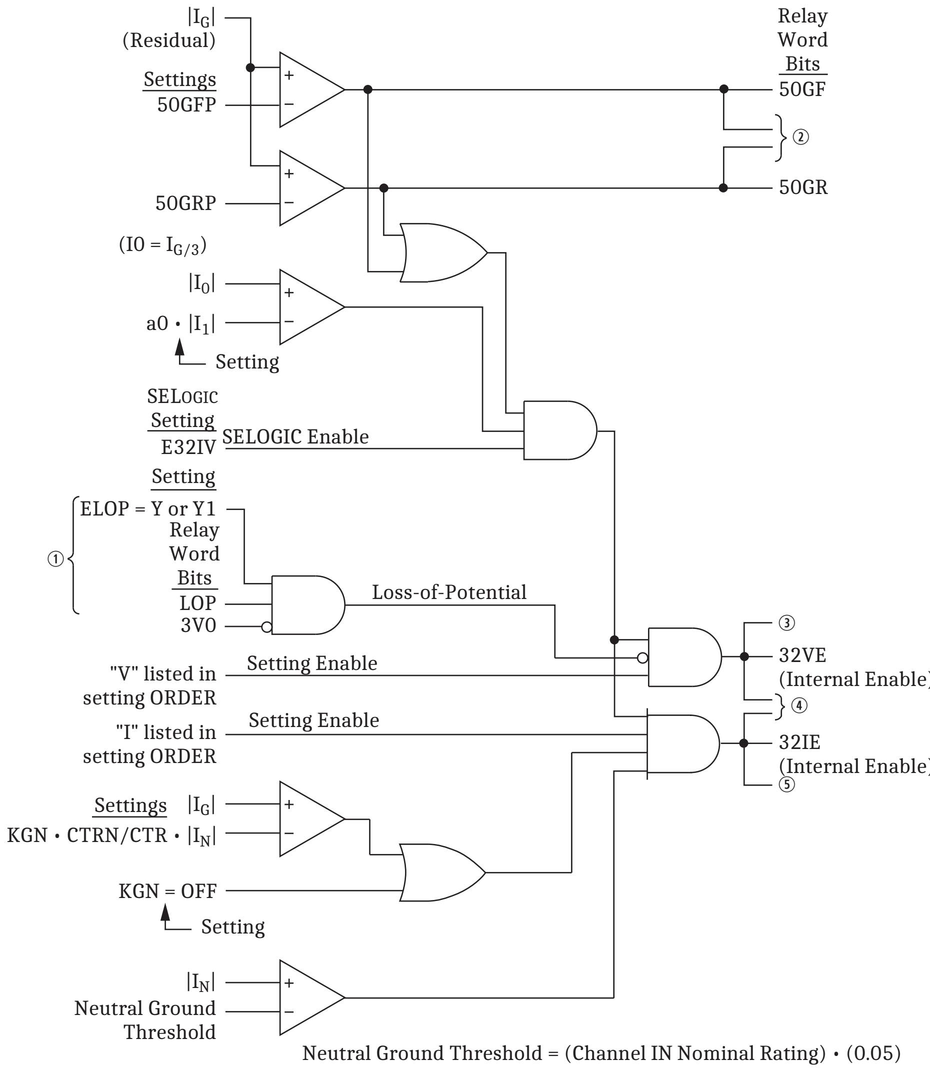
See the beginning of *Directional Control Settings* on page 4.43 for discussion of the operation of level direction settings DIR1 through DIR4 when the directional control enable setting E32 is set to E32 = N.

In some applications, level direction settings DIR1 through DIR4 are not flexible enough in assigning the desired direction for certain overcurrent elements. *Directional Control Provided by Torque-Control Settings* on page 4.69 describes how to avoid this limitation for special cases.



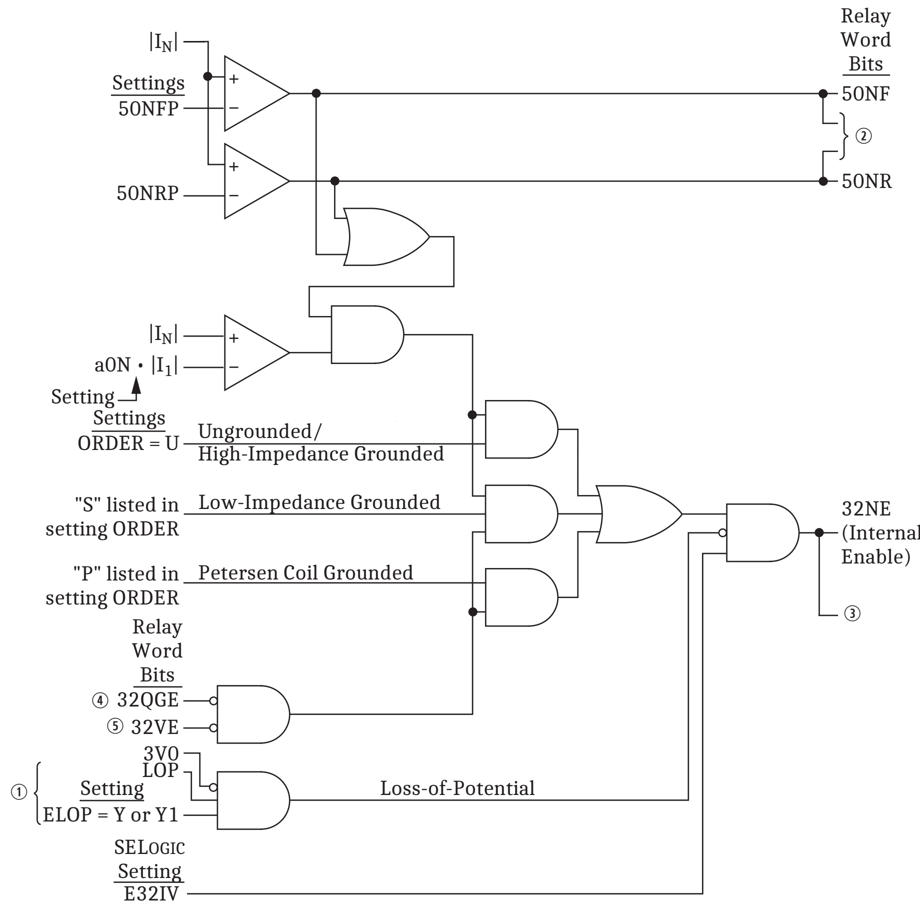
① From *Figure 4.1*. ② From *Figure 4.12*. ③ To *Figure 4.14* and *Figure 4.25*. ④ To *Figure 4.25* and *Figure 4.26*. ⑤ To *Figure 4.14*, *Table 4.4*, and *Table 4.5*.

Figure 4.11 Internal Enables (32QE and 32QGE) Logic for Negative-Sequence Voltage-Polarized Directional Elements



① From *Figure 4.1*. ② To *Figure 4.15* and *Figure 4.16*. ③ To *Figure 4.15*. ④ To *Figure 4.11*, *Figure 4.20*, *Figure 4.21*, *Table 4.4*, and *Table 4.5*. ⑤ To *Figure 4.16*.

Figure 4.12 Internal Enables (32VE and 32IE) Logic for Zero-Sequence Voltage-Polarized and Channel IN Current-Polarized Directional Elements

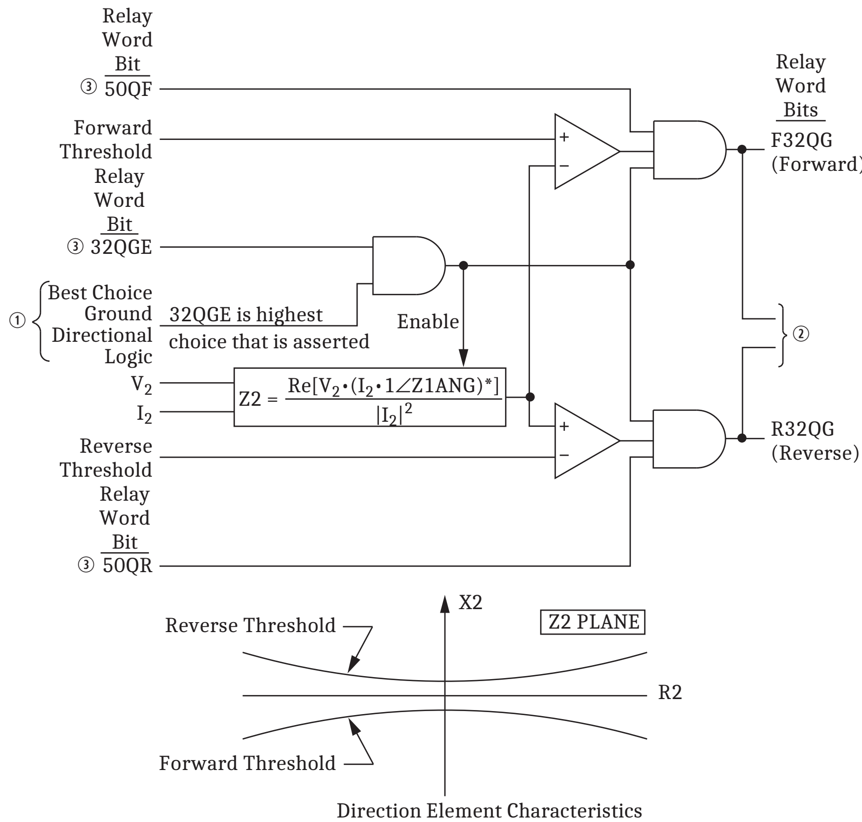


① From *Figure 4.1*. ② To *Figure 4.17* and *Figure 4.19*. ③ To *Figure 4.8*, *Figure 4.9*, *Figure 4.17*, *Figure 4.18*, *Figure 4.19*, *Table 4.4*, and *Table 4.5*. ④ From *Figure 4.11*. ⑤ From *Figure 4.12*.

Figure 4.13 Internal Enable (32NE) Logic for Zero-Sequence Voltage-Polarized Directional Elements (Low-Impedance Grounded, Petersen Coil-Grounded, and Ungrounded/High-Impedance Grounded Systems)

NOTE: Residual ground current I_G is used in place of neutral current I_N under certain circumstances. See *Switch Between I_N and I_G for Low-Impedance Grounded and Ungrounded/High-Impedance Grounded Systems* on page 4.19.

Refer to *E32IV—SELOGIC Control Equation Enable* on page 4.68 for information on using SELOGIC setting E32IV.



Forward Threshold:

If Z2F Setting ≤ 0, Forward Threshold = $0.75 \cdot Z2F - 0.25 \cdot \left|\frac{V_2}{I_2}\right|$

If Z2F Setting > 0, Forward Threshold = $1.25 \cdot Z2F - 0.25 \cdot \left|\frac{V_2}{I_2}\right|$

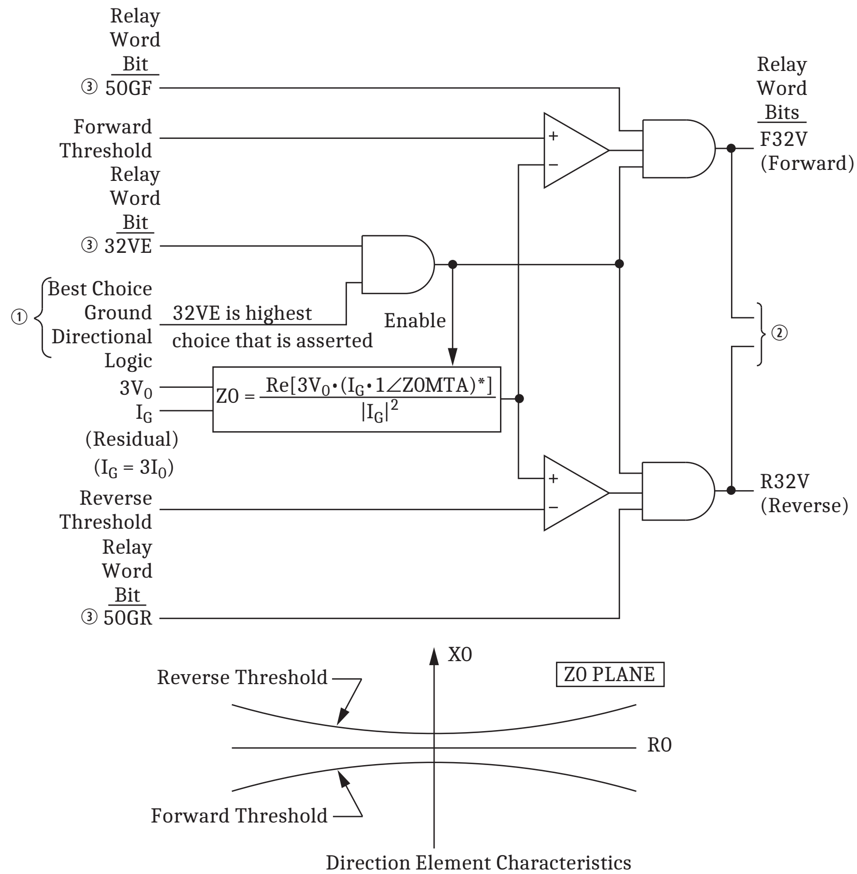
Reverse Threshold:

If Z2R Setting ≥ 0, Reverse Threshold = $0.75 \cdot Z2R + 0.25 \cdot \left|\frac{V_2}{I_2}\right|$

If Z2R Setting < 0, Reverse Threshold = $1.25 \cdot Z2R + 0.25 \cdot \left|\frac{V_2}{I_2}\right|$

① From *Table 4.5*. ② To *Figure 4.20* and *Figure 4.21*. ③ From *Figure 4.11*.

Figure 4.14 Negative-Sequence Voltage-Polarized Directional Element for Neutral Ground and Residual Ground Overcurrent Elements



<u>Forward Threshold:</u>

If Z0F Setting ≤ 0, Forward Threshold = $0.75 \cdot \text{Z0F} - 0.25 \cdot \left|\frac{V_0}{I_0}\right|$

If Z0F Setting > 0, Forward Threshold = $1.25 \cdot \text{Z0F} - 0.25 \cdot \left|\frac{V_0}{I_0}\right|$

<u>Reverse Threshold:</u>

If Z0R Setting ≥ 0, Reverse Threshold = $0.75 \cdot \text{Z0R} + 0.25 \cdot \left|\frac{V_0}{I_0}\right|$

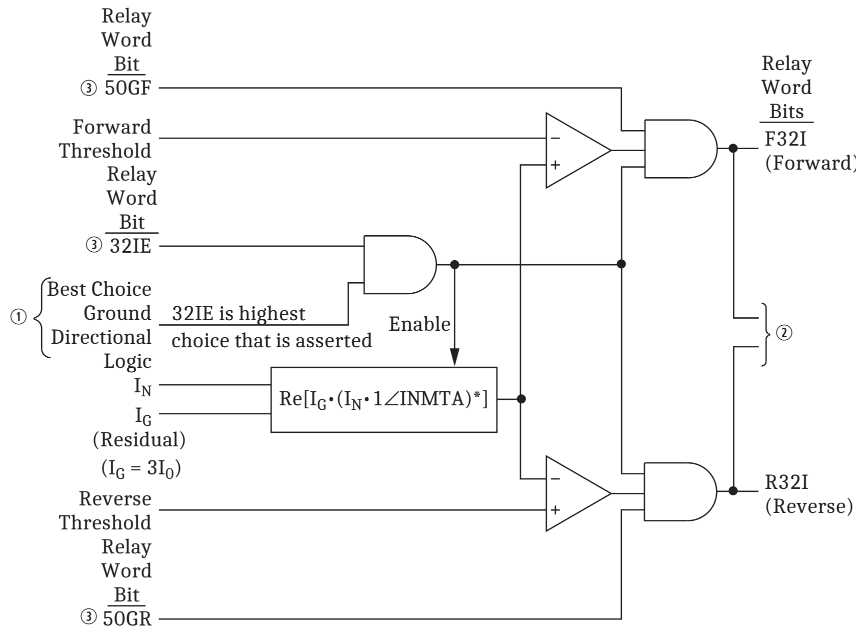
If Z0R Setting < 0, Reverse Threshold = $1.25 \cdot \text{Z0R} + 0.25 \cdot \left|\frac{V_0}{I_0}\right|$

① From *Table 4.5*. ② To *Figure 4.20* and *Figure 4.21*. ③ From *Figure 4.12*.

Figure 4.15 Zero-Sequence Voltage-Polarized Directional Element

The $3V_0$ input to *Figure 4.15* may be either a calculated value (when Global settings VSCONN = VS and PTCONN = WYE) or a measured value (when Global setting VSCONN = 3V0). See *Zero-Sequence Voltage Sources* on page 4.21.

NOTE: Group setting INMTA is hidden and forced to 0.00 when KGN = OFF.



Forward Threshold:

Forward Threshold =
(Channel IN Nominal Rating) • (Phase Channels Nominal Rating) • $(0.05)^2$

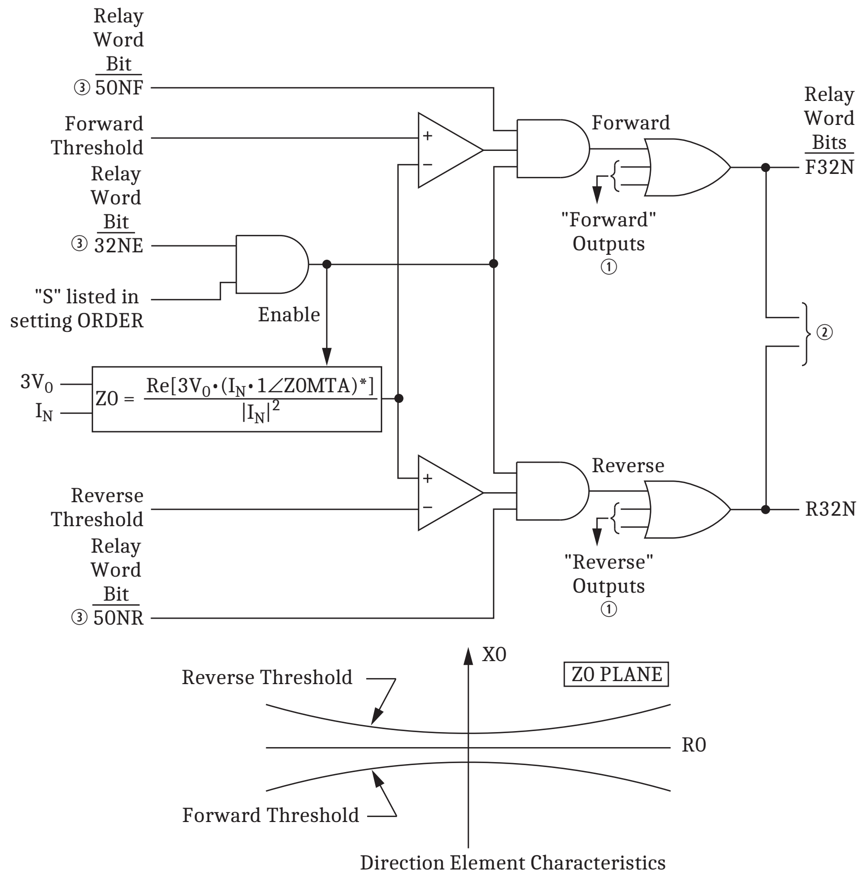
Reverse Threshold:

Reverse Threshold =
–(Channel IN Nominal Rating) • (Phase Channels Nominal Rating) • $(0.05)^2$

① From *Table 4.5*. ② To *Figure 4.20* and *Figure 4.21*. ③ From *Figure 4.12*.

Figure 4.16 Channel IN Current-Polarized Directional Element

NOTE: Residual ground current I_G is used in place of neutral current I_N under certain conditions. See *Switch Between I_N and I_G for Low-Impedance Grounded and Ungrounded/High-Impedance Grounded Systems* on page 4.19



Forward Threshold:

$$\text{If Z0F Setting} \le 0\text{, Forward Threshold} = 0.75 \cdot \text{Z0F} - 0.25 \cdot \left|\frac{3V_0}{I_N}\right|$$

$$\text{If Z0F Setting} > 0\text{, Forward Threshold} = 1.25 \cdot \text{Z0F} - 0.25 \cdot \left|\frac{3V_0}{I_N}\right|$$

Reverse Threshold:

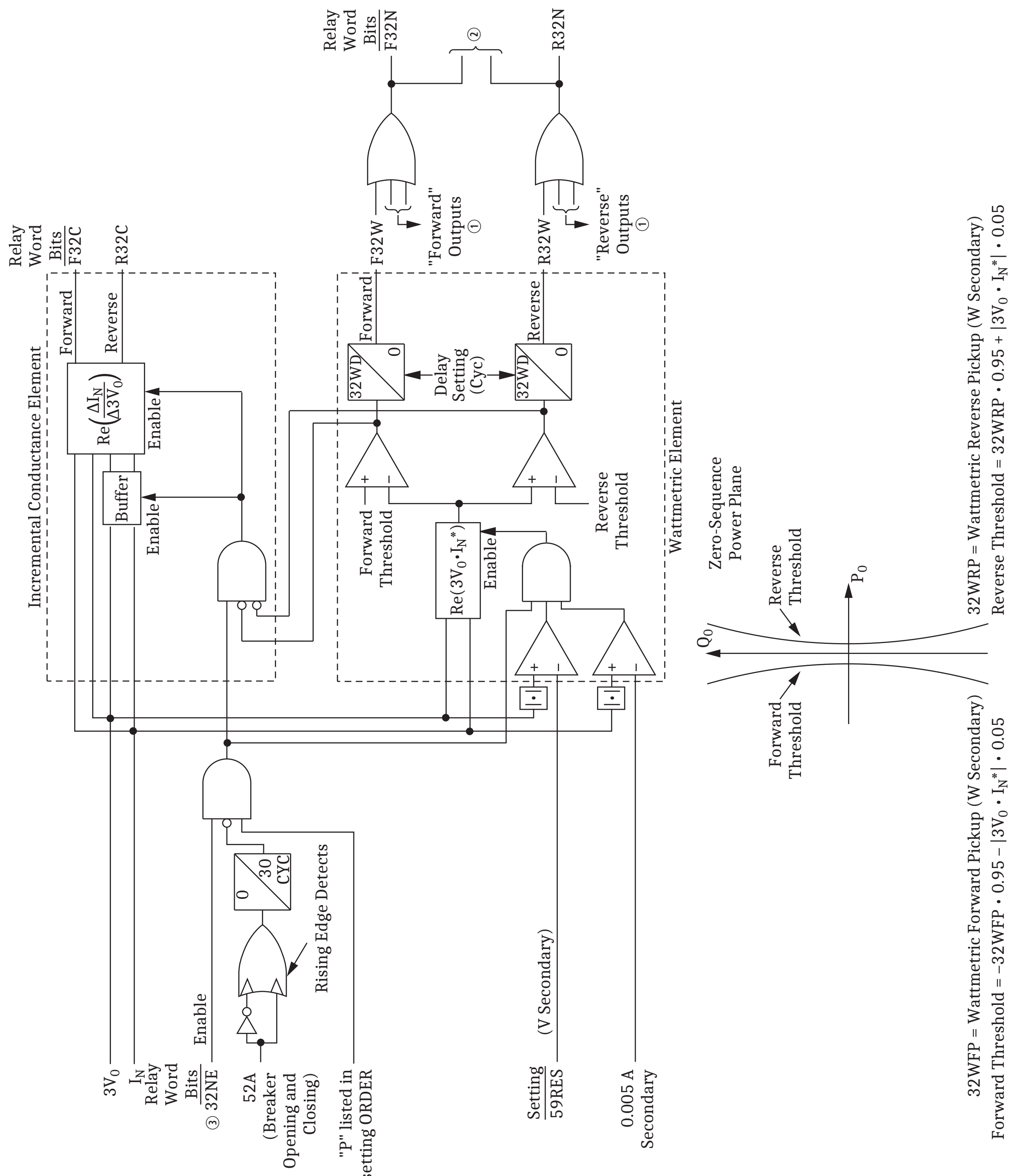
$$\text{If Z0R Setting} \ge 0\text{, Reverse Threshold} = 0.75 \cdot \text{Z0R} + 0.25 \cdot \left|\frac{3V_0}{I_N}\right|$$

$$\text{If Z0R Setting} < 0\text{, Reverse Threshold} = 1.25 \cdot \text{Z0R} + 0.25 \cdot \left|\frac{3V_0}{I_N}\right|$$

① From *Figure 4.18* and *Figure 4.19*. ② To *Figure 4.20* and *Figure 4.21*. ③ From *Figure 4.13*.

Figure 4.17 Zero-Sequence Voltage-Polarized Directional Element (Low-Impedance Grounded Systems)

The $3V_0$ input to *Figure 4.17* may be either a calculated value (when Global settings VSCONN = VS and PTCONN = WYE) or a measured value (when Global setting VSCONN = 3V0). See *Zero-Sequence Voltage Sources* on page 4.21.

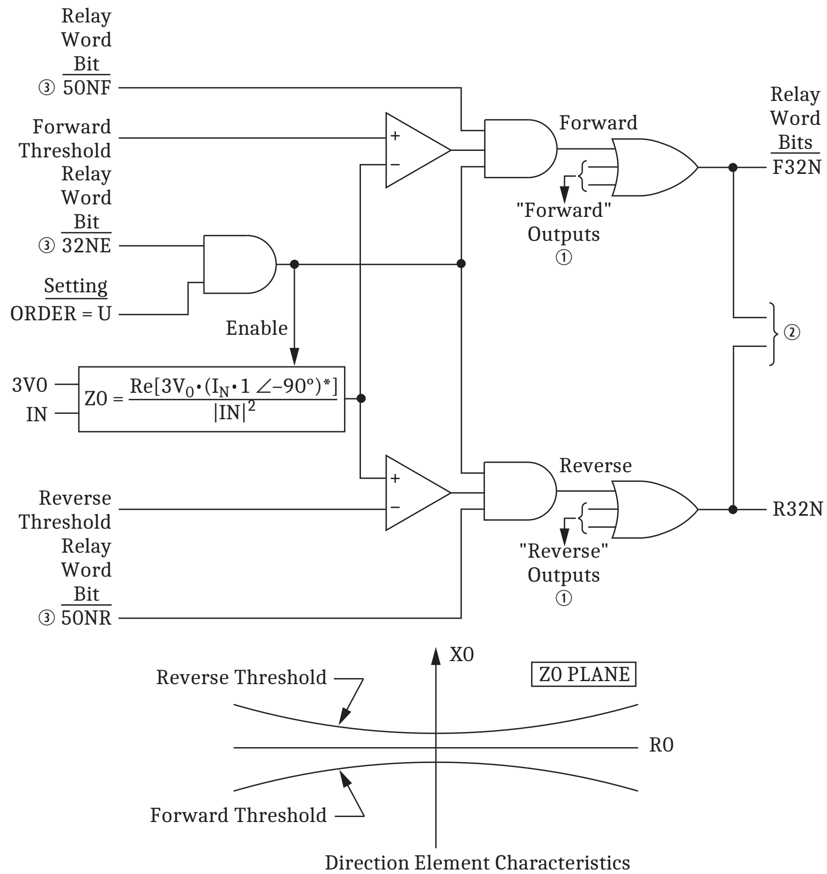


① From *Figure 4.17* and *Figure 4.19*. ② To *Figure 4.20* and *Figure 4.21*. ③ From *Figure 4.13*.

Figure 4.18 Wattmetric and Incremental Conductance Directional Elements (Petersen Coil-Grounded Systems)

The $3V_0$ input to *Figure 4.18* may be either a calculated value (when Global settings VSCONN = VS and PTCONN = WYE) or a measured value (when Global setting VSCONN = 3V0). See *Zero-Sequence Voltage Sources* on page 4.21.

NOTE: Residual ground current I_G is used in place of neutral current I_N under certain conditions. See *Switch Between I_N and I_G for Low-Impedance Grounded and Ungrounded/High-Impedance Grounded Systems* on page 4.19



Forward Threshold:

$$Z0F = -0.10, \text{ Forward Threshold} = 0.75 \cdot Z0F - 0.25 \cdot \left|\frac{3V_0}{IN}\right|$$

Reverse Threshold:

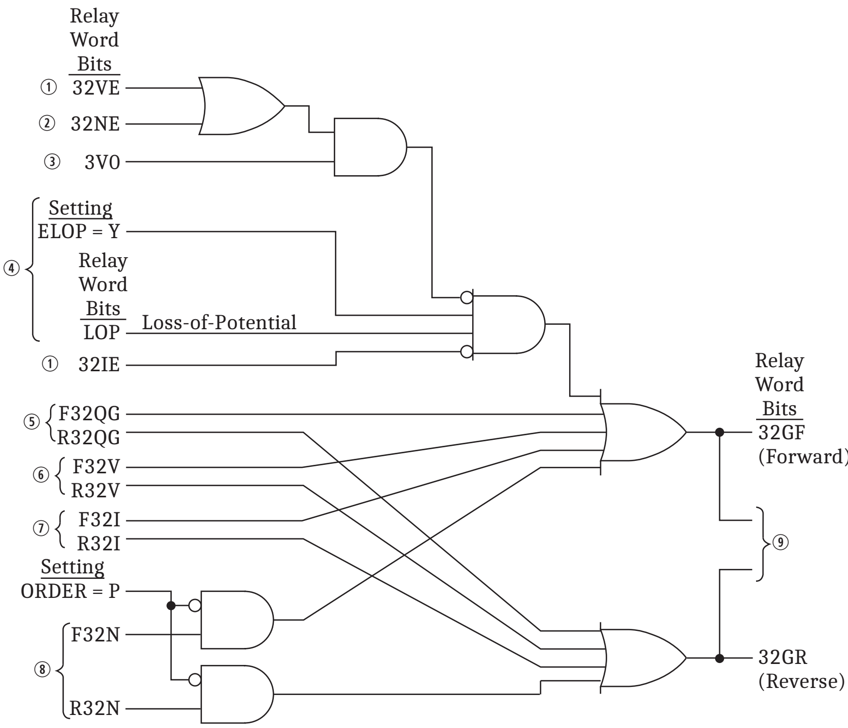
$$Z0R = 0.10, \text{ Reverse Threshold} = 0.75 \cdot Z0R + 0.25 \cdot \left|\frac{3V_0}{IN}\right|$$

For setting ORDER = U, settings Z0F and Z0R are set internally, as shown above, and hidden.
Note: 1 ∠–90° = One Ohm at –90° Angle

① From *Figure 4.17* and *Figure 4.18*. ② To *Figure 4.20* and *Figure 4.21*. ③ From *Figure 4.13*.

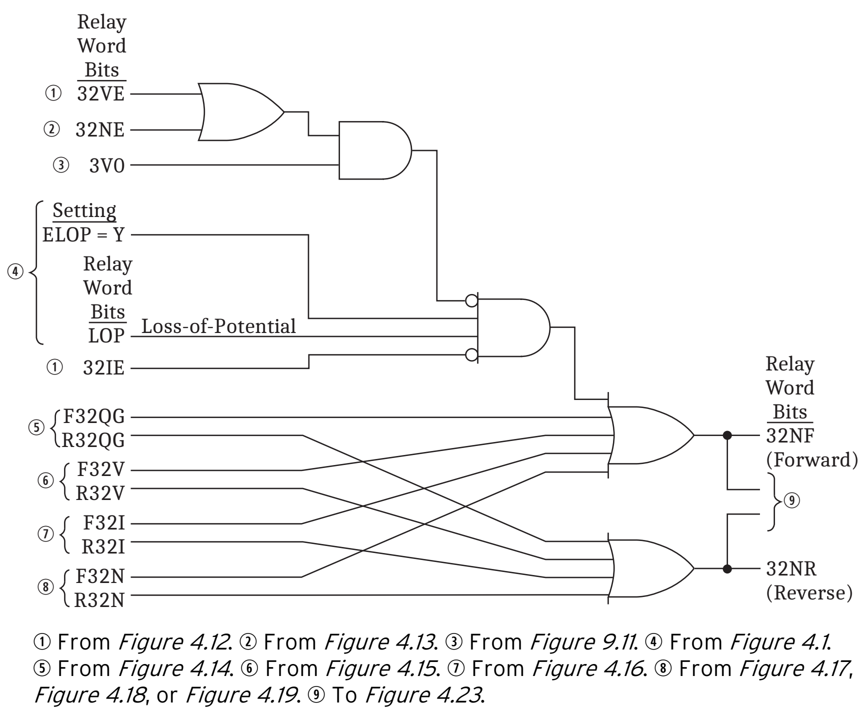
Figure 4.19 Zero-Sequence Voltage-Polarized Directional Element (Ungrounded/High-Impedance Grounded Systems)

The $3V_0$ input to *Figure 4.19* may be either a calculated value (when Global settings VSCONN = VS and PTCONN = WYE) or a measured value (when Global setting VSCONN = 3V0). See *Zero-Sequence Voltage Sources* on page 4.21.



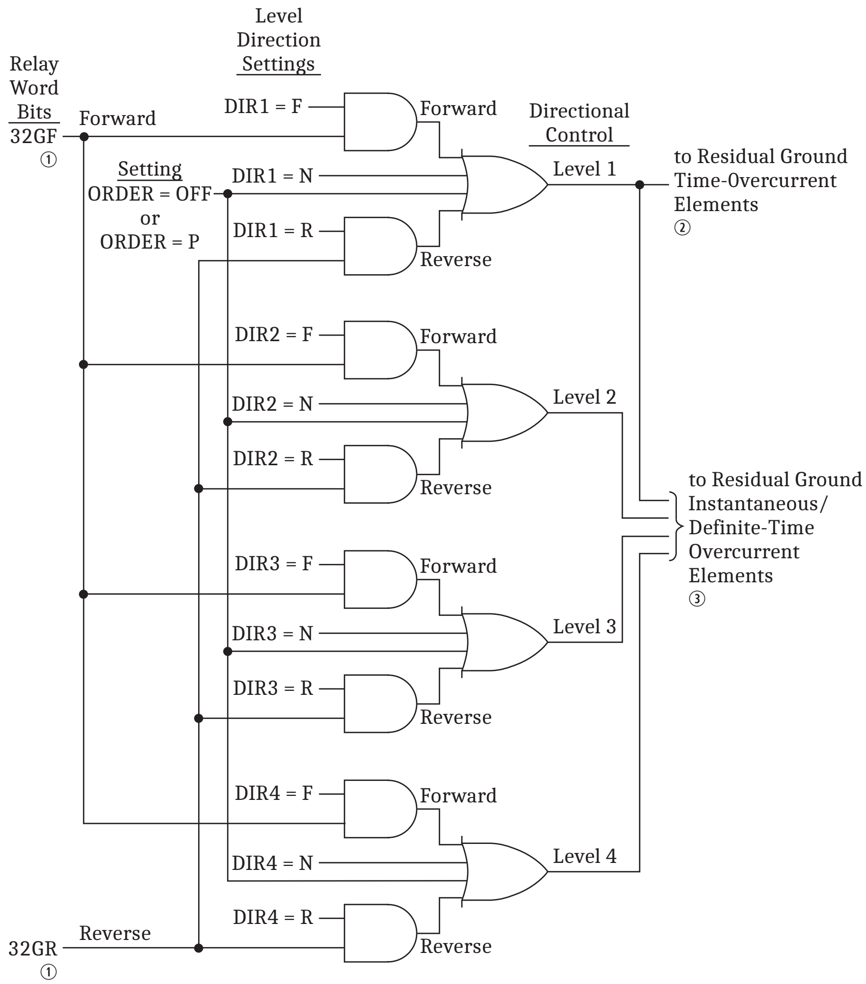
① From *Figure 4.12*. ② From *Figure 4.13*. ③ From *Figure 9.11*. ④ From *Figure 4.1*. ⑤ From *Figure 4.14*. ⑥ From *Figure 4.15*. ⑦ From *Figure 4.16*. ⑧ From *Figure 4.17*, *Figure 4.18*, or *Figure 4.19*. ⑨ To *Figure 4.22*.

Figure 4.20 Routing of Directional Elements to Residual Ground Overcurrent Elements



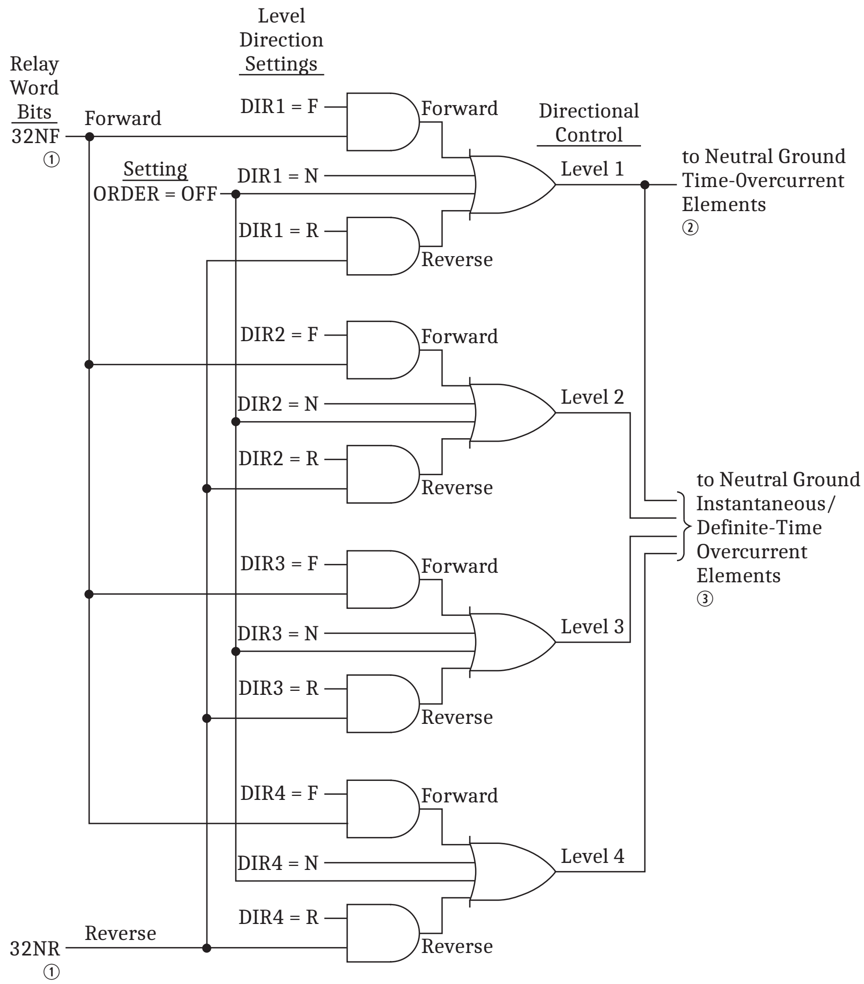
① From *Figure 4.12*. ② From *Figure 4.13*. ③ From *Figure 9.11*. ④ From *Figure 4.1*. ⑤ From *Figure 4.14*. ⑥ From *Figure 4.15*. ⑦ From *Figure 4.16*. ⑧ From *Figure 4.17*, *Figure 4.18*, or *Figure 4.19*. ⑨ To *Figure 4.23*.

Figure 4.21 Routing of Directional Elements to Neutral-Ground Overcurrent Elements



① From *Figure 4.20*. ② *Figure 3.19*. ③ *Figure 3.10*.

Figure 4.22 Direction Forward/Reverse Logic for Residual Ground Overcurrent Elements



① From *Figure 4.21*. ② *Figure 3.18*. ③ *Figure 3.8*.

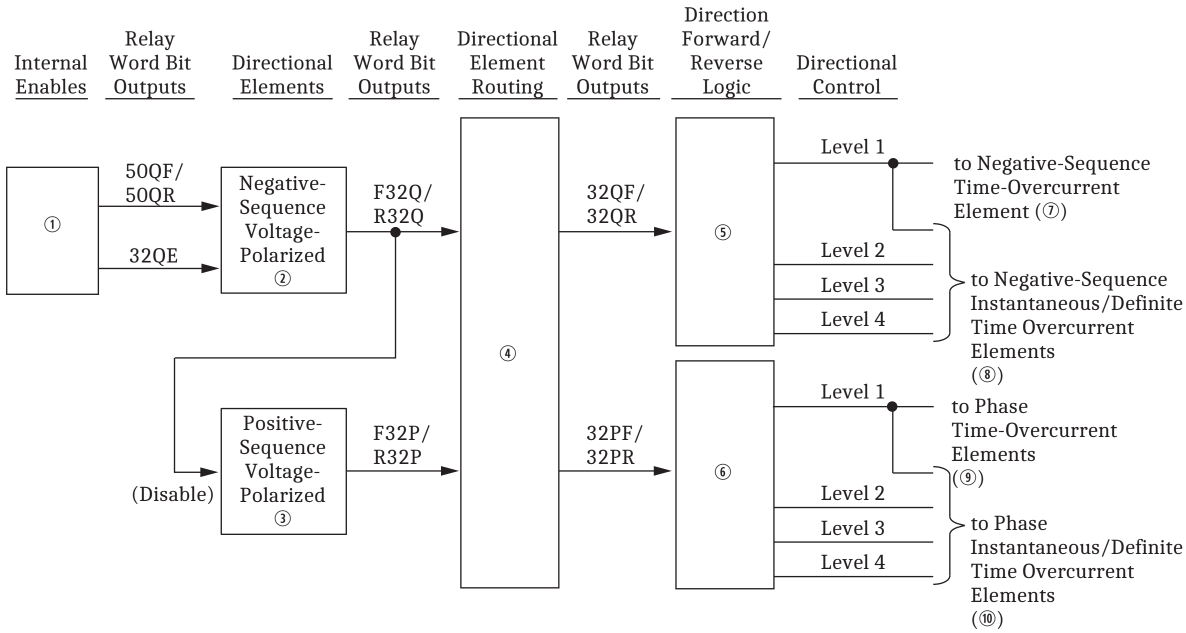
Figure 4.23 Direction Forward/Reverse Logic for Neutral-Ground Overcurrent Elements

Directional Control for Negative-Sequence and Phase Overcurrent Elements

The directional control for overcurrent elements is enabled by making directional control enable setting E32. Setting E32 and other directional control settings are described in *Directional Control Settings* on page 4.43.

The negative-sequence voltage-polarized directional element controls the negative-sequence overcurrent elements. Negative-sequence voltage-polarized and positive-sequence voltage-polarized directional elements control the phase overcurrent elements. *Figure 4.24* gives an overview of how the negative-sequence voltage-polarized and positive-sequence voltage-polarized directional elements are enabled and routed to control the negative-sequence and phase overcurrent elements.

If three-phase voltage signals are not available, make the Group setting VNOM = OFF. If Global setting PTCONN = SINGLE, setting VNOM is set to OFF. This turns off the negative-sequence voltage-polarized and positive-sequence voltage-polarized elements to prevent them from operating on false voltage quantities, yet still allows the Best-Choice Ground Directional Element logic, if available, to operate for ground faults. This shut-down logic is shown in the center portions of *Figure 4.11* and *Figure 4.26*. See *Settings for Voltage Input Configuration* on page 9.18 for a complete list of changes caused by setting VNOM = OFF.



① *Figure 4.11*. ② *Figure 4.25*. ③ *Figure 4.26*. ④ *Figure 4.27*. ⑤ *Figure 4.28*. ⑥ *Figure 4.29*. ⑦ *Figure 3.21*. ⑧ *Figure 3.12*. ⑨ *Figure 3.14–Figure 3.17*. ⑩ *Figure 3.3*.

Figure 4.24 General Logic Flow of Directional Control for Negative-Sequence and Phase Overcurrent Elements

The directional control for negative sequence and phase overcurrent elements is intended to control overcurrent elements with pickup settings above load current to detect faults. In some applications, it may be necessary to set a sensitive overcurrent element to detect currents in one direction (reverse, for example) and a less sensitive overcurrent element for the other direction (forward). In such applications, with default relay logic, a reverse overcurrent element with pickup setting below forward load may operate for some remote, unbalanced, reverse faults. If possible, overcurrent element pickup settings should be set above the current expected for load in either direction. If this is not possible, refer to the technical paper "Use of Directional Elements at the Utility-Industrial Interface" by Dave Costello, Greg Bow, and Martin Moon, available on the SEL website, or contact SEL for assistance.

Internal Enables

Refer to *Figure 4.11* and *Figure 4.24*.

The internal enable 32QE corresponds to the negative-sequence voltage-polarized directional element.

Note that *Figure 4.11* has extra internal enable 32QGE, which is used in the directional element logic that controls the neutral ground and residual ground overcurrent elements (see *Figure 4.8*).

The settings involved with internal enable 32QE in *Figure 4.11* (e.g., settings a2, k2) are explained in *Directional Control Settings* on page 4.43.

Directional Elements

Refer to *Figure 4.24*, *Figure 4.25*, and *Figure 4.26*.

If enable setting ELOP = Y or Y1 and a loss-of-potential condition occurs (Relay Word bit LOP asserts), the negative-sequence voltage-polarized and positive-sequence voltage-polarized directional elements are disabled (see *Figure 4.11* and *Figure 4.26*).

Refer to *Figure 4.1* and accompanying text for more information on loss-of-potential.

Note in *Figure 4.24* and *Figure 4.26* that the negative-sequence voltage-polarized directional element has priority over the positive-sequence voltage-polarized directional element in controlling the phase overcurrent elements. The negative-sequence voltage-polarized directional element operates for unbalanced faults while the positive-sequence voltage-polarized directional element operates for three-phase faults.

Note also in *Figure 4.26* that the assertion of ZLOAD disables the positive-sequence voltage-polarized directional element. ZLOAD asserts when the relay is operating in a user-defined load region (see *Figure 4.6*).

Directional Element Routing

Refer to *Figure 4.24* and *Figure 4.27*.

The directional element outputs are routed to the forward (Relay Word bits 32QF and 32PF) and reverse (Relay Word bits 32QR and 32PR) logic points and then on to the direction forward/reverse logic in *Figure 4.28* and *Figure 4.29*.

Loss-of-Potential

Note if *both* the following are true:

- ➤ Enable setting ELOP = Y,
- ➤ A loss-of-potential condition occurs (Relay Word bit LOP asserts),

then the forward logic points (Relay Word bits 32QF and 32PF) assert to logical 1, thus enabling the negative-sequence and phase overcurrent elements that are set direction forward (with settings DIR1 = F, DIR2 = F, etc.). These direction forward overcurrent elements effectively become nondirectional and provide overcurrent protection during a loss-of-potential condition.

As detailed previously (in *Figure 4.11* and *Figure 4.26*), voltage-based directional elements are disabled during a loss-of-potential condition. Thus, the overcurrent elements controlled by these voltage-based directional elements are also disabled. But this disable condition is overridden for the overcurrent elements set direction forward if setting ELOP = Y.

Refer to *Figure 4.1* and accompanying text for more information on loss-of-potential.

Direction Forward/Reverse Logic

Refer to *Figure 4.24*, *Figure 4.28*, and *Figure 4.29*.

The forward (Relay Word bits 32QF and 32PF) and reverse (Relay Word bits 32QR and 32PR) logic points are routed to the different levels of overcurrent protection by the level direction settings DIR1 through DIR4.

Table 4.9 shows the overcurrent elements that are controlled by each level direction setting. Note in *Table 4.9* that all the time-overcurrent elements (51_T elements) are controlled by the DIR1 level direction setting.

In most communications-assisted trip schemes, the levels are set as follows (see *Figure 5.4*):

- Level 1 overcurrent elements set direction forward (DIR1 = F)
- Level 2 overcurrent elements set direction forward (DIR2 = F)
- Level 3 overcurrent elements set direction reverse (DIR3 = R)

If a level direction setting (e.g., DIR1) is set:

DIR1 = **N** (nondirectional)

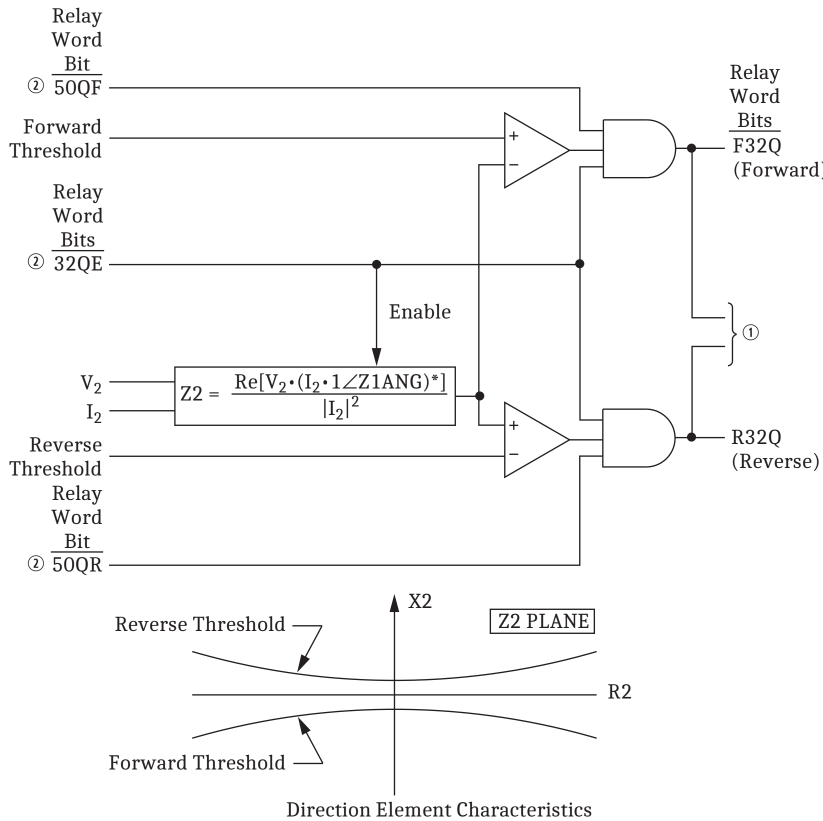
then the corresponding Level 1 directional control outputs in *Figure 4.28* and *Figure 4.29* assert to logical 1. The referenced Level 1 overcurrent elements in *Figure 4.28* and *Figure 4.29* are then not controlled by the directional control logic.

NOTE: When Global setting PTCONN = SINGLE, Group setting VNOM is hidden and forced to OFF internally.

If Group setting VNOM = OFF, then the directional control outputs in *Figure 4.28* and *Figure 4.29* assert to logical 1. This effectively makes the phase and negative-sequence elements nondirectional, even in cases where E32 can still be set.

See the beginning of *Directional Control Settings* on page 4.43 for a discussion of the operation of level direction settings DIR1 through DIR4 when the directional control enable setting E32 is set to E32 = N.

In some applications, level direction settings DIR1 through DIR4 are not flexible enough in assigning the desired direction for certain overcurrent elements. *Directional Control Provided by Torque-Control Settings* on page 4.69 describes how to avoid this limitation for special cases.



Forward Threshold:

If Z2F Setting ≤ 0, Forward Threshold = $0.75 \cdot Z2F - 0.25 \cdot \left|\frac{V_2}{I_2}\right|$

If Z2F Setting > 0, Forward Threshold = $1.25 \cdot Z2F - 0.25 \cdot \left|\frac{V_2}{I_2}\right|$

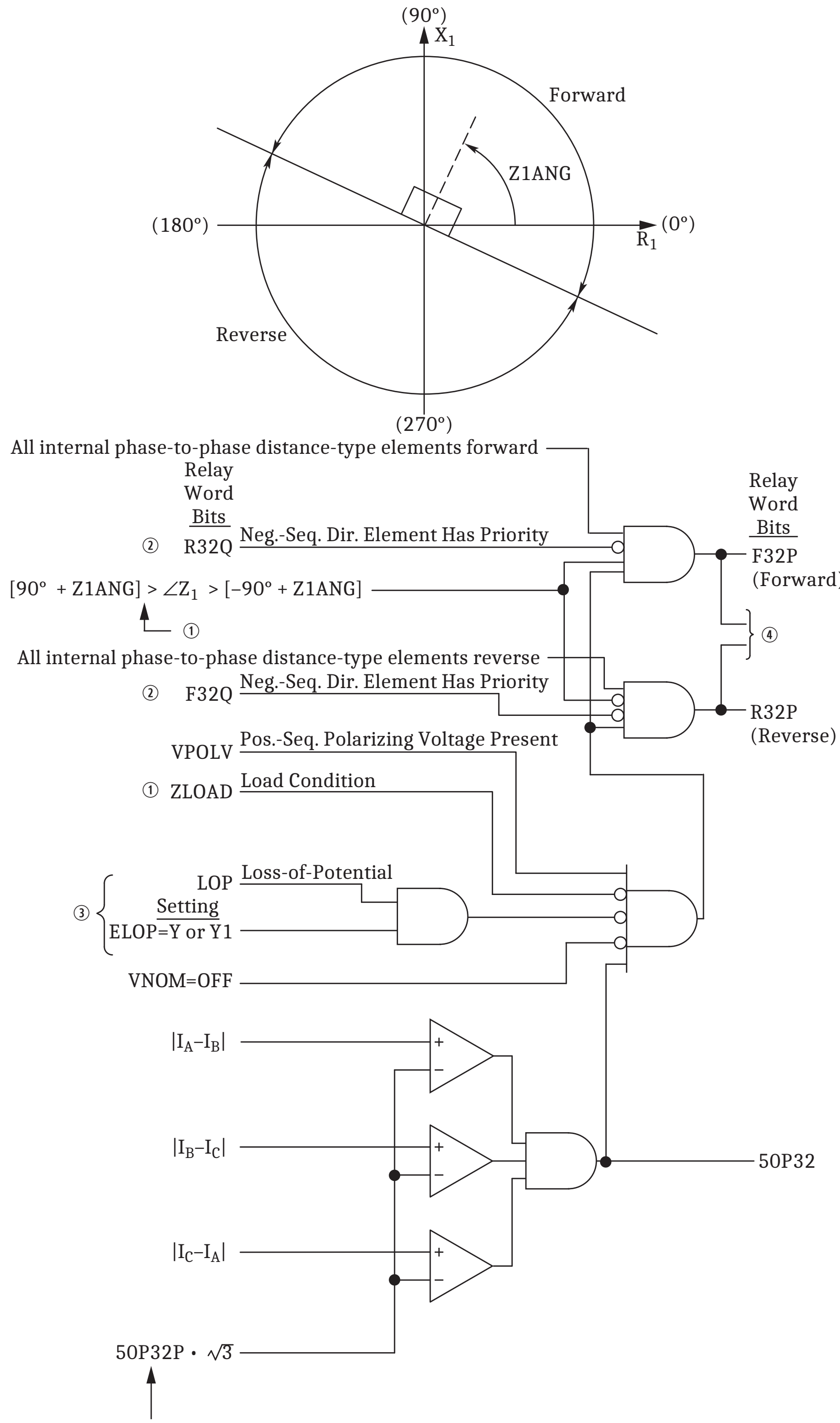
Reverse Threshold:

If Z2R Setting ≥ 0, Reverse Threshold = $0.75 \cdot Z2R + 0.25 \cdot \left|\frac{V_2}{I_2}\right|$

If Z2R Setting < 0, Reverse Threshold = $1.25 \cdot Z2R + 0.25 \cdot \left|\frac{V_2}{I_2}\right|$

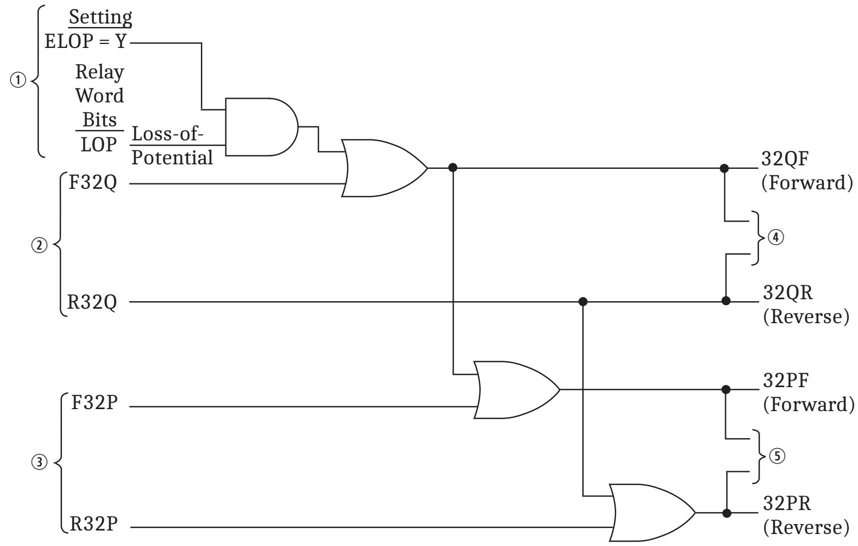
① To *Figure 4.26* and *Figure 4.27*. ② From *Figure 4.11*.

Figure 4.25 Negative-Sequence Voltage-Polarized Directional Element for Negative-Sequence and Phase Overcurrent Elements



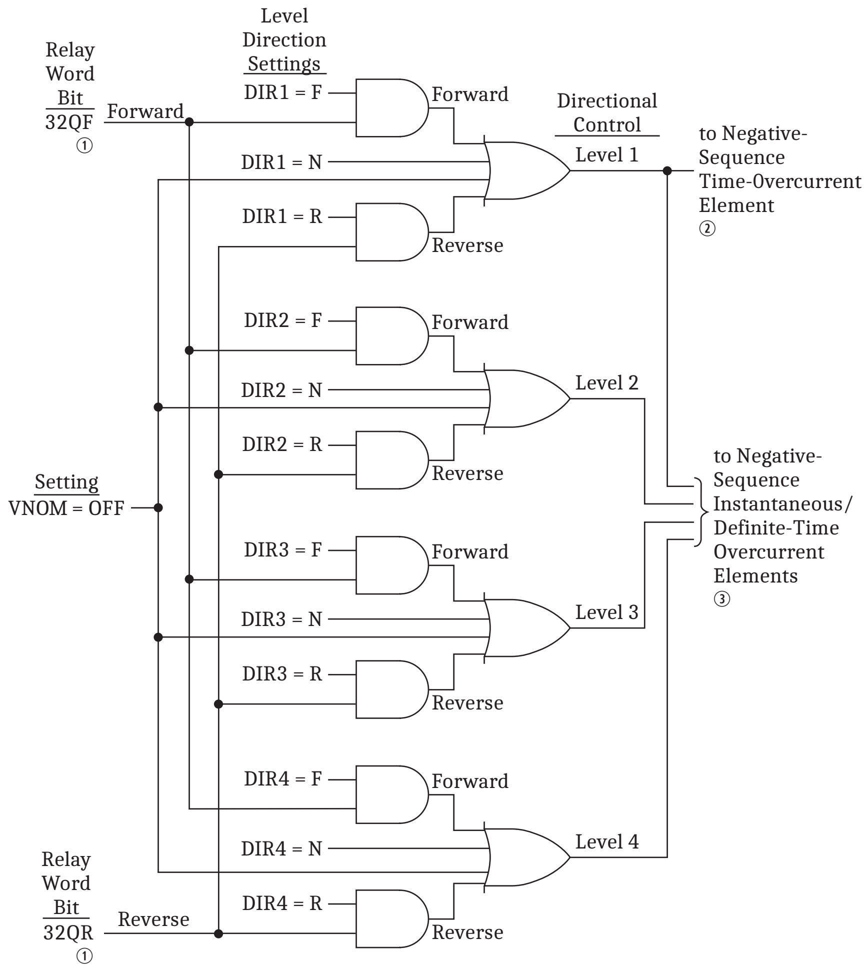
① From *Figure 4.6*. ② From *Figure 4.25*. ③ From *Figure 4.1*. ④ To *Figure 4.27*.

Figure 4.26 Positive-Sequence Voltage-Polarized Directional Element for Phase Overcurrent Elements



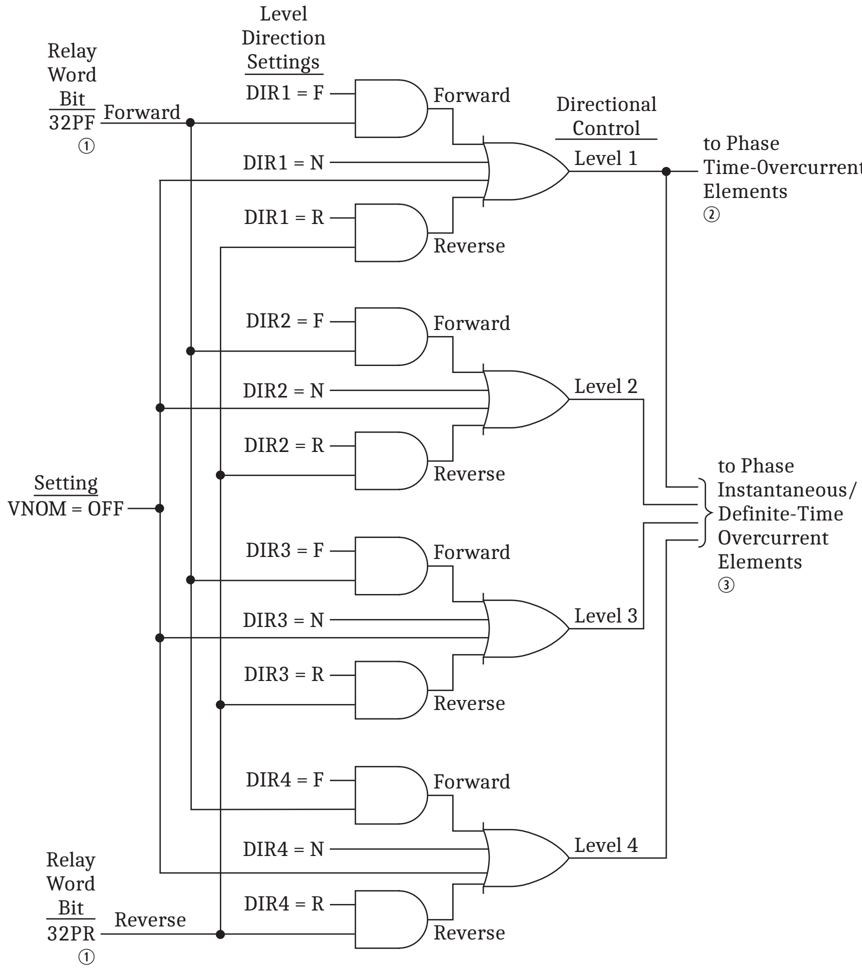
① From *Figure 4.1*. ② From *Figure 4.25*. ③ From *Figure 4.26*. ④ To *Figure 4.28*. ⑤ To *Figure 4.29*.

Figure 4.27 Routing of Directional Elements to Negative-Sequence and Phase Overcurrent Elements



① From *Figure 4.27*. ② *Figure 3.21*. ③ *Figure 3.12*.

Figure 4.28 Direction Forward/Reverse Logic for Negative-Sequence Overcurrent Elements



① From *Figure 4.27*. ② *Figure 3.14–Figure 3.17*. ③ *Figure 3.3*.

Figure 4.29 Direction Forward/Reverse Logic for Phase Overcurrent Elements

Directional Control Settings

The directional control for overcurrent elements is enabled by making directional control enable setting E32. Setting E32 has setting choices:

- Y enable directional control
- N disable directional control
- AUTO enable directional control and set many of the directional element settings automatically

If directional control enable setting E32 = N, directional control is disabled and no directional control settings are made. All level direction settings are set internally as:

DIR1 = **N** (no directional control for Level 1 overcurrent elements)

DIR2 = **N** (no directional control for Level 2 overcurrent elements)

DIR3 = **N** (no directional control for Level 3 overcurrent elements)

DIR4 = **N** (no directional control for Level 4 overcurrent elements)

With the above settings, the directional control outputs in *Figure 4.22*, *Figure 4.23*, *Figure 4.28*, and *Figure 4.29* assert to logical 1. The overcurrent elements referenced in *Figure 4.22*, *Figure 4.23*, *Figure 4.28*, and *Figure 4.29* are then not controlled by the directional control logic.

NOTE: Depending on relay model and Global settings PTCONN and VSCONN, Group setting E32 might not offer the AUTO settings choice, or E32 might be hidden. When E32 is hidden, it is internally set to N. See discussion following *Table 4.6*.

There is one case that does not allow Group setting E32 = Y or AUTO. If all three of the following are true, E32 can only be set to "N."

- The relay model has a 0.2 A or 0.05 A nominal neutral channel.
- Global setting VSCONN = VS.
- Group setting VNOM = OFF.

Settings Made Automatically

If the directional control enable setting E32 is set:

E32 = **AUTO**

then the following directional control settings are calculated and set automatically:

Z2F, Z2R, 50QFP, 50QRP, a2, k2, 50GFP, 50GRP, a0, Z0F, Z0R, and Z0MTA

NOTE: Settings Z2F, Z2R, Z0F, and Z0R are calculated based on the line impedance settings Z1MAG and Z0MAG. Enter Z1MAG and Z0MAG values appropriate for the application when E32 = AUTO.

If

E32 = **AUTO**

then Z0MTA is set equal to Z0ANG and Z0MTA is hidden.

Once these settings are calculated automatically, they can only be modified if the user goes back and changes the directional control enable setting to E32 = Y.

Use caution when you set E32 = AUTO. It is not appropriate for all applications. Systems with a strong negative-sequence source (e.g., equivalent negative-sequence impedance of less than $2.5/I_{NOM}$ in ohms) can use E32 = AUTO. It is best to use the settings in *Table 4.7* if any of the following apply:

- the negative-sequence impedance of the source is greater than $2.5/I_{NOM}$ in ohms
- the line impedance is unknown
- a non-fault condition occurs, such as a switching transformer energization causing the negative-sequence voltage to be approximately zero

Table 4.7 Ground Directional Element Preferred Settings (Sheet 1 of 2)

Name	5 A nominal	1 A nominal
E32	Y	Y
Z2F	–0.30	–1.5
Z2R	0.30	1.5
Z0F	–0.30	–1.5
Z0R	0.30	1.5
Z0MTA	Set equal to Z0ANG	Set equal to Z0ANG
50QFP /50GFP	0. 50 A	0.10 A
50QRP /50GRP	0. 25 A	0.05 A
a2	0.10	0.10

Table 4.7 Ground Directional Element Preferred Settings (Sheet 2 of 2)

Name	5 A nominal	1 A nominal
k2	0.20	0.20
a0	0.10	0.10

The preferred settings in *Table 4.7* will provide equal or better protection than E32 = AUTO for most systems.

E32 = AUTO is designed for line protection applications where CT polarity is such that the forward tripping direction is toward the line, as shown in *Figure 2.15*. When E32 = AUTO and negative-sequence or zero-sequence voltage is low, the negative-sequence and zero-sequence directional elements declare unbalanced faults forward. Where directional elements are used in applications that do not involve lines, or where the CT polarity is reversed, setting E32 = AUTO might be inappropriate. See Application Guide *AG2009-17, Enabling Sensitive Directional Elements for Non-Line Protection Applications with SEL-351 Series Relays*, or contact SEL for assistance.

The remaining directional control settings are *not* set automatically if setting E32 = AUTO. They have to be set by the user, whether setting E32 = AUTO or Y. These settings are:

NOTE: Group settings KGN and INMTA are only available when E32 = Y.

> DIR1, DIR2, DIR3, DIR4, ORDER, 50P32P, KGN, INMTA, 50NFP, 50NRP, a0N, 59RES, 32WFP, 32WRP, 32WD, and E32IV (E32IV is a SELogic setting)

All these settings are explained in detail in the remainder of this subsection.

Not all these directional control settings (set automatically or by the user) are used in every application. The following are directional control settings that are hidden/not made for particular conditions:

Table 4.8 Directional Control Settings Not Made for Particular Conditions

Settings hidden/not made:	for condition:
50P32P	setting ELOAD = Y
50GFP, 50GRP, a0	setting ORDER does not contain V or I
Z0F, Z0R, Z0MTA	setting ORDER does not contain V or S
59RES, 32WFP, 32WRP, 32WD	setting ORDER does not contain P
50NFP, 50NRP, a0N	setting ORDER does not contain S or U
KGN, INMTA	setting ORDER does not contain I or E32 = AUTO
INMTA	setting KGN = OFF

Settings

DIR1—Level 1 Overcurrent Element Direction Setting

DIR2—Level 2 Overcurrent Element Direction Setting

DIR3—Level 3 Overcurrent Element Direction Setting

DIR4—Level 4 Overcurrent Element Direction Setting

Setting Range:

F = Direction Forward

R = Direction Reverse

N = Nondirectional

Table 4.9 shows the overcurrent elements that are controlled by each level direction setting. Note in *Table 4.9* that all the time-overcurrent elements (51_T elements) are controlled by the DIR1 level direction setting. *Figure 4.22*, *Figure 4.23*, *Figure 4.28*, and *Figure 4.29* show the logic implementation of the control listed in *Table 4.9*.

Table 4.9 Overcurrent Elements Controlled by Level Direction Settings DIR1 Through DIR4 (Corresponding Overcurrent Element Figure Numbers in Parentheses)

Level Direction Settings	Phase	Neutral Ground	Residual Ground	Negative-Sequence
DIR1	67P1 (*Figure 3.3*) 67P1T (*Figure 3.3*) 51PT (*Figure 3.14*) 51AT (*Figure 3.15*) 51BT (*Figure 3.16*) 51CT (*Figure 3.17*)	67N1 (*Figure 3.8*) 67N1T (*Figure 3.8*) 51NT (*Figure 3.18*)	67G1 (*Figure 3.10*) 67G1T (*Figure 3.10*) 51GT (*Figure 3.19*) 51G2T (*Figure 3.20*)	67Q1 (*Figure 3.12*) 67Q1T (*Figure 3.12*) 51QT (*Figure 3.21*)
DIR2	67P2 (*Figure 3.3*) 67P2T (*Figure 3.3*) 67P2S (*Figure 3.3*)	67N2 (*Figure 3.8*) 67N2T (*Figure 3.8*) 67N2S (*Figure 3.8*)	67G2 (*Figure 3.10*) 67G2T (*Figure 3.10*) 67G2S (*Figure 3.10*)	67Q2 (*Figure 3.12*) 67Q2T (*Figure 3.12*) 67Q2S (*Figure 3.12*)
DIR3	67P3 (*Figure 3.3*) 67P3T (*Figure 3.3*)	67N3 (*Figure 3.8*) 67N3T (*Figure 3.8*)	67G3 (*Figure 3.10*) 67G3T (*Figure 3.10*)	67Q3 (*Figure 3.12*) 67Q3T (*Figure 3.12*)
DIR4	67P4 (*Figure 3.3*) 67P4T (*Figure 3.3*)	67N4 (*Figure 3.8*) 67N4T (*Figure 3.8*)	67G4 (*Figure 3.10*) 67G4T (*Figure 3.10*)	67Q4 (*Figure 3.12*) 67Q4T (*Figure 3.12*)

In most communications-assisted trip schemes, the levels are set as follows (see *Figure 5.4*):

- ➤ Level 1 overcurrent elements set direction forward (DIR1 = F)
- ➤ Level 2 overcurrent elements set direction forward (DIR2 = F)
- ➤ Level 3 overcurrent elements set direction reverse (DIR3 = R)

In some applications, level direction settings DIR1 through DIR4 are not flexible enough in assigning the desired direction for certain overcurrent elements. *Directional Control Provided by Torque-Control Settings* on page 4.69 describes how to avoid this limitation for special cases.

ORDER—Ground Directional Element Priority Setting

Setting ORDER can be set with the elements listed and defined in *Table 4.4*, subject to the setting combination constraints in *Table 4.5* and *Table 4.6*. Note that *Table 4.4* and *Table 4.5* also list directional element availability per model (according to the neutral channel [IN] rating). *Table 4.6* lists the ground directional element availability as a result of the voltage connection settings.

The *order* in which the directional elements are listed in setting ORDER determines the priority in which these elements operate to provide Best Choice Ground Directional Element logic control.

For example, if setting:

ORDER = **QVS**

then the first listed directional element (Q = negative-sequence voltage-polarized directional element; see *Figure 4.14*) is the first priority directional element to provide directional control for the neutral ground and residual ground overcurrent elements.

If the negative-sequence voltage-polarized directional element is not operable (i.e., it does not have sufficient operating quantity as indicated by its internal enable, 32QGE, not being asserted; see *Figure 4.11*), then the second listed directional element (V = zero-sequence voltage-polarized directional element; see *Figure 4.15*) provides directional control for the neutral ground and residual ground overcurrent elements.

If the zero-sequence voltage-polarized directional element is not operable (i.e., it does not have sufficient operating quantity as indicated by its internal enable, 32VE, not being asserted; see *Figure 4.12*), then the third listed directional element (S = zero-sequence voltage-polarized directional element [low-impedance]; see *Figure 4.17*) provides directional control for the neutral ground and residual ground overcurrent elements.

If the zero-sequence voltage-polarized directional element (low-impedance) is not operable (i.e., it does not have sufficient operating quantity as indicated by its internal enable, 32NE [low-impedance], not being asserted; see *Figure 4.13*), then no directional control is available. The neutral ground and residual ground overcurrent elements will not operate, even though these elements are designated with the DIR*n* (*n* = 1–4) settings to be directionally controlled (see *Figure 4.22* and *Figure 4.23*).

Another example, if setting:

ORDER = **V**

then the zero-sequence voltage-polarized directional element (V = zero-sequence voltage-polarized directional element; see *Figure 4.15*) provides directional control for the neutral ground and residual ground overcurrent elements at all times (assuming it has sufficient operating quantity). If there is not sufficient operating quantity during an event (i.e., internal enable 32VE is not asserted; see *Figure 4.12*), then no directional control is available. The neutral ground and residual ground overcurrent elements will not operate, even though these elements are designated with the DIR*n* (*n* = 1–4) settings to be directionally controlled (see *Figure 4.22* and *Figure 4.23*).

If setting:

ORDER = **OFF**

then all of the ground directional elements are inoperable. Note in *Figure 4.22* and *Figure 4.23* that setting ORDER = OFF effectively makes the neutral ground and residual ground overcurrent elements nondirectional (the directional control outputs of *Figure 4.22* and *Figure 4.23* are continuously asserted to logical 1).

Petersen Coil Considerations for Setting ORDER

Note in *Figure 4.22* that if setting ORDER = P, the residual ground overcurrent elements are not controlled by the directional control logic (much like when ORDER = OFF). In such a scenario, where only the wattmetric directional element provides ground overcurrent element directional control (setting ORDER = P), presumably there is no bypass around the Petersen Coil. With the tuned Petersen Coil in-place (and not shorted out by a bypass), very little current flows for a ground fault. With such low current levels, the neutral-ground overcurrent elements (referenced in *Figure 4.23*) are the elements that detect the ground fault, not the residual-ground overcurrent elements (referenced in *Figure 4.22*). The residual ground overcurrent elements (including forward and reverse fault detectors 50GF and 50GR, respectively; see *Figure 4.12*) should be set above any ground fault current level with the Petersen Coil in place.

If there is a bypass around the Petersen Coil and the bypass is used at times (i.e., shorting out the Petersen Coil), much higher currents can flow for a ground fault when the bypass is closed. In such a scenario, setting ORDER should be set something like ORDER = QP or ORDER = QVP (see *Table 4.5*). Then, the residual ground elements (*Figure 4.22*) are controlled by the directional control logic and provide directional protection for higher ground fault currents.

50P32P—Phase Directional Element Three-Phase Current Pickup

Setting Range:

0.50–10.00 A secondary (5 A nominal phase current inputs, IA, IB, IC)

0.1–2.00 A secondary (1 A nominal phase current inputs, IA, IB, IC)

The 50P32P setting is set to pick up for all three-phase faults that need to be covered by the phase overcurrent elements. It supervises the positive-sequence voltage-polarized directional elements F32P and R32P (see *Figure 4.26*).

If the load-encroachment logic is enabled (enable setting ELOAD = Y), then setting 50P32P is not made or displayed, but is fixed internally at:

0.5 A secondary (5 A nominal phase current inputs, IA, IB, IC)

0.1 A secondary (1 A nominal phase current inputs, IA, IB, IC)

Z2F—Forward Directional Z2 Threshold

Z2R—Reverse Directional Z2 Threshold

Setting Range:

–128.00 to 128.00 Ω secondary (5 A nominal phase current inputs, IA, IB, IC)

–640.00 to 640.00 Ω secondary (1 A nominal phase current inputs, IA, IB, IC)

Z2F and Z2R are used to calculate the Forward and Reverse Thresholds, respectively, for the negative-sequence voltage-polarized directional elements (see *Figure 4.14* and *Figure 4.25*).

If enable setting E32 = Y, settings Z2F and Z2R (negative-sequence impedance values) are calculated and entered by the user, but setting Z2R must be greater in value than setting Z2F by 0.1 Ω secondary.

Z2F and Z2R Set Automatically

NOTE: If Z2F or Z2R exceeds the setting range, the quantity is set to the upper limit of the setting range.

If enable setting E32 = AUTO, settings Z2F and Z2R (negative-sequence impedance values) are calculated automatically, using the positive-sequence line impedance magnitude setting Z1MAG as follows:

Z2F = **Z1MAG/2** (Ω secondary)

Z2R = **Z1MAG/2 + z** (Ω secondary; "z" listed in table below)

Relay Configuration	z (Ω secondary)
5 A nominal current	0.2
1 A nominal current	1.0

Figure 4.32 and *Figure 4.33* and supporting text concern the zero-sequence impedance network, relay polarity, and the derivation of settings Z0F and Z0R. The same general approach outlined for deriving settings Z0F and Z0R can also be applied to deriving settings Z2F and Z2R in the negative-sequence impedance network, though the preceding method of automatically making settings Z2F and Z2R usually suffices.

50QFP—Forward Directional Negative-Sequence Current Pickup

50QRP—Reverse Directional Negative-Sequence Current Pickup

Setting Range:

0.25–5.00 A secondary (5 A nominal phase current inputs, IA, IB, IC)

0.05–1.00 A secondary (1 A nominal phase current inputs, IA, IB, IC)

The 50QFP setting ($3I_2$ current value) is the pickup for the forward fault detector 50QF of the negative-sequence voltage-polarized directional elements (see *Figure 4.11*). Ideally, the setting is above normal load unbalance and below the lowest expected negative-sequence current magnitude for unbalanced forward faults.

The 50QRP setting ($3I_2$ current value) is the pickup for the reverse fault detector 50QR of the negative-sequence voltage-polarized directional elements (see *Figure 4.11*). Ideally, the setting is above normal load unbalance and below the lowest expected negative-sequence current magnitude for unbalanced reverse faults.

50QFP and 50QRP Set Automatically

If enable setting E32 = AUTO, settings 50QFP and 50QRP are set automatically at:

50QFP = 0.50 A secondary (5 A nominal phase current inputs, IA, IB, IC)

50QRP = 0.25 A secondary (5 A nominal phase current inputs, IA, IB, IC)

50QFP = 0.10 A secondary (1 A nominal phase current inputs, IA, IB, IC)

50QRP = 0.05 A secondary (1 A nominal phase current inputs, IA, IB, IC)

a2—Positive-Sequence Current Restraint Factor, I_2/I_1

Setting Range:

0.02–0.50 (unitless)

Refer to *Figure 4.11*.

The a2 factor increases the security of the negative-sequence voltage-polarized directional elements. It keeps the elements from operating for negative-sequence current (system unbalance), which circulates because of line asymmetries, CT saturation during three-phase faults, etc.

a2 Set Automatically

If enable setting E32 = AUTO, setting a2 is set automatically at:

a2 = **0.1**

For setting a2 = 0.1, the negative-sequence current (I_2) magnitude has to be greater than 1/10 of the positive-sequence current (I_1) magnitude in order for the negative-sequence voltage-polarized directional elements to be enabled ($|I_2| > 0.1 \bullet |I_1|$).

k2—Zero-Sequence Current Restraint Factor, I_2/I_0

Setting Range:

0.10–1.20 (unitless)

Note the internal enable logic outputs in *Figure 4.11*:

- 32QE—internal enable for the negative-sequence voltage-polarized directional element that controls the negative-sequence and phase overcurrent elements
- 32QGE—internal enable for the negative-sequence voltage-polarized directional element that controls the neutral ground and residual ground overcurrent elements

The k2 factor is applied to internal enable 32QGE. The negative-sequence current (I_2) magnitude has to be greater than the zero-sequence current (I_0) magnitude multiplied by k2 in order for the 32QGE internal enable (and following negative-sequence voltage-polarized directional element in *Figure 4.14*) to be enabled:

$$|I_2| > k2 \bullet |I_0|$$

Equation 4.1

This check ensures that the relay uses the most robust analog quantities in making directional decisions for the neutral-ground and residual-ground overcurrent elements.

The zero-sequence current (I_0), referred to in the above application of the k2 factor, is from the residual current (I_G), which is derived from phase currents I_A, I_B, and I_C:

$$I_0 = \frac{I_G}{3}$$

$$3I_0 = I_G = I_A + I_B + I_C$$

Equation 4.2

If both of the internal enables:

- 32VE—internal enable for the zero-sequence voltage-polarized directional element that controls the neutral-ground and residual-ground overcurrent elements
- 32IE—internal enable for the channel **IN** current-polarized directional element that controls the neutral-ground and residual-ground overcurrent elements

are deasserted, then factor k2 is ignored as a logic enable for the 32QGE internal enable. This effectively puts less restrictions on the operation of the negative-sequence voltage-polarized directional element.

k2 Set Automatically

If enable setting E32 = AUTO, setting k2 is set automatically at:

k2 = **0.2**

For setting k2 = 0.2, the negative-sequence current (I_2) magnitude has to be greater than 1/5 of the zero-sequence current (I_0) magnitude in order for the negative-sequence voltage-polarized directional elements to be enabled ($|I_2| > 0.2 \bullet |I_0|$). Again, this presumes at least one of the internal enables 32VE or 32IE is asserted.

50GFP—Forward Directional Residual Ground Current Pickup

50GRP—Reverse Directional Residual Ground Current Pickup

Setting Range:

0.05–5.00 A secondary (5 A nominal phase current inputs, **IA**, **IB**, **IC**)

0.01–1.00 A secondary (1 A nominal phase current inputs, **IA**, **IB**, **IC**)

If setting ORDER does not contain V or I (no zero-sequence voltage-polarized or channel IN current-polarized directional elements are enabled), then settings 50GFP and 50GRP are not made or displayed.

The 50GFP setting ($3I_0$ current value) is the pickup for the forward fault detector 50GF of the zero-sequence voltage-polarized and channel IN current-polarized directional elements (see *Figure 4.12*). Ideally, this setting is above normal load unbalance and below the lowest expected zero-sequence current magnitude for unbalanced forward faults.

The 50GRP setting ($3I_0$ current value) is the pickup for the reverse fault detector 50GR of the zero-sequence voltage-polarized and channel IN current-polarized directional elements (see *Figure 4.12*). Ideally, this setting is above normal load unbalance and below the lowest expected zero-sequence current magnitude for unbalanced reverse faults.

See *Petersen Coil Considerations for Setting ORDER* on page 4.48 for more information on setting 50GFP and 50GRP for a Petersen Coil-grounded system.

50GFP and 50GRP Set Automatically

If enable setting E32 = AUTO, settings 50GFP and 50GRP are set automatically at:

50GFP = 0.50 A secondary (5 A nominal phase current inputs, **IA**, **IB**, **IC**)

50GRP = 0.25 A secondary (5 A nominal phase current inputs, **IA**, **IB**, **IC**)

50GFP = 0.10 A secondary (1 A nominal phase current inputs, **IA**, **IB**, **IC**)

50GRP = 0.05 A secondary (1 A nominal phase current inputs, **IA**, **IB**, **IC**)

Operation of the Channel IN Current-Polarized Directional Element

Figure 4.16 shows the logic for the current-polarized directional element for ground faults. Traditional elements of this type use the directional characteristics shown in *Figure 4.30*, where the maximum torque line of the element is in phase with the polarizing current, I_N. This is adequate for solidly-grounded and most low-impedance grounded systems.

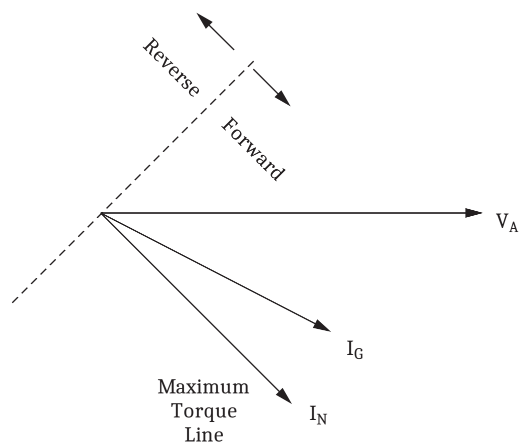


Figure 4.30 Traditional Channel IN Current-Polarized Directional Element

In certain impedance grounded systems with high line charging capacitance, capacitive currents can cause the traditional element to improperly declare reverse currents as forward, causing unfaulted circuits to trip during ground faults. This can be prevented by adjustment of the maximum torque angle using the setting INMTA, as shown in *Figure 4.31*.

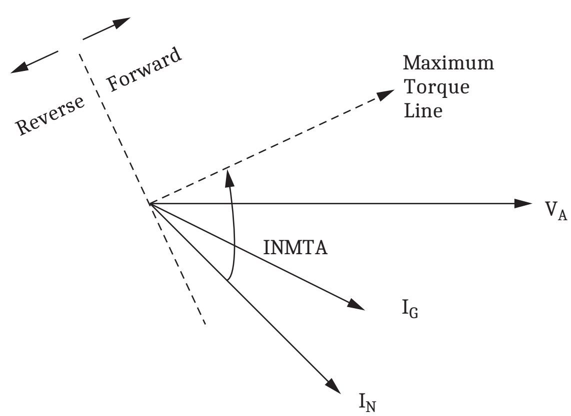


Figure 4.31 Current-Polarized Directional Element Characteristic When INMTA ≠ 0.00

KGN—Neutral Restraint Factor

Setting Range:

OFF, 0.001–0.1 (unitless)

If setting ORDER does not contain I (no channel IN current-polarized directional elements are enabled), or E32 = N, or E32 = AUTO, then setting KGN is not made or displayed and KGN is set to OFF internally.

When traditional operation of the Channel IN Current-Polarized Directional Element is desired, set KGN = OFF. With this setting, the maximum torque line of the element is in phase with the polarizing current, I_N, i.e., INMTA is effectively 0 (see *Figure 4.30*). This is the proper setting for solidly-grounded and most impedance grounded applications.

When KGN is set to a value other than OFF, the measured residual current, IG, must be greater than KGN • I_N • CTRN/CTR before the element is allowed to operate (see *Figure 4.12*). This provides additional security for the directional element when there is false residual current because of mismatch of the phase CTs of an unfaulted feeder. The neutral channel current, I_N, is scaled by CTRN/CTR to place it on the same base as the residual current, I_G.

INMTA—Neutral Maximum Torque Angle

Setting Range:

0–85 degrees

If KGN = OFF, then setting INMTA is not made or displayed and INMTA is set to 0 internally.

The polarizing quantity IN of the Channel IN Current-Polarized Directional Element is rotated INMTA degrees counter-clockwise (see *Figure 4.31*).

See the technical paper "Selecting Directional Elements for Impedance-Grounded Distribution Systems" by Ronald Lavorin, Daqing Hou, Hector J. Altuve, Normann Fischer, and Fernando Calero, available on the SEL website for more information on how to determine the settings for KGN and INMTA.

a0—Positive-Sequence Current Restraint Factor, I_0/I_1

Setting Range:

0.02–0.50 (unitless) when KGN is set to OFF
0.001–0.50 (unitless) when KGN is set to a value other than OFF

If setting ORDER does not contain V or I (no zero-sequence voltage-polarized or channel IN current-polarized directional elements are enabled), then setting a0 is not made or displayed.

Refer to *Figure 4.12*.

The a0 factor increases the security of the zero-sequence voltage-polarized and channel IN current-polarized directional elements. This factor keeps the elements from operating for zero-sequence current (system unbalance), which circulates because of line asymmetries, CT saturation during three-phase faults, etc.

The zero-sequence current (I_0), referred to in the application of the a0 factor, is from the residual current (I_G), which is derived from phase currents I_A, I_B, and I_C:

$$I_0 = \frac{I_G}{3}$$
$$3I_0 = I_G = I_A + I_B + I_C$$

Equation 4.3

a0 Set Automatically

If enable setting E32 = AUTO, setting a0 is set automatically at:

a0 = **0.1**

For setting a0 = 0.1, the zero-sequence current (I_0) magnitude has to be greater than 1/10 of the positive-sequence current (I_1) magnitude in order for the zero-sequence voltage-polarized and channel IN current-polarized directional elements to be enabled ($|I_0| > 0.1 \cdot |I_1|$).

Z0F—Forward Directional Z0 Threshold

Z0R—Reverse Directional Z0 Threshold

Setting Range:

–128.00 to 128.00 Ω secondary (300 V voltage inputs, **VA**, **VB**, **VC**; 5 A nominal phase current inputs, **IA**, **IB**, **IC**)

–640.00 to 640.00 Ω secondary (300 V voltage inputs, **VA**, **VB**, **VC**; 1 A nominal phase current inputs, **IA**, **IB**, **IC**)

If setting ORDER does not contain V or S (no zero-sequence voltage-polarized directional element is enabled), then settings Z0F and Z0R are not made by the user or displayed.

Z0F and Z0R are used to calculate the Forward and Reverse Thresholds, respectively, for the zero-sequence voltage-polarized directional elements (see *Figure 4.15* and *Figure 4.17*).

If enable setting E32 = Y, settings Z0F and Z0R (zero-sequence impedance values) are calculated by the user and entered by the user, but setting Z0R must be greater in value than setting Z0F by 0.1 Ω secondary.

Z0F and Z0R Set Automatically

NOTE: If Z0F or Z0R exceeds the setting range, the quantity is set to the upper limit of the setting range.

NOTE: Z0F and Z0R (Ω secondary) are set in reference to the phase current channels **IA**, **IB**, and **IC**, as are settings Z2F and Z2R. However, settings Z0F and Z0R are applied to *Figure 4.17*, and *Figure 4.19*, where neutral current I_N, from neutral current channel **IN**, is also applied. Settings Z0F and Z0R are adjusted internally (with CT ratio settings) to operate on this I_N current base, when needed (effectively, Z0F • CTRN/CTR and Z0R • CTRN/CTR). See *Internal Enables* on page 4.19.

If enable setting E32 = AUTO, settings Z0F and Z0R (zero-sequence impedance values) are calculated automatically, using the zero-sequence line impedance magnitude setting Z0MAG as follows:

Z0F = **Z0MAG/2** (Ω secondary)

Z0R = **Z0MAG/2 + z** (Ω secondary; “z” listed in table below)

Relay Configuration	z (Ω secondary)
5 A nominal current	0.2
1 A nominal current	1.0

If setting ORDER = U (ungrounded or high-impedance grounded system; see *Figure 4.19*), the following settings are made internally and hidden:

Z0F = **-0.10 Ω secondary**

Z0R = **0.10 Ω secondary**

Deriving Z0F and Z0R Settings

Figure 4.32 shows the voltage and current polarity for an SEL-351 in a zero-sequence impedance network (the same approach can be instructive for negative-sequence impedance analysis, too). For a forward fault, the SEL-351 effectively sees the sequence impedance behind it as:

$Z_M = V_0/(-I_0) = -(V_0/I_0)$

$V_0/I_0 = -Z_M$ (what the relay sees for a forward fault)

For a reverse fault, the SEL-351 effectively sees the sequence impedance in front of it:

$Z_N = V_0/I_0$

$V_0/I_0 = Z_N$ (what the relay sees for a reverse fault)

If the system in *Figure 4.32* is a solidly-grounded system (mostly inductive; presume uniform system angle), and the load is connected line-to-neutral, the impedance plot (in the R + jX plane) would appear as in *Figure 4.33a*, with resultant Z0F and Z0R settings as in *Figure 4.33b*. The zero-sequence line angle noted in *Figure 4.33a* (∠Z0MTA) is the same angle found in *Figure 4.15* and *Figure 4.17* (in the equation box with the Enable line).

The preceding method of automatically making settings Z0F and Z0R (where both Z0F and Z0R are positive values and Z0R > Z0F) usually suffices for mostly inductive systems—*Figure 4.32* and *Figure 4.33* just provide a theoretical background.

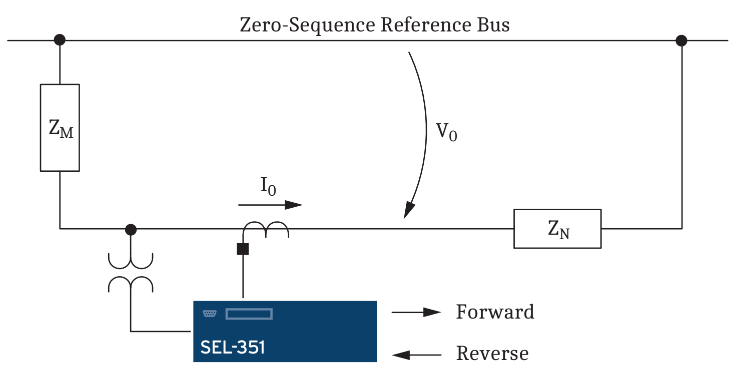


Figure 4.32 Zero-Sequence Impedance Network and Relay Polarity

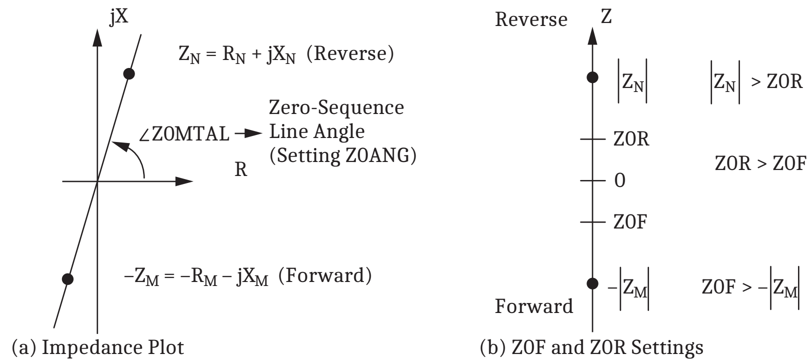


Figure 4.33 Zero-Sequence Impedance Plot for Solidly-Grounded, Mostly Inductive System

Z0MTA—Zero-Sequence Maximum Torque Angle

Setting Range:

–90.00 to –5.00 degrees and 5.00 to 90.00 degrees

The Z0MTA setting is at the heart of the zero-sequence voltage-polarized directional element of *Figure 4.15*. Z0MTA is only available if both of the following conditions are true:

- enable setting E32 = AUTO or Y
- setting ORDER contains the value "V" or "S"

Otherwise, Z0MTA is hidden and of no consequence. Z0MTA can be set one of two ways:

STILL MAKE SETTING Z0ANG WHEN E32 = Y
Even though setting Z0MTA is not automatically set equal to the value of setting Z0ANG when enable setting E32 = Y, setting Z0ANG should still be made for fault location purposes.

- If enable setting E32 = AUTO, then Z0MTA is automatically set equal to the value of setting Z0ANG (the setting range of Z0MTA encompasses that of setting Z0ANG).

  As long as E32 = AUTO, Z0MTA can be seen, but not changed. This automatic setting mode is primarily for traditional applications, where the angle of the zero-sequence system impedance behind the relay is deemed to be essentially the same as the angle of the zero-sequence line impedance in front of it (see *Figure 4.32* and *Figure 4.33*[a]).
- If enable setting E32 = Y, then Z0MTA is set independently within its setting range.

  This option is primarily used for such applications as low-impedance grounded systems, which are discussed in the balance of this subsection.

The distribution system in *Figure 4.34* is low-impedance grounded at the substation by either of the following methods:

- a resistance in the transformer bank neutral
- a grounding bank with a resistance in its broken-delta secondary (effectively making it a neutral resistance)

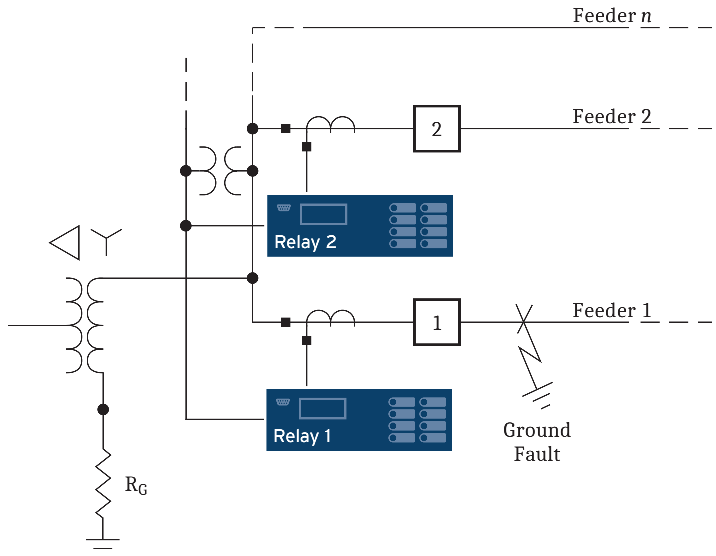


Figure 4.34 Low-Impedance Grounded Distribution System With a Ground Fault on Feeder 1

A grounding bank is installed if low-impedance grounding is desired at a substation and the transformer bank is to remain ungrounded. *Figure 4.34* also shows a ground fault out on Feeder 1 (a forward fault from the perspective of Relay 1). This example assumes that SEL-351 Relays (Relay 1, Relay 2, etc.) are installed at feeder positions in a distribution substation.

Figure 4.35 shows the resultant zero-sequence impedance network for the ground fault on Feeder 1 in *Figure 4.34*. V_0 in *Figure 4.35* is the zero-sequence voltage seen by all the relays connected to the distribution substation bus three-phase voltage.

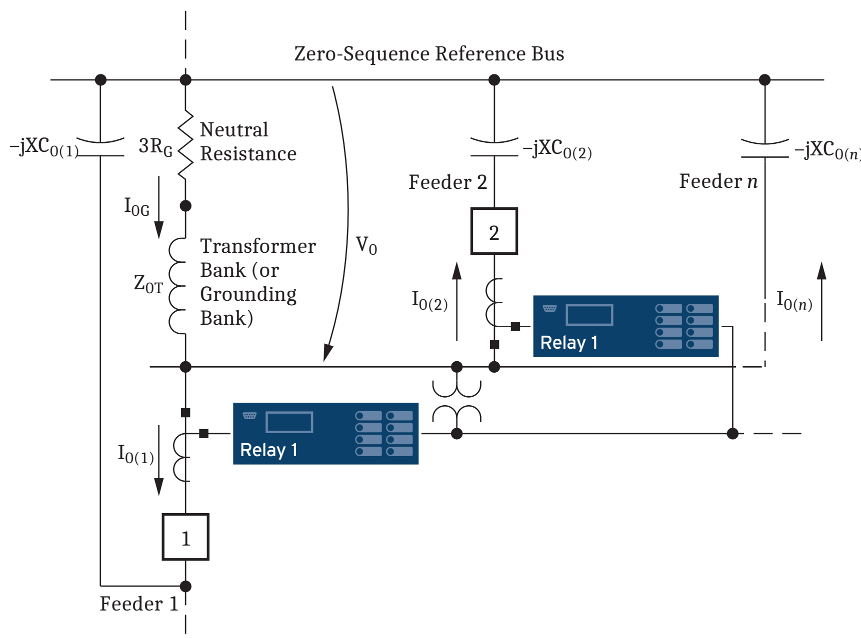


Figure 4.35 Zero-Sequence Impedance Network for Low-Impedance Grounded Distribution System With a Ground Fault on Feeder 1

Impedance definitions for *Figure 4.35*:

- $-jXC_{0(1)}$ = zero-sequence capacitive reactance for Feeder 1 (the faulted feeder)
- $-jXC_{0(2)}$ = zero-sequence capacitive reactance for Feeder 2
- $-jXC_{0(n)}$ = zero-sequence capacitive reactance for the cumulative other feeders
- Z_{0T} = transformer bank (or grounding bank) zero-sequence impedance
- R_G = neutral resistance, connected to transformer bank (or grounding bank)

The zero-sequence capacitive reactance values of the feeders are much larger than the zero-sequence feeder line impedances, so the zero-sequence feeder line impedances are ignored in this fault analysis.

Current definitions for *Figure 4.35*:

- $I_{0(1)}$ = zero-sequence current flow for Feeder 1 (forward direction for Relay 1)
- $I_{0(2)}$ = zero-sequence current flow for Feeder 2 (forward direction for Relay 2)
- $I_{0(n)}$ = zero-sequence current flow for cumulative other feeders (forward direction for relays on other feeders)
- I_{0G} = zero-sequence current flow through neutral resistance R_G and transformer bank (or grounding bank)

Presume there is a substantial capacitance-creating network (e.g., underground cable) on the individual feeders. As cable capacitance increases, capacitive reactance decreases, allowing for increased capacitive current flow. For the ground fault in *Figure 4.34* (a reverse fault from the perspective of Relay 2), Relay 2 sees zero-sequence current $I_{0(2)}$ flow toward the zero-sequence capacitive reactance $-jXC_{0(2)}$. If this current flow is high enough, a false trip may occur, unless otherwise prevented (e.g., by directional control).

Figure 4.36 plots the increase in zero-sequence current I_{0G} resulting from decreasing neutral resistance R_G.

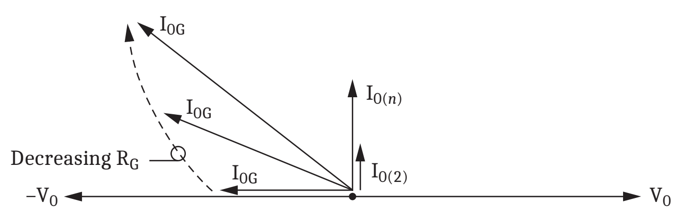


Figure 4.36 Decreasing Neutral Resistance R_G Results in Increasing Zero-Sequence Current I_{0G}

Vectorially add currents $I_{0(2)}$ and $I_{0(n)}$ to I_{0G} (per direction in *Figure 4.35*):

$$I_{0(1)} = I_{0G} - I_{0(2)} - I_{0(n)}$$

Figure 4.37 plots the increase in zero-sequence current $I_{0(1)}$ (seen by Relay 1) resulting from decreasing neutral resistance R_G.

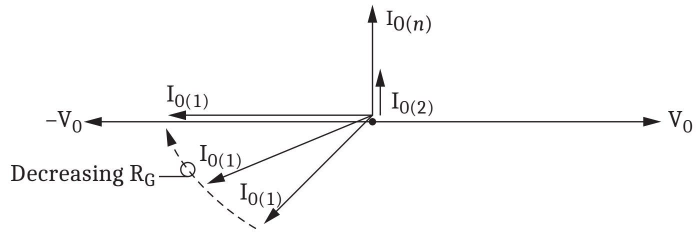


Figure 4.37 Decreasing Neutral Resistance R_G Results in Increasing Zero-Sequence Current $I_{0(1)}$ (Seen by Relay 1)

In *Figure 4.37*, the lowest magnitude of zero-sequence current $I_{0(1)}$ (at 225 degrees from zero-sequence voltage V_0) represents a high-resistance grounded system. The following (absolute value) comparisons are typically true for a high-resistance grounded system:

- $3R_G >> Z_{0T}$ (ignore transformer bank [or grounding bank] impedance Z_{0T})
- $3R_G$ = resultant impedance from the parallel combination of zero-sequence capacitive reactance values $-jXC_{0(2)}$ and $-jXC_{0(n)}$ (the total capacitive reactance behind Relay 1)

As neutral resistance R_G decreases, zero-sequence current $I_{0(1)}$ increases in *Figure 4.37*. The system is moving away from being a high-resistance grounded system toward being a low-resistance grounded system.

The zero-sequence voltage/current vector values of *Figure 4.37* are converted (using polarity and impedances in *Figure 4.35*) to the apparent zero-sequence impedances that the respective relays see, as plotted in *Figure 4.38*:

- Ground fault on Feeder 1 is in the forward direction for Relay 1:

$V_0/(-I_{0(1)})$ = parallel combination of zero-sequence impedance values $-jXC_{0(2)}$, $-jXC_{0(n)}$, and $3R_G + Z_{0T}$

$V_0/I_{0(1)}$ = –(parallel combination of zero-sequence impedance values $-jXC_{0(2)}$, $-jXC_{0(n)}$, and $3R_G + Z_{0T}$)

$V_0/I_{0(1)}$ = the negative value of the aggregate zero-sequence impedance behind Relay 1

- Ground fault on Feeder 1 is in the reverse direction for Relay 2:

$V_0/I_{0(2)} = -jXC_{0(2)}$

$V_0/I_{0(2)}$ = the zero-sequence capacitive reactance for Feeder 2 in front of Relay 2

APPLY ZOMTA TO HIGH-RESISTANCE GROUNDED SYSTEM?

This example for the ZOMTA setting discussion addresses low-impedance grounded systems. A high-resistance grounded system (with its lower zero-sequence current values for ground fault conditions) requires that channel IN be connected to a separate current transformer, instead of in a factory-standard residual connection with the phase current channels.

Such a separate current transformer would have the three primary phase wires running through its core, eliminating any false residual current. Such current transformer applications are often referred to by one of the following names: flux-summing, core-balance, zero-sequence, ground fault, or window current transformers.

Other settings (see *Figure 4.12* and *Figure 4.15*) also have to be considered to make sure they are sensitive enough for a high-resistance grounded system application.

The technical paper referenced at the end of this subsection also discusses directional element applications for high-resistance grounded systems.

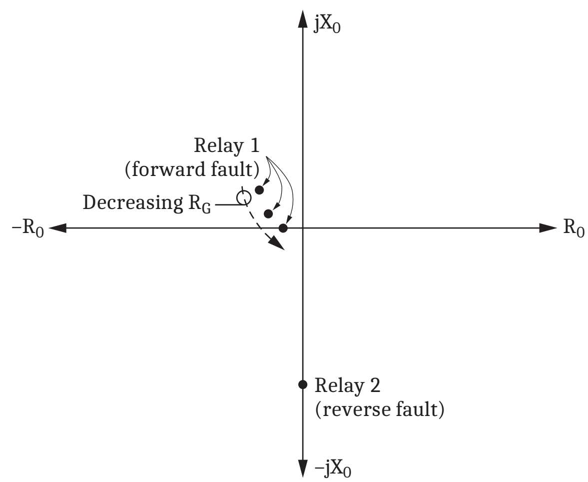


Figure 4.38 Zero-Sequence Impedance Plots for Ground Fault on Low-Impedance Grounded Distribution System

Presuming that all of the feeders in this distribution substation example have roughly the same amount of capacitance-creating network (e.g., underground cable), then the following will apply:

- The Relay 1 apparent zero-sequence impedance plot in *Figure 4.38* is representative of a ground fault in front of any relay in the substation (forward fault).
- The Relay 2 apparent zero-sequence impedance plot in *Figure 4.38* is representative of a ground fault behind any relay in the substation (e.g., a ground fault on another parallel feeder; reverse fault).

The forward/reverse impedance plots in *Figure 4.38* appear asymmetric, especially when compared to *Figure 4.33*(a) for a solidly grounded system with sources at each end. The Z0MTA setting in *Figure 4.33*(a) would (by inspection) be approximately 75 degrees.

Contrastingly, the Z0MTA setting for *Figure 4.38* has to allow the forward/reverse characteristic to fit in between the forward/reverse impedance plots. The forward impedance plot is the most critical to accommodate—one definitely wants to operate for a forward fault. This necessitates a Z0MTA setting of approximately –40 degrees (for the lowest value of neutral resistance R_G), as shown in *Figure 4.39* for this example. Necessary settings are as follows:

Group Settings

E32 = **Y**

Z0F = **–0.05**

Z0R = **0.05**

Z0MTA = **–40.00**

Other directional settings also have to be made (see *Figure 4.12* and *Figure 4.15*).

All these settings, zero-sequence voltage, and zero-sequence current converge on the zero-sequence voltage-polarized directional element in *Figure 4.15* (and its preceding enable logic in *Figure 4.12*) to produce the directional characteristic in *Figure 4.39*.

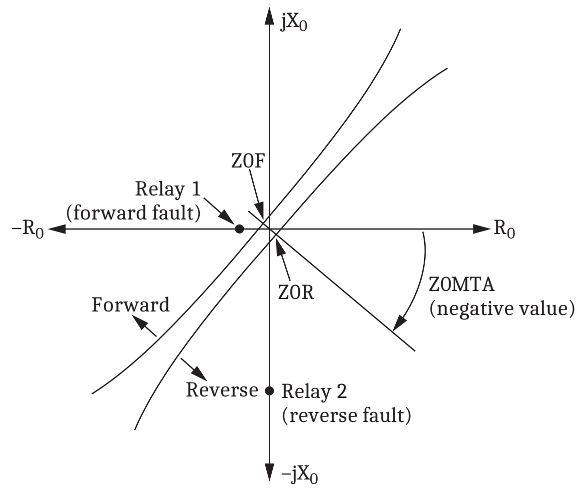


Figure 4.39 Z0MTA Setting Provides Forward/Reverse Ground Fault Discrimination in a Low-Impedance Grounded Distribution System

For more details on applying the Z0MTA setting on low-impedance grounded systems, refer to the following technical paper (available at selinc.com):

> *Selecting Directional Elements for Impedance-Grounded Distribution Systems* by Ronald Lavorin (Southern California Edison), Daqing Hou, Héctor J. Altuve, Normann Fischer, and Fernando Calero (Schweitzer Engineering Laboratories, Inc.)

In this paper, especially see pertinent discussion on modified 32V (zero-sequence voltage-polarized directional) elements in the following subsections:

- V. Modified Directional Elements for Low-Impedance-Grounded Systems with High Charging Capacitances
- VI. Analysis of a Practical Resistance-Grounded System

  This subsection includes setting considerations involving the transformer bank (or grounding bank) zero-sequence impedance Z_{0T} and the neutral resistance R_G.

50NFP—Forward Directional Neutral Ground Current Pickup

50NRP—Reverse Directional Neutral Ground Current Pickup

Setting Range:

> 0.005–5.00 A secondary (0.2 A nominal neutral channel input, **IN**)

If setting ORDER does not contain S or U (zero-sequence voltage-polarized directional elements: low-impedance or ungrounded/high-impedance grounded, are not enabled) or the model does not have a 0.2 A nominal neutral channel (IN), then settings 50NFP and 50NRP are not made or displayed.

NOTE: 50NFP and 50NRP (A secondary) are set in terms of the neutral current I_N, from neutral current channel IN. However, as discussed in *Internal Enables* on page 4.19, settings 50NFP and 50NRP are applied to *Figure 4.13*, *Figure 4.17*, and *Figure 4.19*, where residual current I_G (derived from phase current channels **IA**, **IB**, and **IC**) can be applied, depending on current magnitudes. Settings 50NFP and 50NRP are adjusted internally to operate on this residual current I_G base, when needed (effectively, 50NFP • CTRN/CTR and 50NRP • CTRN/CTR).

The 50NFP setting (I_N current value) is the pickup for the forward fault detector 50NF of the zero-sequence voltage-polarized directional elements: low-impedance or ungrounded/high-impedance grounded (see *Figure 4.13*). Ideally, this setting is above normal load unbalance and below the lowest expected zero-sequence current magnitude for unbalanced forward faults.

The 50NRP setting (I_N current value) is the pickup for the reverse fault detector 50NR of the zero-sequence voltage-polarized directional elements: low-impedance or ungrounded/high-impedance grounded (see *Figure 4.13*). Ideally, this setting is above normal load/system unbalance and below the lowest expected zero-sequence current magnitude for unbalanced reverse faults.

a0N—Positive-Sequence Current Restraint Factor, I_N/I_1

Setting Range:

0.001–0.500 (unitless)

If setting ORDER does not contain S or U (zero-sequence voltage-polarized directional elements: low-impedance grounded or ungrounded/high-impedance grounded, are not enabled) or the model does not have a 0.2 A nominal neutral channel (IN), then setting a0N is not made or displayed.

Refer to *Figure 4.13*. The following comparison is made as part of internal enable 32NE (for low-impedance grounded and ungrounded/high-impedance grounded systems):

$|I_N| > a0N \bullet |I_1|$

I_N is the secondary current measured by neutral channel **IN**. I_1 is the positive-sequence secondary current derived from the phase current channels **IA**, **IB**, and **IC**. Presumably, channel **IN** is connected in such a manner that it sees the system zero-sequence current (e.g., channel **IN** is connected to a core-balance CT through which the three phase conductors pass; in such a connection, channel IN sees $3I_0$ zero-sequence current, $I_N = 3I_0$; see *Figure 2.23*, *Figure 2.25*, and *Figure 2.26*).

If a core-balance current transformer is connected to neutral channel **IN**, it most likely has a different ratio, compared to the current transformers connected to the phase current channels **IA**, **IB**, and **IC** (CT ratio settings CTRN and CTR, respectively).

From a primary system study, load profile values, or metering values, derive a0N as follows:

$a0N = (3I_0 \text{ pri.}/I_1 \text{ pri.}) \bullet (CTR/CTRN)$

$3I_0$ pri. = standing system unbalance current (zero-sequence; A primary)

I_1 pri. = maximum load current (positive-sequence; A primary)

Adjust the final setting value of a0N from the above derived value of a0N, depending on your security philosophy, etc.

The a0N factor increases the security of the zero-sequence voltage-polarized directional elements: low-impedance grounded or ungrounded/high-impedance grounded. It keeps the elements from operating for zero-sequence current (system unbalance), which circulates because of line asymmetries, etc.

59RES—Wattmetric $3V_0$ Overvoltage Pickup (Petersen Coil-Grounded System)

Setting Range:

1.00–430.00 V secondary (300 V nominal voltage inputs, **VA**, **VB**, **VC**)

If setting ORDER does not contain P (Petersen Coil directional element is not enabled) or the model does not have a 0.2 A nominal neutral channel (**IN**), then setting 59RES is not made or displayed.

Setting 59RES should be set greater than the value of $3V_0$ zero-sequence voltage present for normal system unbalance. It is part of the enabling logic for the wattmetric element part of the Petersen Coil directional element (see *Figure 4.18*).

The $3V_0$ input to *Figure 4.18* may come either from a calculation or from a direct measurement, as described in *Zero-Sequence Voltage Sources* on page 4.21. When using a broken-delta PT connection to terminals **VS-NS** as the zero-sequence voltage source (Global setting VSCONN = 3V0), there are some special considerations in making the 59RES setting that are related to the scaling of the **VS-NS** input signal. The 59RES setting must be entered on the same secondary base as the voltage terminals **VA**, **VB**, and **VC**. See *Settings Considerations for Petersen Coil-Grounded Systems* on page 4.65 for an example.

32WFP and 32WRP—Wattmetric Forward and Reverse Pickups (Petersen Coil-Grounded System)

Setting Range:

0.001–150.000 Ω secondary

If setting ORDER does not contain P (Petersen Coil directional element is not enabled) or the model does not have a 0.2 A nominal neutral channel (**IN**), then settings 32WFP and 32WRP are not made or displayed.

Quantities needed to make the 32WFP and 32WRP wattmetric pickups calculations are:

$3V_0$ zero-sequence voltage in secondary (from inputs, **VA**, **VB**, **VC**; or input **VS** when VSCONN = 3V0)

I_N current in secondary (from 0.2 A nominal neutral channel input, **IN**)

The $3V_0$ input to *Figure 4.18* may come either from a calculation or from a direct measurement, as described in *Zero-Sequence Voltage Sources* on page 4.21. When using a broken-delta PT connection to terminals **VS-NS** as the zero-sequence voltage source (Global setting VSCONN = 3V0), there are some special considerations in making the 32WFP and 32WRP settings that are related to the scaling of the **VS-NS** input signal. The 32WFP and 32WRP settings must be entered on the same secondary base as the voltage terminals **VA**, **VB**, and **VC**. See *Settings Considerations for Petersen Coil-Grounded Systems* on page 4.65 for an example.

I_N is the current measured by current channel **IN**. Channel **IN** is connected in such a manner that it monitors the system zero-sequence current (e.g., channel **IN** is connected to a window CT through which the three phase conductors pass and thus monitors $3I_0$ zero-sequence current, see *Figure 2.24*). With such a connection:

$I_N = 3I_0$

In *Figure 2.24*, only one feeder position is shown, but one can imagine the bus extending to the right, with other feeder positions. The Petersen Coil in the transformer neutral is tuned to cancel out the cumulative zero-sequence line capacitance of all the connected feeders. The Petersen Coil and the zero-sequence line capacitance are a parallel LC circuit. In a "tuned state," they create a high impedance circuit and thus a power system that is essentially ungrounded (with much less current flow than a traditional ungrounded system). In such an optimum tuned state, little current flows through the Petersen Coil. Some Petersen Coils are continually adjusted automatically, as load levels/system topology change, so that tuning remains optimum. The "tuned circuit" resists sustaining an arc, so many ground faults are self-extinguished by the circuit itself (no circuit breaker operation necessary).

Consider a permanent line-to-ground fault out on the feeder in *Figure 2.24* (refer to the relay and feeder shown in *Figure 2.24* as Relay 1 and Feeder 1, respectively. Other feeders on the same bus, though not shown in *Figure 2.24*, are then Relay 2/Feeder 2, etc.). In the zero-sequence network view in *Figure 4.40*, Relay 2 (on unfaulted Feeder 2) sees mostly capacitance in front of it. Assuming a "tuned circuit," $I_0 = 0$ at the fault. Thus, the entire zero-sequence capacitance shown in *Figure 4.40* is canceled out by the inductance of the Petersen Coil. So, with Feeder 1 capacitance C_1 in front of Relay 1, the system behind Relay 1 appears net inductive.

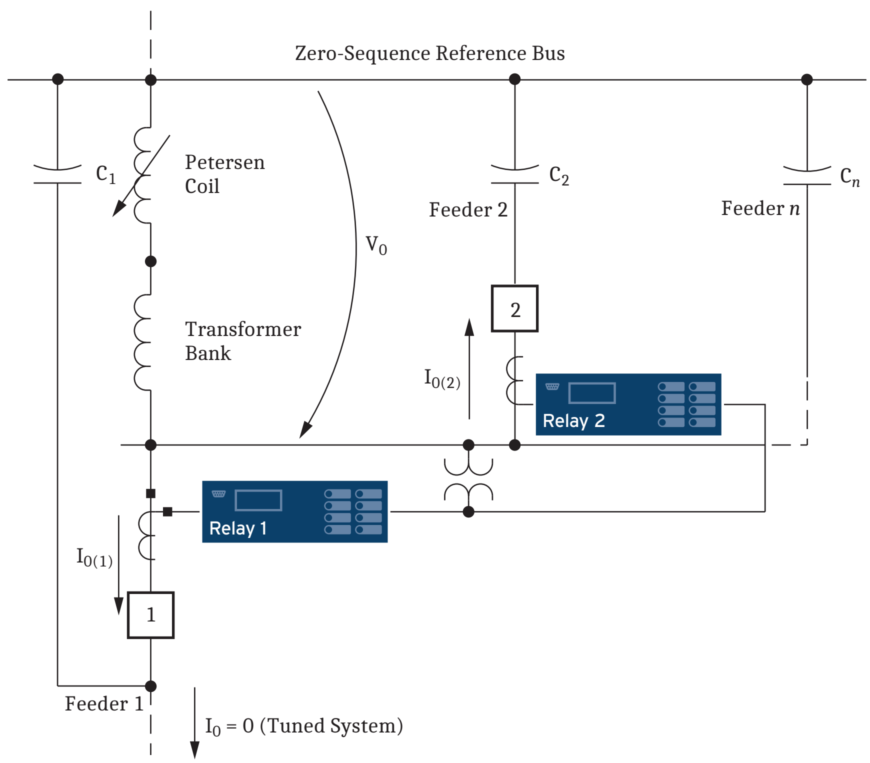


Figure 4.40 Zero-Sequence Impedance Network for Ground Fault on Feeder 1

Figure 4.41 shows the zero-sequence vector relationships described above for *Figure 4.40* (note: the zero-sequence currents $I_{0(1)}$ and $I_{0(2)}$ are what the relays respectively "see," per standard current transformer connections—see *Figure 2.24*). The vectors shown in *Figure 4.41* are perhaps somewhat over-dramatic as far as angle differences—they are primarily for illustrative purposes.

There is always some resistance in a circuit and thus the V_0 and I_0 vector relationship is not 90 degrees, as shown in *Figure 4.41*. This system resistance provides the "real power component" with which the wattmetric directional element

(*Figure 4.18*) operates. Whether the zero-sequence network behind Relay 1 appears net capacitive or net inductive, the wattmetric (real power) portion for Relay 1/faulted Feeder 1 (labeled "WF") is polar-opposite of the wattmetric (real power) portion for Relay 2/unfaulted Feeder 2 (labeled "WR"). The calculations for the 32WFP and 32WRP wattmetric pickups are made as follows:

$$\text{Real }(3V_0 \bullet \text{conjugate }[3I_0]) = |3V_0| \bullet |3I_0| \bullet \cos(\angle 3V_0 - \angle 3I_0) = |3V_0| \bullet |I_N| \bullet \cos(\angle 3V_0 - \angle I_N)$$

The cosine part of the above calculation reveals forward or reverse fault direction: forward faults produce negative calculation values and reverse faults produce positive calculation values on Petersen Coil-grounded systems. Calculate the 32WFP and 32WRP wattmetric pickup settings (in watts secondary), with a margin of more sensitivity than the minimum detected ground faults (forward and reverse, respectively). Enter wattmetric settings as positive values.

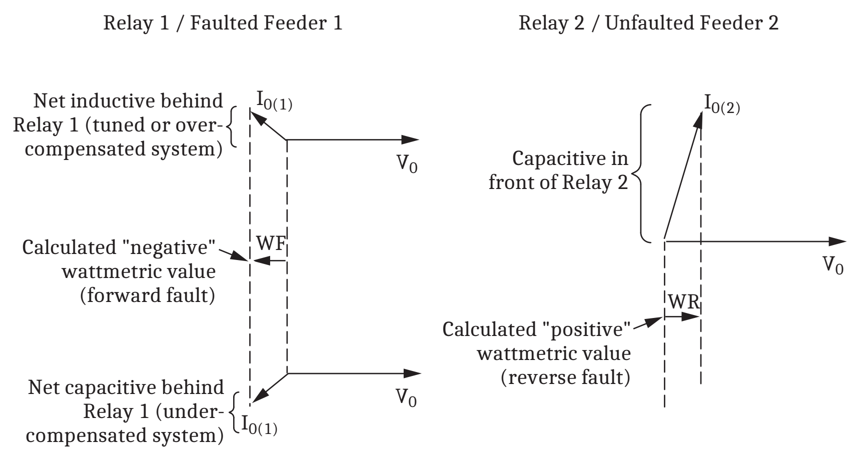


Figure 4.41 Wattmetric Element Operation for Ground Fault on Feeder 1

The sum of settings 32WFP and 32WRP must be 0.1 watts secondary or greater:

$$32WFP + 32WRP \geq 0.1 \text{ watts secondary}$$

In *Figure 4.41*, the calculated wattmetric value for a forward fault is a negative value (shown as WF), while that for a reverse fault is a positive value (shown as WR). Again, corresponding settings 32WFP and 32WRP are both entered as positive values, with some margin of sensitivity. The above "0.1 watts secondary" rule is effectively the minimum distance between settings 32WFP and 32WRP in the wattmetric plane (setting 32WFP is put on the "negative" side of the wattmetric plane: i.e., "–32WFP"; see *Figure 4.18*).

32WD—Wattmetric Delay (Petersen Coil-Grounded System)

Setting Range:

30.00–999,999.00 cycles

If setting ORDER does not contain P (Petersen Coil directional element is not enabled) or the model does not have a 0.2 A nominal neutral channel (**IN**), then setting 32WD is not made or displayed.

Settings Considerations for Petersen Coil-Grounded Systems

The Petersen Coil elements require a zero-sequence voltage source, which is calculated from voltages V_A, V_B, and V_C when the relay is wye-connected (Global setting PTCONN = WYE and VSCONN = VS), or which is measured from the

VS channel when the relay is connected to a broken-delta $3V_0$ source and Global setting VSCONN = 3V0. Three of the required Petersen Coil element settings, 59RES, 32WFP, and 32WRP, depend on the type of $3V_0$ voltage source and on the PTR and PTRS group settings.

When VSCONN = VS and the relay is wye-connected (PTCONN = WYE), the $3V_0$ source is in secondary volts on the **VA**, **VB**, **VC** input terminal base. In fact, $3V_0$ is calculated from the measured V_A, V_B, and V_C voltages. The 59RES, 32WFP, and 32WRP settings are set in terms of this same base.

An example system similar to *Figure 2.24*, with wye-connected PTs (PT ratio 7200:120; setting PTR = 7200/120 = 60) and a core-flux summation CT (CT ratio 50:5; setting CTRN = 50/5 =10), is used to demonstrate the required setting scaling.

If the desired zero-sequence voltage pickup for the Wattmetric element in primary $3V_0$ is 400 V primary, obtain the proper setting for 59RES by dividing the primary voltage by the PT ratio for voltage inputs **VA**, **VB**, and **VC**:

$$59RES = \frac{\text{V primary}}{\text{PTR}} = \frac{\text{400 V primary}}{60} = \text{6.67 V secondary}$$

If the desired forward Wattmetric element threshold is 24 kW primary, and the desired reverse threshold is 10 kW primary, the correct settings are:

$$32WFP = \frac{\text{W primary}}{\text{PTR} \bullet \text{CTRN}} = \frac{\text{24000 W primary}}{60 \bullet 10} = \text{40.000 W secondary}$$

$$32WRP = \frac{\text{W primary}}{\text{PTR} \bullet \text{CTRN}} = \frac{\text{10000 W primary}}{60 \bullet 10} = \text{16.667 W secondary}$$

When VSCONN = 3V0, with a broken-delta $3V_0$ voltage source connected to the **VS** channel (terminals **VS-NS**), Group setting PTRS must be properly set to give the signal on the **VS** channel the correct scaling in primary units, as displayed under `VS` in the **METER** command response, available via serial port or front panel. The example value PTRS = 96, as shown in *Potential Transformer Ratios and PT Nominal Secondary Voltage Settings* on page 9.22, is used for subsequent examples.

The relay internally converts the **VS** channel signal to the **VA**, **VB**, **VC** voltage base before using it as the $3V_0$ quantity, as shown in *Table 4.10*. Thus, when the zero-sequence voltage pickup for the Wattmetric element is known in terms of the system primary voltage level, the required calculation for setting 59RES is the same as the calculation for the VSCONN = VS example shown previously, which converts the primary zero-sequence voltage value into a secondary value on the **VA**, **VB**, **VC** input terminal base.

Using the example quantities from the VSCONN = VS subsection:

$$59RES = \frac{\text{V primary}}{\text{PTR}} = \frac{\text{400 V primary}}{60} = \text{6.67 V secondary}$$

Note that the primary voltage is divided by the PTR setting, *not* the PTRS setting.

Similarly, the derivation of the 32WFP and 32WRP settings, if they are known in primary Watts, follows the same formula as before:

$$32WFP = \frac{\text{W primary}}{\text{PTR} \bullet \text{CTRN}} = \frac{\text{24000 W primary}}{60 \bullet 10} = \text{40.000 W secondary}$$

$$32\mathrm{WRP} = \frac{\text{W primary}}{\mathrm{PTR} \bullet \mathrm{CTRN}} = \frac{\text{10000 W primary}}{60 \bullet 10} = \text{16.667 W secondary}$$

However, if the desired voltage pickup for the Wattmetric element is known in terms of **VS** channel volts (secondary), then the setting value must be scaled by PTRS/PTR prior to entry. This prescaling makes the 59RES setting match the scaling the relay does when it internally converts the **VS** channel value to the VA, VB, VC voltage base.

For our example system, the desired $3V_0$ pickup in terms of the voltage applied to channel **VS** is:

$$\text{Voltage value (VS channel base)} = \frac{\text{V primary}}{\mathrm{PTRS}}$$

The example $3V_0$ pickup value in terms of the voltage applied to channel **VS** is:

$$\text{Voltage value (VS channel base)} = \frac{\text{400 V primary}}{96} = \text{4.167 V secondary}$$

The 59RES setting is determined as follows:

$$\begin{aligned}59\mathrm{RES} &= \text{V secondary (VS base)} \bullet \frac{\mathrm{PTRS}}{\mathrm{PTR}}\\ &= 4.167 \bullet \frac{96}{60} = \text{6.67 V secondary}\end{aligned}$$

As expected, this is the same value as before.

Similarly, if the desired Wattmetric pickup for the Wattmetric element is known in terms of **VS** channel volts (secondary) and IN channel current (secondary), then the setting value must be scaled by PTRS/PTR prior to entry. This prescaling makes the 32WFP and 32WRP settings match the scaling the relay does when it converts the **VS** value into the VA, VB, VC voltage base.

For our example system, the desired Wattmetric pickup in terms of the voltage applied to channel **VS** and the current applied to channel **IN** is:

$$\text{Wattmetric value (VS and IN Base)} = \frac{\text{W primary}}{\mathrm{PTR}(\mathrm{S} \bullet \mathrm{CTRN})}$$

Forward = 24000 W / (96 • 10) = 25 W secondary.

Reverse = 10000 W / (96 • 10) = 10.417 Ω secondary.

The 32WFP and 32WRP settings are determined as follows:

$$\begin{aligned}32\mathrm{WFP} &= \text{W secondary (VS and IN base)} \bullet \frac{\mathrm{PTRS}}{\mathrm{PTR}}\\ &= 25\text{ W} \bullet \frac{96}{60} = \text{40.000 W secondary (VA, VB, VC, and IN base)}\end{aligned}$$

$$\begin{aligned}32\mathrm{WRP} &= \text{W secondary (VS and IN base)} \bullet \frac{\mathrm{PTRS}}{\mathrm{PTR}}\\ &= \left(10.417\text{ W} \bullet \frac{96}{60}\right)\\ &= \text{16.667 W secondary (VA, VB, VC, and IN base)}\end{aligned}$$

These details are important in relay testing, when the signal applied to the **VS-NS** terminals represents a $3V_0$ zero-sequence voltage signal, and Global setting VSCONN = 3V0. When making test settings or interpreting test results, remember that the relay scales the measured value by PTRS/PTR before using it in the Petersen Coil directional element and in the various zero-sequence voltage-polarized directional elements.

Table 4.10 Effect of Global Settings VSCONN and PTCONN on Petersen Coil Directional Elements

Relay Function	When VSCONN = VS and PTCONN = WYE	When VSCONN = VS and PTCONN = DELTA	When VSCONN = 3V0 (PTCONN = WYE, DELTA, or SINGLE)
Wattmetric and incremental conductance elements (ORDER setting choice "P").	Use 3V0 calculated from V_A, V_B, V_C as polarizing voltage.	ORDER cannot be set to contain "P" (no zero-sequence voltage source is available)	Use V_S • (PTRS/PTR) as 3V0 polarizing voltage.[a]

[a] The PTRS/PTR adjustment brings the broken-delta 3V0 quantity to the same base voltage as the relay settings 59RES, 32WFP, and 32WRP, which are based on the VA, VB, VC voltage base.

E32IV—SELOGIC Control Equation Enable

Refer to *Figure 4.12* and *Figure 4.13*.

SELOGIC control equation setting E32IV must be asserted to logical 1 to enable the zero-sequence voltage-polarized and channel IN current-polarized directional elements for directional control of neutral ground and residual ground overcurrent elements.

For most applications, set E32IV directly to logical 1:

E32IV = **1** (numeral 1)

For situations where zero-sequence source isolation can occur (e.g., by opening a circuit breaker) and result in possible mutual coupling problems for the zero-sequence voltage-polarized and channel IN current-polarized directional elements, SELOGIC control equation setting E32IV should be deasserted to logical 0. In this example, connect a circuit breaker auxiliary contact from the isolating circuit breaker to the SEL-351:

E32IV = **IN106** (52a connected to optoisolated input IN106)

Almost any desired control can be set in SELOGIC control equation setting E32IV.

Ungrounded/High-Impedance Grounded System Considerations for Setting E32IV

On ungrounded/high-impedance grounded systems (when setting ORDER = U), phase-to-phase or unbalanced three-phase faults can cause the ungrounded/high-impedance grounded element to operate on false quantities. To prevent this situation, SELOGIC setting E32IV may be used as follows:

E32IV = **V1GOOD * !32QE**

The V1GOOD Relay Word bit (see *Figure 4.1*) deasserts during a three-phase fault, and the 32QE Relay Word bit (see *Figure 4.11*) asserts during a phase-to-phase fault. If either one of these occur, the E32IV setting evaluates to logical 0, and the ungrounded/high-impedance grounded directional element is blocked (see *Figure 4.13*).

When a switch or breaker closes, the poles can close sequentially (not at the same time), creating a momentary current unbalance condition. To avoid any possible operation of the ungrounded/ high-impedance grounded element for this momentary current unbalance condition, set 3PO (three-pole open condition; see *Figure 5.3*) in SELOGIC setting E32IV as follows:

E32IV = **... + !3PO** (= … + NOT[3PO])

The 3PO dropout time (setting 3POD) provides the extended blocking (3PO = logical 1; !3PO = logical 0) for this momentary current unbalance condition.

Directional Control Provided by Torque-Control Settings

For most applications, the level direction settings DIR1 through DIR4 are used to set overcurrent elements direction forward, reverse, or nondirectional. *Table 4.9* shows the overcurrent elements that are controlled by each level direction setting. Note in *Table 4.9* that all the time-overcurrent elements (51_T elements) are controlled by the DIR1 level direction setting. See *Figure 4.22*, *Figure 4.23*, *Figure 4.28*, and *Figure 4.29*.

In most communications-assisted trip schemes, the levels are set as follows (see *Figure 5.4*):

- ➤ Level 1 overcurrent elements set direction forward (DIR1 = F)
- ➤ Level 2 overcurrent elements set direction forward (DIR2 = F)
- ➤ Level 3 overcurrent elements set direction reverse (DIR3 = R)

Suppose that the Level 1 overcurrent elements should be set as follows:

67P1 direction forward

67G1 direction forward

51PT direction forward

51AT direction reverse

51BT direction reverse

51CT direction reverse

51NT nondirectional

51GT direction forward

To accomplish this, the DIR1 setting is “turned off,” and the corresponding SELOGIC control equation torque-control settings for the above overcurrent elements are used to make the elements directional (forward or reverse) or nondirectional. The required settings are:

DIR1 = **N** (“turned off”; see *Figure 4.22*, *Figure 4.23*, *Figure 4.28*, and *Figure 4.29*)

67P1TC = **32PF** (direction forward; see *Figure 3.3*)

67G1TC = **32GF** (direction forward; see *Figure 3.10*)

51PTC = **32PF** (direction forward; see *Figure 3.14*)

51ATC = **32PR** (direction reverse; see *Figure 3.15*)

51BTC = **32PR** (direction reverse; see *Figure 3.16*)

51CTC = **32PR** (direction reverse; see *Figure 3.17*)

51NTC = **1** (nondirectional; see *Figure 3.18*)

51GTC = **32GF** (direction forward; see *Figure 3.19*)

This is just one example of using SELOGIC control equation torque-control settings to make overcurrent elements directional (forward or reverse) or nondirectional. This example shows only Level 1 overcurrent elements (controlled by level direction setting DIR1). The same setting principles apply to the other levels as well. Many variations are possible.

SECTION 5

Trip and Target Logic

Overview

This section provides a detailed explanation for the SEL-351 trip and targeting functions, including logic diagrams for the communications-assisted tripping schemes. Each subsection provides an explanation of the function, along with a list of the corresponding settings and Relay Word bits, and a description of the factory default values for certain settings.

The logic is described in the following subsections:

Trip Logic

Trip Logic Settings

NOTE: Trip logic is also used in the relay to illuminate front-panel trip target LEDs and generate an oscillographic event report record.

The trip logic in *Figure 5.1* provides flexible tripping with SELOGIC control equation settings:

TRCOMM—Communications-Assisted Trip Conditions. Setting TRCOMM is supervised by communications-assisted trip logic. See *Communications-Assisted Trip Logic—General Overview* on page 5.13 for more information on communications-assisted tripping.

DTT—Direct Transfer Trip Conditions. Note in *Figure 5.1* that setting DTT is unsupervised. Any element that asserts in setting DTT will cause Relay Word bit TRIP to assert to logical 1.

Although settings TR and TRQUAL are also unsupervised, setting DTT is provided separate from settings TR and TRQUAL for target LED purposes. (**COMM** target LED on the front panel illuminates when DTT asserts to logical 1; see *COMM Target LED* on page 5.35).

A typical setting for DTT is:

DTT = **IN106**

where input **IN106** is connected to the output of direct transfer trip communications equipment.

Setting DTT is also used for Direct Underreaching Transfer Trip (DUTT) schemes.

TRSOTF—Switch-Onto-Fault Trip Conditions. Setting TRSOTF is supervised by the switch-onto-fault logic enable SOTFE and optionally, by the disturbance detector when EDDSOTF = Y. See *Switch-Onto-Fault (SOTF) Trip Logic* on page 5.9 for more information on switch-onto-fault logic.

TRQUAL—Qualified Trip Conditions. The SEL-351 has self-test functions to detect most hardware problems and prevent misoperation. A small number of transient memory or processor errors may not be detected. The TRQUAL equation and EDDSOTF Switch-Onto-Fault supervision improve security for some of these transient conditions without increasing relay operating time under most fault conditions. Setting TRQUAL is supervised by the disturbance detector logic, as shown in *Figure 5.1*. The disturbance detector (DD) logic detail is shown in *Figure 4.2*.

When the SEL-351 evaluates the TRQUAL equation to logical 1, the relay trips immediately if the DD Relay Word bit is already asserted. If DD is not asserted, the relay waits as long as two cycles for DD to assert. If the TRQUAL equation remains asserted, the relay trips after the two-cycle timer expires.

The disturbance detector is very sensitive to fault conditions, and will almost always assert before an instantaneous overcurrent element asserts for a new fault condition. The DD element also contains a 10-cycle dropout timer to maintain DD asserted after a disturbance is detected. Using the TRQUAL equation for instantaneous overcurrent elements will almost never increase operating time.

Security is improved when the TRQUAL equation asserts momentarily because of a transient memory or processor error, but the disturbance detector does not assert. If the TRQUAL equation resets before the two-cycle timer expires, no TRIP is issued.

Use the TRQUAL setting with instantaneous elements, such as in the setting:

TRQUAL = **67P1**

Overcurrent elements with an intentional time delay may be used in the TRQUAL equation. In certain conditions, such as during bench testing with delays set longer than 10 cycles, the disturbance detector element may deassert before the time-delayed element asserts in the TRQUAL equation. This adds two cycles to the overall trip time.

For example, if setting TRQUAL contains a negative-sequence time-overcurrent element:

TRQUAL = **... + 51QT**

the observed trip time may be as long as two cycles longer than the expected time-overcurrent characteristic. For backup protection delays lasting several seconds, this extra time is of no consequence. If this extra delay is not desirable, use the time-delayed elements in the TR equation instead.

Certain elements that assert for nonfault conditions, such as breaker open commands, should not be used in the TRQUAL equation. Relay Word DD will not assert for nonfault conditions, and these elements often assert for only one processing interval, which is not long enough for the two-cycle timer to expire. Use the unsupervised TR setting for automation or control tripping instead.

Setting EDDSOTF = Y enables similar supervision for the switch-onto-fault logic.

TR—Other Trip Conditions. Setting TR is the SELOGIC control equation trip setting most often used if tripping does not involve communications-assisted (settings TRCOMM and DTT), the switch-onto-fault (setting TRSOTF) trip logic, or a qualified trip condition (setting TRQUAL).

Note in *Figure 5.1* that setting TR is unsupervised. Any element that asserts in setting TR will cause Relay Word bit TRIP to assert to logical 1.

The TR equation is appropriate for automation and control trips, such as breaker open commands. These conditions may be present for only one processing interval, but the SEL-351 issues a TRIP immediately upon evaluating the TR equation to logical 1.

ULTR—Unlatch Trip Conditions. The ULTR SELOGIC control equation defines the conditions that must be true before the TRIP bit can reset. Most often this is set in one of the following ways:

- With the inverted current elements to indicate that the breaker is open when they deassert
- With the inverted 52A breaker status bit
- With a combination of current and breaker status elements

TDURD—Minimum Trip Duration Time. This timer establishes the minimum time duration for which the TRIP Relay Word bit asserts. This is a rising-edge initiated timer. See *Figure 5.2*.

More than one trip setting (or all five trip settings TRCOMM, DTT, TRSOTF, TR, and TRQUAL) can be set. For example, in a communications-assisted trip scheme, TRCOMM is set with direction forward overreaching Level 2 overcurrent elements, TR or TRQUAL is set with direction forward underreaching Level 1 overcurrent elements and other time-delayed elements (e.g., Level 2 definite-time overcurrent elements), and TRSOTF is set with nondirectional overcurrent elements.

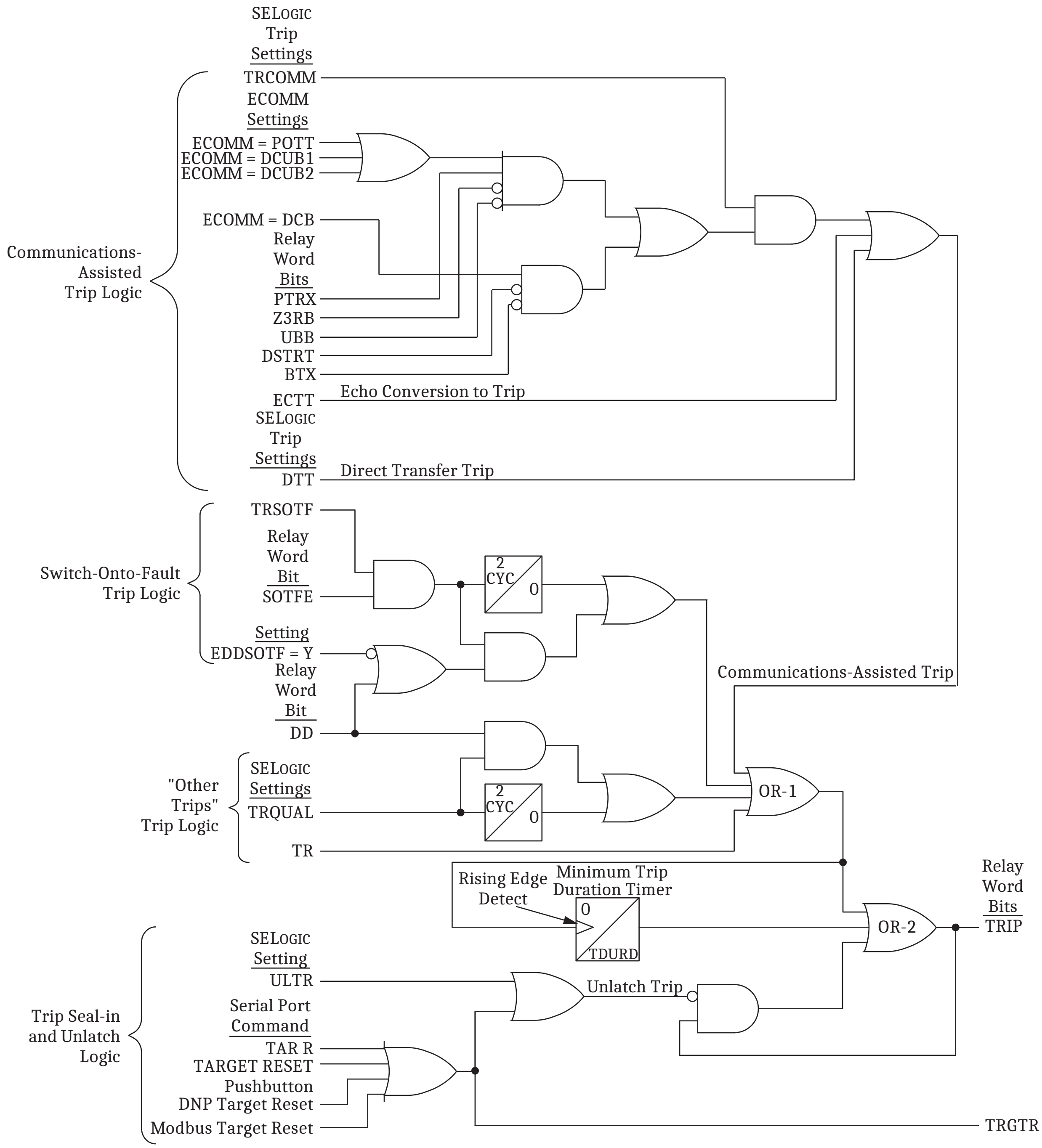


Figure 5.1 Trip Logic

Set Trip

Refer to *Figure 5.1*. All trip conditions:

- ➤ Communications-Assisted Trip
- ➤ Direct Transfer Trip
- ➤ Switch-Onto-Fault Trip
- ➤ Other Trips

are combined into OR-1 gate. The output of OR-1 gate asserts Relay Word bit TRIP to logical 1, regardless of other trip logic conditions. It also is routed into the Minimum Trip Duration Timer (setting TDURD).

As shown in the time line example in *Figure 5.2*, the Minimum Trip Duration Timer (with setting TDURD) outputs a logical 1 for a time duration of “TDURD” cycles any time it sees a *rising edge* on its input (logical 0 to logical 1 transition), if it is not already timing (timer is reset). The TDURD timer ensures that the TRIP Relay Word bit remains asserted at logical 1 for a *minimum* of “TDURD” cycles. If the output of OR-1 gate is logical 1 beyond the TDURD time, Relay Word bit TRIP remains asserted at logical 1 for as long as the output of OR-1 gate remains at logical 1, regardless of other trip logic conditions.

The Minimum Trip Duration Timer can be set no less than four cycles.

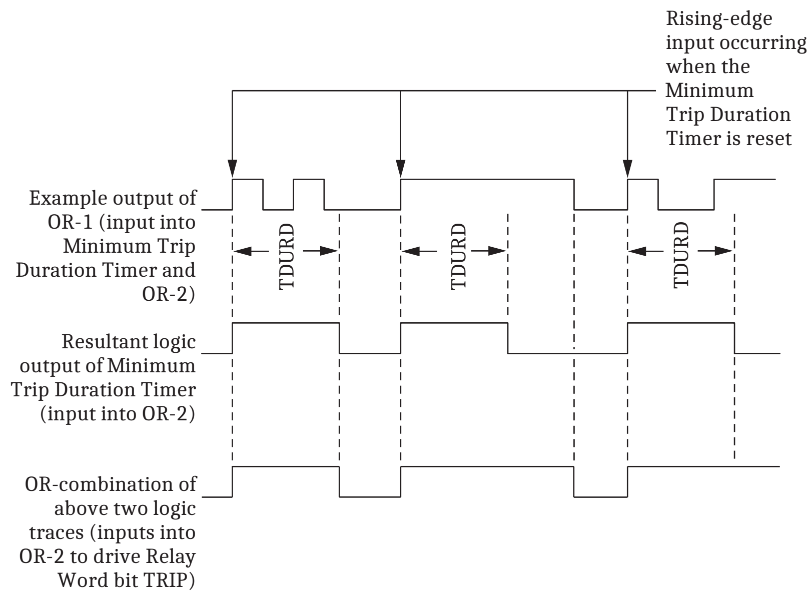


Figure 5.2 Minimum Trip Duration Timer Operation (See Bottom of *Figure 5.1*)

Unlatch Trip

Once Relay Word bit TRIP is asserted to logical 1, it remains asserted at logical 1 until all the following conditions come true:

- Minimum Trip Duration Timer stops timing (logic output of the TDURD timer goes to logical 0)
- Output of OR-1 gate deasserts to logical 0
- One of the following occurs:
  - SELOGIC control equation setting ULTR asserts to logical 1
  - The front-panel TARGET RESET pushbutton is pressed
  - The **TAR R** (Target Reset) command is executed via the serial port
  - A Target Reset command is received from a DNP or Modbus master

The front-panel TARGET RESET pushbutton, the **TAR R** (Target Reset) serial port command, and the DNP or Modbus target reset commands are used to force the TRIP Relay Word bit to logical 0 if setting ULTR does not assert to unlatch the trip. This might occur during testing or when ULTR has been set to logical 0.

Setting ULTR = 0 allows TRIP to stay asserted until the targets are reset by the front-panel **TARGET RESET** pushbutton, the **TAR R** command, or the DNP or Modbus Target Reset. This allows the relay to provide a lockout function.

SELOGIC control equation RSTTRGT (see *SELOGIC Control Equation Setting RSTTRGT* on page 5.39) does not unlatch TRIP. See *Optional Logic to Clear Trip Seal-In and Reset Targets* on page 5.39 for more information.

Other Applications for the Target Reset Function

Refer to the bottom of *Figure 5.1*. Note that the combination of the **TARGET RESET** pushbutton, the DNP and Modbus target reset inputs, and the **TAR R** (Target Reset) serial port command is also available as Relay Word bit TRGTR. See *Figure 5.20* and accompanying text for applications for Relay Word bit TRGTR.

Settings Example (Using Settings TR and TRQUAL)

In this example, the "communications-assisted" and "switch-onto-fault" trip logic at the top of *Figure 5.1* are not used. The SELOGIC control equation trip setting TR and TRQUAL are now the only inputs into the OR-1 gate and flow into the "seal-in and unlatch" logic for Relay Word bit TRIP.

The example settings for the trip logic SELOGIC control equation settings are:

NOTE: This is an example of how to use the TR and TRQUAL equations. Carefully consider any changes to SELOGIC control equations.

TR = **OC + LB3** (trip conditions)

TRQUAL = **51PT + 51GT + 81D1T + 50P1 * SHO**

ULTR = **!(51P1 + 51G1)** (unlatch trip conditions)

The factory setting for the Minimum Trip Duration Timer setting is:

TDURD = **9.00 cycles**

See the settings sheets in *Section 9: Setting the Relay* for setting ranges.

Set Trip

In SELOGIC control equation setting

TR = **OC + LB3**

Relay Word bit OC asserts when the **OPEN** command is issued. See ***OPE (Open Breaker)*** on page 10.63 for more information on the **OPEN** command.

Local bit LB3 trips directly (operates as a manual trip switch via the front panel). See *Local Control Switches* on page 7.5 for more information on local bits.

In SELOGIC control equation setting

TRQUAL = **51PT + 51GT + 81D1T + 50P1 * SHO**

⚠CAUTION
Do not use Relay Word bits that assert momentarily in the TRQUAL equation. For example, the open breaker command Relay Word bit OC and local bit LB3 only assert for one processing interval, and may not cause a trip using the TRQUAL equation. Use these types of Relay Word bits in the TR equation instead.

Time-overcurrent elements 51PT and 51GT trip directly. However, time-overcurrent and definite-time overcurrent elements can be torque controlled (e.g., elements 51PT and 51GT can be torque controlled by directional settings and SELOGIC control equation settings 51PTC and 51GTC, respectively). Check torque-control settings to see if any control is applied to time-overcurrent and definite-time overcurrent elements. Such control is not apparent by mere inspection of trip setting TR or any other SELOGIC control equation trip setting. Overcurrent element torque control is explained more fully in the first half of *Section 3: Overcurrent,* *Harmonic Blocking, Voltage, Synchronism Check, Frequency, and Power Elements*. Overcurrent element directional control is explained in *Section 4: Loss-of-Potential, Load-Encroachment, and Directional Element Logic*.

Frequency element 81D1T trips directly.

Phase instantaneous overcurrent element 50P1 is supervised by Relay Word bit SH0 in an ANDed condition 50P1 * SH0. Element 50P1 can only generate a trip when SH0 = logical 1 (reclosing relay is at shot = 0). After the first trip in a reclose cycle, the shot counter increments from 0 to 1, SH0 = logical 0, and element 50P1 cannot generate a trip. See *Section 6: Close and Reclose Logic* for more information on reclosing relay operation.

With setting TDURD = 9.00 cycles, once the TRIP Relay Word bit asserts via SELOGIC control equation setting TR or TRQUAL, it remains asserted for a *minimum* of nine cycles.

Unlatch Trip

In SELOGIC control equation setting

ULTR = **!(51P + 51G)**

both time-overcurrent element pickups 51P and 51G must be deasserted before the trip logic unlatches and the TRIP Relay Word bit deasserts to logical 0.

ULTR = **!(51P + 51G)** = NOT(51P OR 51G) = NOT(51P) AND NOT(51G)

Additional Settings Examples

The factory setting for SELOGIC control equation setting ULTR is a current-based trip unlatch condition. A circuit breaker status unlatch trip condition can be programmed as shown in the following examples.

Unlatch Trip With 52a Circuit Breaker Auxiliary Contact

A 52a circuit breaker auxiliary contact is wired to optoisolated input **IN101**.

52A = **IN101** (SELOGIC control equation circuit breaker status setting—see *Optoisolated Inputs* on page 7.1)

ULTR = **!52A**

Input **IN101** has to be de-energized (52a circuit breaker auxiliary contact has to be open) before the trip logic unlatches and the TRIP Relay Word bit deasserts to logical 0.

ULTR = **!52A** = NOT(52A)

Unlatch Trip With 52b Circuit Breaker Auxiliary Contact

A 52b circuit breaker auxiliary contact is wired to optoisolated input **IN101**.

52A = **!IN101** (SELOGIC control equation circuit breaker status setting—see *Optoisolated Inputs* on page 7.1)

ULTR = **!52A**

Input **IN101** must be energized (52b circuit breaker auxiliary contact has to be closed) before the trip logic unlatches and the TRIP Relay Word bit deasserts to logical 0.

Program an Output Contact for Tripping

In the factory settings, the result of the trip logic in *Figure 5.1* is routed to output contact **OUT101** with the following SELOGIC control equation setting:

OUT101 = **TRIP**

If more than one TRIP output contact is needed, program other output contacts with the TRIP Relay Word bit. Examples of uses for additional TRIP output contacts:

- Tripping more than one breaker
- Keying an external breaker failure relay
- Keying communication equipment in a Direct Transfer Trip scheme

See *Output Contacts* on page 7.33 for more information on programming output contacts.

TRIP Used in Other Settings

Besides operating a trip output contact (e.g., OUT101 = TRIP), the TRIP Relay Word bit is used in a number of other factory-default SELOGIC control equations settings:

ULCL = **TRIP** unlatch close—see *Figure 6.2*

79RI = **TRIP** reclose initiate—see *Table 6.4* and following explanation

79STL = **TRIP** stall open interval timing—see *Table 6.4* and following explanation

79BRS = **TRIP** block reset timing—see *Table 6.4* and following explanation

SV1 = **TRIP** breaker failure timing—see *Factory Settings Example* on page 7.27

BKMON = **TRIP** breaker monitor initiation—see *Breaker Monitor* on page 8.1

Change the Trip Settings—Check Other Settings

Any time trip settings are changed/modified (e.g., via SELOGIC control equation trip settings TR and TRQUAL), the following SELOGIC control equations should be checked or given consideration for modification:

ULTR (unlatch trip—see *Figure 5.1* and following explanation). For example, if negative-sequence time-overcurrent element 51QT is added to the factory-default trip settings (TR or TRQUAL = … + 51QT), consideration should be given to adding its pickup indication (51Q) to the unlatch trip setting [e.g., ULTR = !(… + 51Q)].

79DTL (drive-to-lockout setting—see *Drive-to-Lockout and Drive-to-Last Shot Settings (79DTL and 79DLS, Respectively)* on page 6.22). For example, if frequency element 81D1T is added to the factory-default trip settings (TR or TRQUAL = … + 81D1T), but no autoreclosing should occur after an underfrequency load-shedding trip, then frequency element 81D1T should be added to the drive-to-lockout setting (e.g., 79DTL = … + 81D1T).

Note that the factory-default local bit LB3 and serial port **OPEN** command (OC) trip settings (TR = … + LB3 + OC) are already in the factory-default drive-to-lockout setting.

ER (event report trigger conditions—see *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*). For example, if negative-sequence time-overcurrent element 51QT is added to the factory-default trip settings (TR or TRQUAL = … + 51QT), consideration should be given to adding its pickup indication (51Q) to the event report trigger conditions setting (ER = … + /51Q). A rising edge operator (/) is added on front of the element (see *Appendix F: Setting SELOGIC Control Equations* for more explanation on rising edge operators).

FAULT (fault indication—see *SELOGIC Control Equation Setting FAULT* on page 5.39). For example, if negative-sequence time-overcurrent element 51QT is added to the factory-default trip settings (TR or TRQUAL = … + 51QT), consideration should be given to adding its pickup indication (51Q) to the fault indication setting (FAULT = … + 51Q).

Switch-Onto-Fault (SOTF) Trip Logic

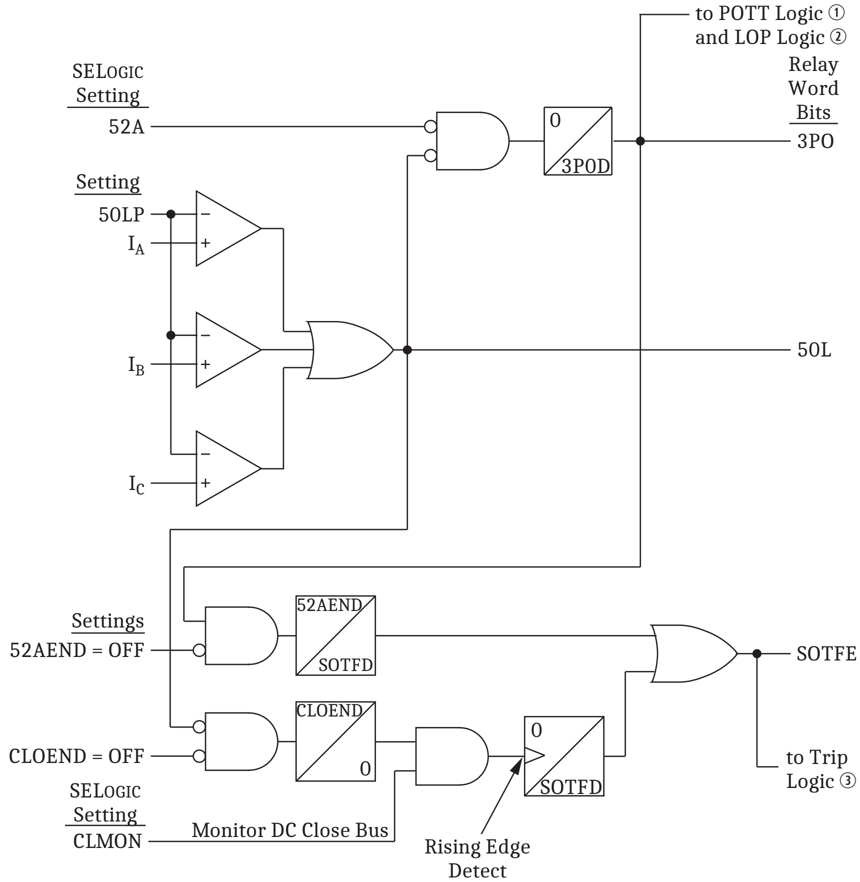
Switch-Onto-Fault (SOTF) trip logic provides a programmable time window for selected elements to trip right after the circuit breaker closes. “Switch-onto-fault” implies that a circuit breaker is closed into an existing fault condition. For example, suppose safety grounds are accidentally left attached to a line after a clearance. If the circuit breaker is closed into such a condition, the resulting fault needs to be cleared right away and reclosing blocked. An instantaneous overcurrent element is usually set to trip in the SOTF trip logic.

For added security, the SEL-351 features a selectable disturbance detector supervision function on the switch-onto-fault trip condition. Enable this logic by setting EDDSOTF = Y. The operation is described in *Disturbance Detector Supervision for Switch-Onto-Fault Logic* on page 5.12.

Refer to the switch-onto-fault trip logic in *Figure 5.1* (middle of figure). The SOTF trip logic permits tripping if both the following occur:

- An element asserts in SELOGIC control equation trip setting TRSOTF
- Relay Word bit SOTFE is asserted to logical 1

Relay Word bit SOTFE (the output of the SOTF logic) provides the effective time window for an element in trip setting TRSOTF (e.g., TRSOTF = 50P2) to trip after the circuit breaker closes. *Figure 5.3* and the following discussion describe the three-pole open (3PO) logic and the SOTF logic.



① *Figure 5.6*. ② *Figure 4.1*. ③ *Figure 5.1*.

Figure 5.3 Three-Pole Open Logic (Top) and Switch-Onto-Fault Logic (Bottom)

Three-Pole Open Logic

Three-pole open (3PO) logic is the top half of *Figure 5.3*. It is not affected by enable setting ESOTF (see *Other Enable Settings* on page SET.7).

The open circuit breaker condition is determined from the combination of:

- Circuit breaker status (52A)
- Load current condition (50L)

If the circuit breaker is open (52A = logical 0) *and* current is below phase pickup 50LP (50L = logical 0), then the three-pole open (3PO) condition is true:

3PO = logical 1 (circuit breaker open)

The 3POD dropout time qualifies circuit breaker closure, whether detected by circuit breaker status (52A) or load current level (50L). When the circuit breaker is closed:

3PO = logical 0 (circuit breaker closed)

Determining Three-Pole Open Condition Without Circuit Breaker Auxiliary Contact

If a circuit breaker auxiliary contact is not connected to the SEL-351, SELOGIC control equation setting 52A is set:

52A = **0** (numeral 0)

With SELOGIC control equation setting 52A continually at logical 0, 3PO logic is controlled solely by load detection element 50L. Phase pickup 50LP is set below load current levels.

When the circuit breaker is open, Relay Word bit 50L drops out (= logical 0) and the 3PO condition asserts:

3PO = logical 1 (circuit breaker open)

When the circuit breaker is closed, Relay Word bit 50L picks up (= logical 1; current above phase pickup 50LP) and the 3PO condition deasserts after the 3POD dropout time:

3PO = logical 0 (circuit breaker closed)

Note that the 3PO condition is also routed to the permissive overreaching transfer trip (POTT) logic (see *Figure 5.6*) and the loss-of-potential (LOP) logic (see *Figure 4.1*).

Circuit Breaker Operated Switch-Onto-Fault Logic

Circuit breaker operated switch-onto-fault logic is enabled by making time setting 52AEND (52AEND ≠ OFF). Time setting 52AEND qualifies the three-pole open (3PO) condition and then asserts Relay Word bit SOTFE:

SOTFE = logical 1

Note that SOTFE is asserted when the circuit breaker is open. This allows elements set in the SELOGIC control equation trip setting TRSOTF to operate if a fault occurs when the circuit breaker is open (see *Figure 5.1*). In such a scenario (e.g., flashover inside the circuit breaker tank), the tripping via setting TRSOTF cannot help in tripping the circuit breaker (the circuit breaker is already open), but can initiate breaker failure protection, if a breaker failure scheme is implemented in the SEL-351 (see output contact **OUT103** example in *Output Contacts* on page 7.33) or externally.

When the circuit breaker is closed, the 3PO condition deasserts (3PO = logical 0) after the 3POD dropout time (setting 3POD is usually set for no more than a cycle). The SOTF logic output, SOTFE, continues to remain asserted at logical 1 for dropout time SOTFD time.

Close Bus Operated Switch-Onto-Fault Logic

Close bus operated switch-onto-fault logic is enabled by making time setting CLOEND (CLOEND ≠ OFF). Time setting CLOEND qualifies the deassertion of the load detection element 50L (indicating that the circuit breaker is open).

Circuit breaker closure is detected by monitoring the dc close bus. This is accomplished by wiring an optoisolated input on the SEL-351 (e.g., **IN105**) to the dc close bus. When a manual close or automatic reclosure occurs, optoisolated input **IN105** is energized. SELOGIC control equation setting CLMON (close bus monitor) monitors the optoisolated input **IN105**:

CLMON = **IN105**

When optoisolated input **IN105** is energized, CLMON asserts to logical 1. At the instant that optoisolated input **IN105** is energized (close bus is energized), the circuit breaker is still open so the output of the CLOEND timer continues to be asserted to logical 1. Thus, the ANDed combination of these conditions latches in the SOTFD timer. The SOTFD timer outputs a logical 1 for a time duration of "SOTFD" cycles any time it sees a rising edge on its input (logical 0 to logical 1 transition), if it is not already timing. The SOTF logic output, SOTFE, asserts to logical 1 for SOTFD time.

Switch-Onto-Fault Logic Enable (SOTFE)

Relay Word bit SOTFE is the output of the circuit breaker operated SOTF logic or the close bus operated SOTF logic described previously. Time setting SOTFD in each of these logic paths provides the effective time window for the overcurrent elements in SELOGIC control equation trip setting TRSOTF to trip after the circuit breaker closes (see *Figure 5.1*—middle of figure). Time setting SOTFD is usually set around 30 cycles.

A SOTF trip illuminates the **SOTF** front-panel LED.

Disturbance Detector Supervision for Switch-Onto-Fault Logic

The SEL-351 features selectable disturbance detector supervision for switch-onto-fault trip. Enable this logic by setting EDDSOTF = Y.

Refer to *Figure 5.1* for the EDDSOTF influence on the SOTF logic.

When EDDSOTF = N, the switch-onto-fault logic works with no DD supervision, and the relay immediately asserts SOTFT and TRIP when TRSOTF evaluates to logical 1 with SOTFE asserted.

When EDDSOTF = Y, the relay checks the state of the Disturbance Detector (DD) Relay Word bit when TRSOTF evaluates to logical 1 with SOTFE asserted.

- If DD is asserted, the relay immediately asserts the SOTFT output, which causes an immediate trip.
- If DD is not asserted, and the TRSOTF and SOTFE conditions remain asserted, the relay delays the SOTFT assertion for as long as 2 cycles (until the DD element asserts, or until the 2-cycle wait time expires).
- If one of the TRSOTF or SOTFE conditions deasserts before the 2-cycle timer expires, and the DD bit does not assert, no trip is issued. This provides a security improvement in cases where an element in the TRSOTF equation was transient.

The relay also uses the disturbance detector in the TRQUAL equation, as described in *TRQUAL—Qualified Trip Conditions.* on page 5.2. The disturbance detector is very sensitive to fault conditions, and will almost always assert before a high-set overcurrent element asserts for a new fault condition. The DD element also contains a 10-cycle dropout timer to maintain Relay Word bit DD asserted after a disturbance is detected. Using the EDDSOTF = Y setting with instantaneous overcurrent elements in the TRSOTF equation will almost never increase operating time.

Switch-Onto-Fault Trip Logic Trip Setting (TRSOTF)

An instantaneous overcurrent element is usually set to trip in the SELOGIC control equation trip setting TRSOTF (e.g., TRSOTF = 50P2).

If the voltage potential for the relay is from the line-side of the circuit breaker, the instantaneous overcurrent element in the SELOGIC control equation trip setting TRSOTF should be nondirectional. When the circuit breaker is open and the line is de-energized, the relay sees zero voltage. If a close-in three-phase fault condition exists on the line (e.g., safety grounds accidentally left attached to the line after a clearance) and then the circuit breaker is closed, the relay continues to see zero voltage. The directional elements have no voltage for reference and cannot operate.

Communications-Assisted Trip Logic—General Overview

The SEL-351 includes communications-assisted tripping schemes that provide unit-protection for transmission lines with the help of communications. No external coordination devices are required.

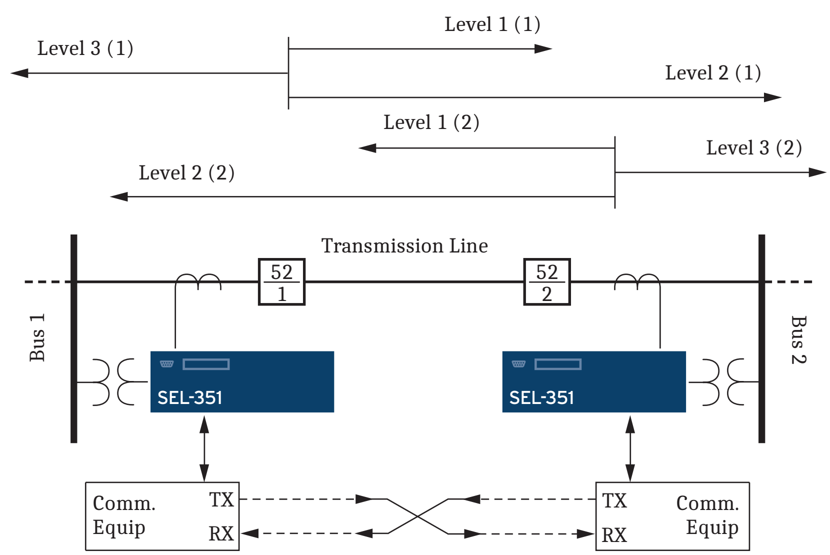


Figure 5.4 Communications-Assisted Tripping Scheme

Refer to *Figure 5.4* and the top half of *Figure 5.1*.

The six available tripping schemes are:

- ➤ Direct Transfer Trip (DTT)
- ➤ Direct Underreaching Transfer Trip (DUTT)
- ➤ Permissive Overreaching Transfer Trip (POTT)
- ➤ Permissive Underreaching Transfer Trip (PUTT)
- ➤ Directional Comparison Unblocking (DCUB)
- ➤ Directional Comparison Blocking (DCB)

Enable Setting ECOMM

The POTT, PUTT, DCUB, and DCB tripping schemes are enabled with enable setting ECOMM. Setting choices are:

ECOMM = **N** [no communications-assisted trip scheme enabled]

NOTE: When Global setting PTCONN = SINGLE, Group setting ECOMM is unavailable, and is internally set to "N".

ECOMM = **POTT** [POTT or PUTT scheme]

ECOMM = **DCUB1** [DCUB scheme for two-terminal line (communications from one remote terminal)]

ECOMM = **DCUB2** [DCUB scheme for three-terminal line (communications from *two* remote terminals)]

ECOMM = **DCB** [DCB scheme]

These tripping schemes can all work in two-terminal or three-terminal line applications. The DCUB scheme requires separate settings choices for these applications (ECOMM = DCUB1 or DCUB2) because of unique DCUB logic considerations.

In most cases, these tripping schemes require (see *Figure 5.4*):

- Level 1 underreaching overcurrent elements set direction forward (setting DIR1 = F)
- Level 2 overreaching overcurrent elements set direction forward (setting DIR2 = F)
- Level 3 overcurrent elements set direction reverse (setting DIR3 = R)

See *Directional Control Settings* on page 4.43 for more information on level direction settings DIR1 through DIR4.

POTT, PUTT, DCUB, and DCB communications-assisted tripping schemes are explained in subsections that follow.

Trip Setting TRCOMM

The POTT, PUTT, DCUB, and DCB tripping schemes use SELOGIC control equation trip setting TRCOMM for those tripping elements that are supervised by the communications-assisted trip logic (see top half of *Figure 5.1*). Setting TRCOMM is typically set with Level 2 overreaching overcurrent elements (set direction forward):

67P2 Level 2 directional phase instantaneous overcurrent element

67N2 Level 2 directional neutral ground instantaneous overcurrent element

67G2 Level 2 directional residual ground instantaneous overcurrent element

67Q2 Level 2 directional negative-sequence instantaneous overcurrent element

The exception is a DCB scheme, where Level 2 overreaching overcurrent elements (set direction forward) with a short delay are used instead:

67P2S Level 2 directional phase instantaneous overcurrent element (with delay 67P2SD)

67N2S Level 2 directional neutral ground instantaneous overcurrent element (with delay 67N2SD)

67G2S Level 2 directional residual ground instantaneous overcurrent element (with delay 67G2SD)

67Q2S Level 2 directional negative-sequence instantaneous overcurrent element (with delay 67Q2SD)

The short delays provide necessary carrier coordination delays (waiting for the block trip signal).

Trip Settings TRSOTF, TRQUAL, and TR

In a communications-assisted trip scheme, the SELOGIC control equation trip settings TRSOTF, TRQUAL, and TR can also be used, in addition to setting TRCOMM.

Setting TRSOTF can be set as described in *Switch-Onto-Fault (SOTF) Trip Logic* on page 5.9.

Settings TR and TRQUAL are typically set with unsupervised Level 1 underreaching overcurrent elements (set direction forward):

67P1 Level 1 directional phase instantaneous overcurrent element

67N1 Level 1 directional neutral ground instantaneous overcurrent element

67G1 Level 1 directional residual ground instantaneous overcurrent element

67Q1 Level 1 directional negative-sequence instantaneous overcurrent element

and other time-delayed elements (e.g., Level 2 definite-time overcurrent elements).

The SEL-351 allows instantaneous tripping for elements in the TRQUAL equation when Relay Word bit DD is asserted. If an element in the TRQUAL setting asserts in isolation from a disturbance detector operation, the trip is delayed for two cycles. See *TRQUAL—Qualified Trip Conditions.* on page 5.2 for full details.

Trip Setting DTT

The DTT and DUTT tripping schemes are realized with SELOGIC control equation trip setting DTT, discussed at the beginning of this section.

MIRRORED BITS protocol default settings provide adequate security for POTT, DCB, and DCUB applications. Set the receive bit security counter RMB1PU – RMB8PU = 2 when using MIRRORED BITS for DTT applications, or any other tripping scheme that is unsupervised by a local fault detector. For example, if Direct Transfer Tripping SELOGIC control equation DTT is set to:

DTT = RMB3A

then make receive bit security counter setting

RMB3PU = 2

on MIRRORED BITS Port A.

When RMB3PU = 2 on MIRRORED BITS Port A, the MIRRORED BITS protocol requires reception of two sequential MIRRORED BITS messages with RMB3 asserted (deasserted) before allowing Relay Word Bit RMB3A to assert (deassert).

Use Existing SEL-321 Application Guides for the SEL-351

The communications-assisted tripping schemes settings in the SEL-351 are very similar to those in the SEL-321. Existing SEL-321 application guides can also be used in setting up these schemes in the SEL-351. The following application guides are available from SEL:

➤ AG93-06 *Applying the SEL-321 Relay to Directional Comparison Blocking (DCB) Schemes*

➤ AG95-29 *Applying the SEL-321 Relay to Permissive Overreaching Transfer Trip (POTT) Schemes*

➤ AG96-19 *Applying the SEL-321 Relay to Directional Comparison Unblocking (DCUB) Schemes*

The major differences are how the optoisolated input settings and the trip settings are made. The following explanations describe these differences.

Optoisolated Input Settings Differences Between the SEL-321 and SEL-351 Relays

The SEL-351 does not have optoisolated input settings like the SEL-321. Rather, the optoisolated inputs of the SEL-351 are available because Relay Word bits are used in SELOGIC control equations. The following optoisolated input setting example is for a Permissive Overreaching Transfer Trip (POTT) scheme.

SEL-321	SEL-351	
IN102 = PT	PT1 = IN102	(received permissive trip)

In the above SEL-351 setting example, Relay Word bit IN102 is set in the PT1 SELOGIC control equation. Optoisolated input IN102 is wired to a communications equipment receiver output contact. Relay Word bit IN102 can also be used in other SELOGIC control equations in the SEL-351. See *Optoisolated Inputs* on page 7.1 for more information on optoisolated inputs.

Trip Settings Differences Between the SEL-321 and SEL-351 Relays

Some of the SELOGIC control equation trip settings of the SEL-321 and SEL-351 Relays are not operationally different, just labeled differently. The correspondence is:

SEL-321	SEL-351	
MTCS	TRCOMM	(Communications-Assisted Trip Conditions)
MTO	TRSOTF	(Switch-Onto-Fault Trip Conditions)
MTU	TR or TRQUAL	(Unconditional or Other Trip Conditions)

The SEL-321 handles trip unlatching with setting TULO. The SEL-351 handles trip unlatching with SELOGIC control equation setting ULTR.

The SEL-321 has single-pole trip logic. The SEL-351 does not have single-pole trip logic.

Using MIRRORED BITS to Implement Communications-Assisted Tripping Schemes

The MIRRORED BITS relay-to-relay communications protocol is available in SEL-351-6 and SEL-351-7 relays, in addition to many other SEL products. MIRRORED BITS implementations have these advantages over traditional communications equipment:

- Less equipment (increases reliability)
- Increased speed (no contact closure delay)
- Better security (through built-in channel monitoring)
- Reduced wiring complexity

The subsections that follow use traditional communications equipment in the examples. If using MIRRORED BITS communications, change some of the SELOGIC control equations to use Transmit MIRRORED BITS instead of output contacts, and Receive MIRRORED BITS instead of optoisolated inputs. Also, MIRRORED BITS communications do not require dc wiring between the relay and communications equipment.

See *Appendix H: MIRRORED BITS Communications (in Firmware Versions 6 and 7)* for details on configuring a relay port to communicate using MIRRORED BITS.

Several Application Guides available on the SEL website (selinc.com) give application examples of MIRRORED BITS in communications-assisted tripping schemes. Although some of the guides were written for the SEL-321-1 and SEL-311C distance relays, these relays are similar to SEL-351 Relays, so the guides will still be helpful in designing SEL-351 applications.

Permissive Overreaching Transfer Trip (POTT) Logic

Enable the POTT logic by setting ECOMM = POTT. The POTT logic in *Figure 5.6* is also enabled for directional comparison unblocking schemes (ECOMM = DCUB1 or ECOMM = DCUB2). The POTT logic performs the following tasks:

- Keys communication equipment to send permissive trip when any element included in the SELOGIC control equation communications-assisted trip equation TRCOMM asserts and the current reversal logic is not asserted.
- Prevents keying and tripping by the POTT logic following a current reversal.
- Echoes the received permissive signal to the remote terminal.
- Prevents channel lockup during echo and test.
- Provides a secure means of tripping for weak- and/or zero-infeed line terminals.

Use Existing SEL-321 POTT Application Guide for the SEL-351

Use the existing SEL-321 POTT application guide (AG95-29) to help set up the SEL-351 in a POTT scheme (see *Use Existing SEL-321 Application Guides for the SEL-351* on page 5.16 for more setting comparison information on the SEL-321/SEL-351 Relays).

External Inputs

See *Optoisolated Inputs* on page 7.1 for more information on optoisolated inputs.

PT1—Received Permissive Trip Signal(s)

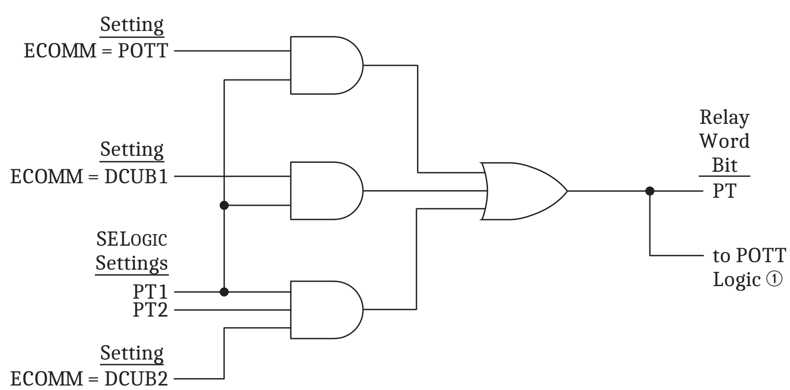
In two-terminal line POTT applications, a permissive trip signal is received from one remote terminal. One optoisolated input on the SEL-351 (e.g., input **IN104**) is driven by a communications equipment receiver output (see *Figure 5.8*). Make SELOGIC control equation setting PT1:

PT1 = **IN104** (two-terminal line application)

In three-terminal line POTT applications, permissive trip signals are received from two remote terminals. Two optoisolated inputs on the SEL-351 (e.g., inputs **IN104** and **IN106**) are driven by communications equipment receiver outputs (see *Figure 5.9*). Make SELOGIC control equation setting PT1 as follows:

PT1 = **IN104 * IN106** (three-terminal line application)

SELOGIC control equation setting PT1 in *Figure 5.5* is routed to control Relay Word bit PT if enable setting ECOMM = POTT. Relay Word bit PT is then an input into the POTT logic in *Figure 5.6* (for echo keying).



① *Figure 5.6*.

Figure 5.5 Permissive Input Logic Routing to POTT Logic

Also note that SELOGIC control equation setting PT1 in *Figure 5.7* is routed to control Relay Word bit PTRX if enable setting ECOMM = POTT. Relay Word bit PTRX is the permissive trip receive input into the trip logic in *Figure 5.1*.

Timer Settings

See *Section 9: Setting the Relay* for setting ranges.

Z3RBD—Zone (Level) 3 Reverse Block Delay

Current-reversal guard timer—typically set at 5 cycles.

EBLKD—Echo Block Delay

Prevents echoing of received PT for settable delay after dropout of local permissive elements in trip setting TRCOMM—typically set at 10 cycles. Set to OFF to defeat EBLKD.

ETDPU—Echo Time Delay Pickup

Sets minimum time requirement for received PT, before echo begins—typically set at 2 cycles. Set to OFF for no echo.

EDURD—Echo Duration

Limits echo duration, to prevent channel lockup—typically set at 3.5 cycles.

Logic Outputs

The following logic outputs can be tested by assigning them to output contacts. See *Output Contacts* on page 7.33 for more information on output contacts.

Z3RB—Zone (Level) 3 Reverse Block

Current-reversal guard asserted (operates as an input into the trip logic in *Figure 5.1* and the DCUB logic in *Figure 5.10*).

ECTT—Echo Conversion to Trip

PT received, converted to a trip condition for a Weak-Infeed Condition (operates as an input into the trip logic in *Figure 5.1*).

KEY—Key Permissive Trip

Signals communications equipment to transmit permissive trip. For example, SELOGIC control equation setting OUT105 is set:

OUT105 = **KEY**

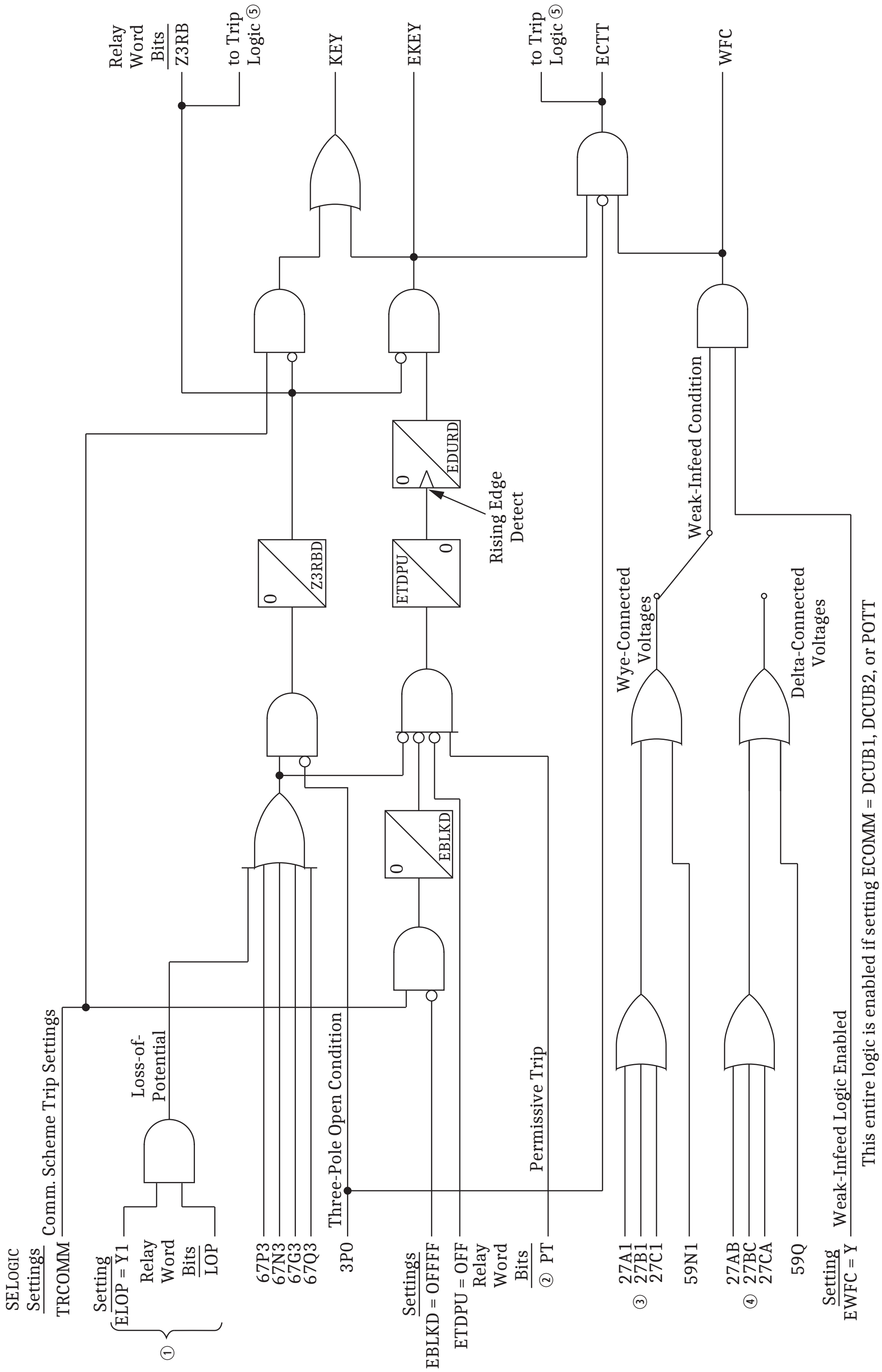
Output contact OUT105 drives a communications equipment transmitter input in a two-terminal line application (see *Figure 5.8*).

In a three-terminal line scheme, output contact OUT107 is set the same as OUT105 (see *Figure 5.9*):

OUT107 = **KEY**

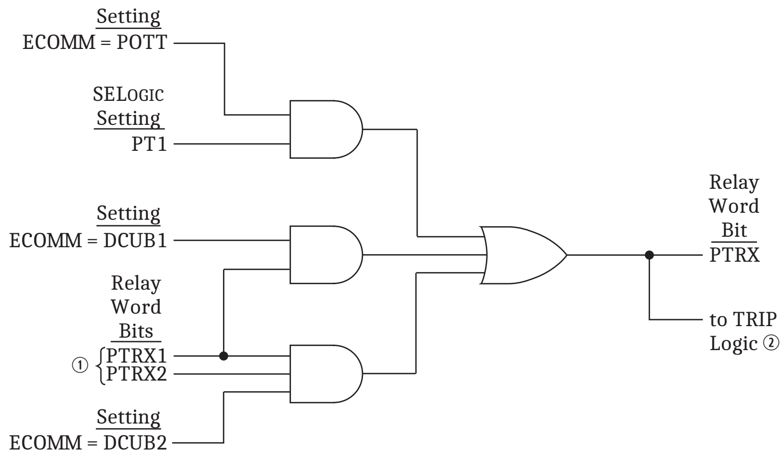
EKEY—Echo Key Permissive Trip

Permissive trip signal keyed by Echo logic (used in testing).



① From *Figure 4.1*. ② From *Figure 5.5*. ③ See *Table 3.11*. ④ See *Table 3.13*. ⑤ *Figure 5.1*.

Figure 5.6 POTT Logic



① *Figure 5.10.* ② *Figure 5.1.*

Figure 5.7 Permissive Input Logic Routing to Trip Logic

Variations for Permissive Underreaching Transfer Trip (PUTT) Scheme

Refer to *Figure 5.4* and *Figure 5.6*. In a PUTT scheme, keying is provided by Level 1 underreaching overcurrent elements (set direction forward), instead of with Relay Word bit KEY. This is accomplished by setting output contact **OUT105** with these elements:

67P1 Level 1 directional phase instantaneous overcurrent element

67N1 Level 1 directional neutral ground instantaneous overcurrent element

67G1 Level 1 directional residual ground instantaneous overcurrent element

67Q1 Level 1 directional negative-sequence instantaneous overcurrent element

instead of with element KEY (see *Figure 5.8*):

OUT105 = **67P1 + 67N1 + 67G1 + 67Q1** (Note: only use enabled elements)

If echo keying is desired, add the echo key permissive trip logic output, as follows:

OUT105 = **67P1 + 67N1 + 67G1 + 67Q1 + EKEY**

In a three-terminal line scheme, output contact **OUT107** is set the same as **OUT105** (see *Figure 5.9*).

Installation Variations

Figure 5.9 shows output contacts **OUT105** and **OUT107** connected to separate communication equipment, for the two remote terminals. Both output contacts are programmed the same (OUT105 = KEY and OUT107 = KEY).

Depending on the installation, perhaps one output contact (e.g., OUT105 = KEY) could be connected in parallel to both transmitter inputs (**TX**) on the communication equipment in *Figure 5.9*. Then output contact **OUT107** can be used for another function.

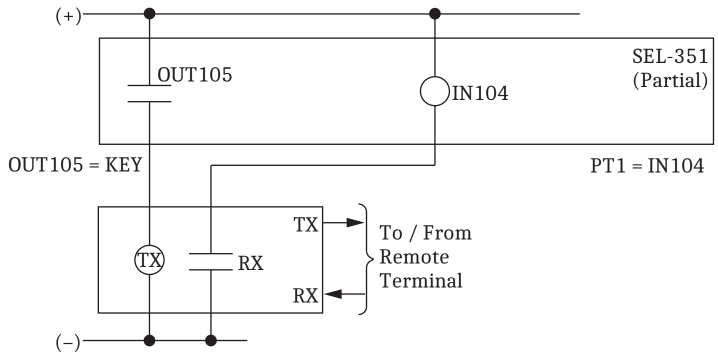


Figure 5.8 Connections to Communications Equipment for a Two-Terminal Line POTT Scheme

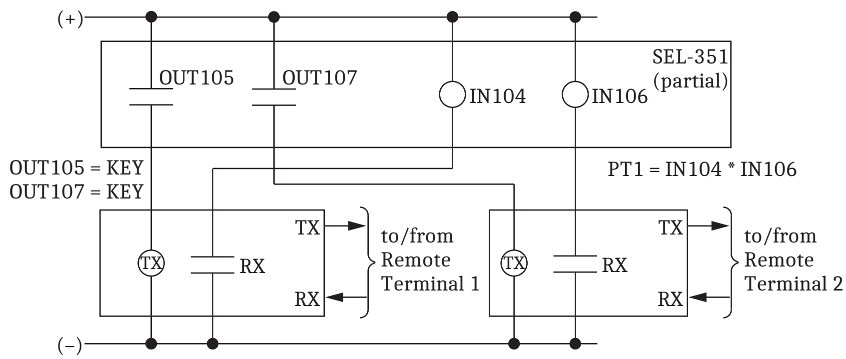


Figure 5.9 Connections to Communications Equipment for a Three-Terminal Line POTT Scheme

Directional Comparison Unblocking (DCUB) Logic

NOTE: When using power line carrier communications equipment that includes DCUB logic, it is typically better to enable the DCUB logic in the communication equipment and not in the relay. In that case, simply enable POTT logic in the relay. Some communications equipment will indicate loss-of-guard because of a fault or noise. The DCUB logic of the relay is unable to discriminate between loss-of-carrier because of a line fault and that caused by noise. The DCUB logic within the communication equipment is better equipped to differentiate between the causes of the loss-of-guard.

Enable the DCUB logic by setting ECOMM = DCUB1 or ECOMM = DCUB2. The DCUB logic in *Figure 5.10* is an extension of the POTT logic in *Figure 5.6*. Thus, the relay requires *all* the POTT settings and logic, *plus* exclusive DCUB settings and logic. The difference between setting choices DCUB1 and DCUB2 is:

DCUB1 directional comparison unblocking scheme for two-terminal line (communications from *one* remote terminal)

DCUB2 directional comparison unblocking scheme for three-terminal line (communications from *two* remote terminals)

The DCUB logic in *Figure 5.10* takes in the loss-of-guard and permissive trip outputs from the communication receivers (see *Figure 5.12* and *Figure 5.13*) and makes permissive (PTRX1/PTRX2) and unblocking block (UBB1/UBB2) logic output decisions.

DCUB schemes are typically implemented with FSK (frequency shift keying) on power line carrier communications medium where there is a direct logical relationship between the loss of carrier signal and a fault on the protected line segment.

Use Existing SEL-321 DCUB Application Guide for the SEL-351

Use the existing SEL-321 DCUB application guide (AG96-19) to help set up the SEL-351 in a DCUB scheme (see *Use Existing SEL-321 Application Guides for the SEL-351* on page 5.16 for more setting comparison information on the SEL-321/SEL-351 Relays).

External Inputs

See *Optoisolated Inputs* on page 7.1 for more information on optoisolated inputs.

PT1, PT2—Received Permissive Trip Signal(s)

In two-terminal line DCUB applications (setting ECOMM = DCUB1), a permissive trip signal is received from one remote terminal. One optoisolated input on the SEL-351 (e.g., input IN104) is driven by a communications equipment receiver output (see *Figure 5.12*). Make SELOGIC control equation setting PT1:

PT1 = **IN104** (two-terminal line application)

In three-terminal line DCUB applications (setting ECOMM = DCUB2), permissive trip signals are received from *two* remote terminals. Two optoisolated inputs on the SEL-351 (e.g., inputs IN104 and IN106) are driven by communications equipment receiver outputs (see *Figure 5.13*). Make SELOGIC control equation settings PT1 and PT2 as follows:

PT1 = **IN104** (three-terminal line application)

PT2 = **IN106**

SELOGIC control equation settings PT1 and PT2 are routed into the DCUB logic in *Figure 5.10* for "unblocking block" and "permissive trip receive" logic decisions.

As explained in *Permissive Overreaching Transfer Trip (POTT) Logic* on page 5.17, the SELOGIC control equation settings PT1 and PT2 in *Figure 5.5* are routed in various combinations to control Relay Word bit PT, depending on enable setting ECOMM = DCUB1 or DCUB2. Relay Word bit PT is then an input into the POTT logic in *Figure 5.6* (for echo keying).

LOG1, LOG2—Loss-of-Guard Signal(s)

In two-terminal line DCUB applications (setting ECOMM = DCUB1), a loss-of-guard signal is received from *one* remote terminal. One optoisolated input on the SEL-351 (e.g., input IN105) is driven by a communications equipment receiver output (see *Figure 5.12*). Make SELOGIC control equation setting LOG1:

LOG1 = **IN105** (two-terminal line application)

In three-terminal line DCUB applications (setting ECOMM = DCUB2), loss-of-guard signals are received from *two* remote terminals. Two optoisolated inputs on the SEL-351 (e.g., input IN105 and IN207) are driven by communications equipment receiver outputs (see *Figure 5.13*). Make SELOGIC control equation settings LOG1 and LOG2 as follows:

LOG1 = **IN105** (three-terminal line application)

LOG2 = **IN207**

SELOGIC control equation settings LOG1 and LOG2 are routed into the DCUB logic in *Figure 5.10* for "unblocking block" and "permissive trip receive" logic decisions.

Timer Settings

See *Section 9: Setting the Relay* for setting ranges.

GARD1D—Guard-Present Delay

Sets minimum time requirement for reinstating permissive tripping following a loss-of-channel condition—typically set at 10 cycles. Channel 1 and 2 logic use separate timers but have this same delay setting.

UBDURD—DCUB Disable Delay

Prevents tripping by POTT logic after a settable time following a loss-of-channel condition—typically set at 9 cycles (150 ms). Channel 1 and 2 logic use separate timers but have this same delay setting.

UBEND—DCUB Duration Delay

Sets minimum time required to declare a loss-of-channel condition—typically set at 0.5 cycles. Channel 1 and 2 logic use separate timers but have this same delay setting.

Logic Outputs

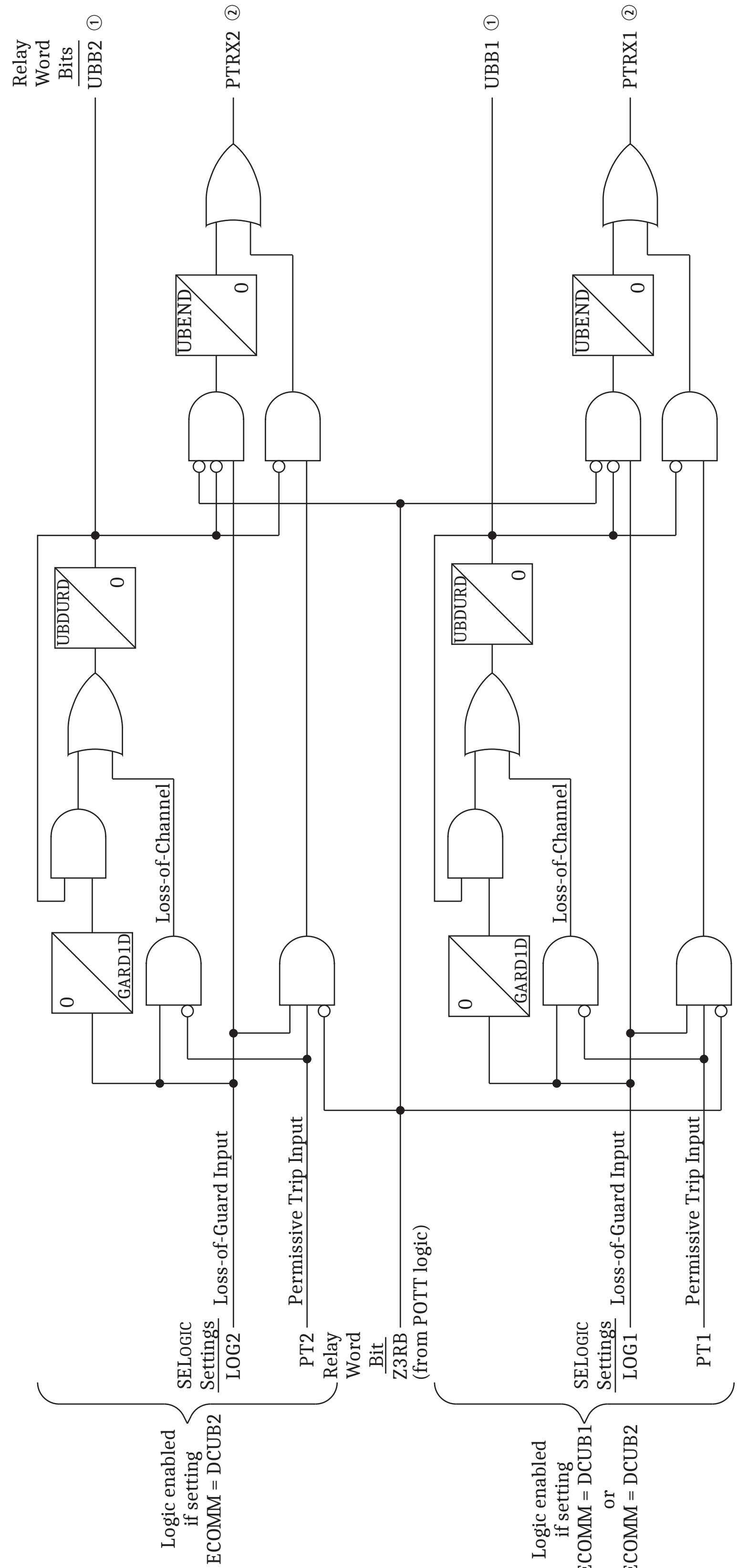
The following logic outputs can be tested by assigning them to output contacts. See *Output Contacts* on page 7.33 for more information on output contacts.

UBB1, UBB2—Unblocking Block Output(s)

In two-terminal line DCUB applications (setting ECOMM = DCUB1), UBB1 disables tripping if the loss-of-channel condition continues for longer than time UBDURD.

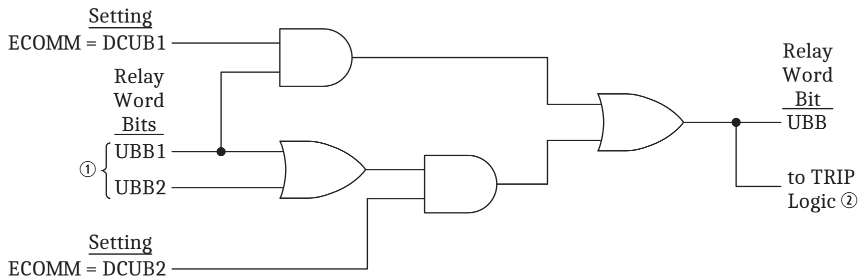
In three-terminal line DCUB applications (setting ECOMM = DCUB2), UBB1 or UBB2 disable tripping if the loss-of-channel condition (for the respective Channel 1 or 2) continues for longer than time UBDURD.

The UBB1 and UBB2 are routed in various combinations in *Figure 5.11* to control Relay Word bit UBB, depending on enable setting ECOMM = DCUB1 or DCUB2. Relay Word bit UBB is the unblock block input into the trip logic in *Figure 5.1*. When UBB asserts to logical 1, tripping is blocked.



① To *Figure 5.11*. ② To *Figure 5.7*.

Figure 5.10 DCUB Logic



① From *Figure 5.10*. ② *Figure 5.1*.

Figure 5.11 Unblocking Block Logic Routing to Trip Logic

PTRX1, PTRX2—Permissive Trip Receive Outputs

In two-terminal line DCUB applications (setting ECOMM = DCUB1), PTRX1 asserts for loss-of-channel or an actual received permissive trip.

In three-terminal line DCUB applications (setting ECOMM = DCUB2), PTRX1 or PTRX2 assert for loss-of-channel or an actual received permissive trip (for the respective Channel 1 or 2).

The PTRX1/PTRX2 Relay Word bits are then routed in various combinations in *Figure 5.7* to control Relay Word bit PTRX, depending on enable setting ECOMM = DCUB1 or DCUB2. Relay Word bit PTRX is the permissive trip receive input into the trip logic in *Figure 5.1*.

Installation Variations

Figure 5.13 shows output contacts OUT105 and OUT107 connected to separate communication equipment, for the two remote terminals. Both output contacts are programmed the same (OUT105 = KEY and OUT107 = KEY).

Depending on the installation, perhaps one output contact (e.g., OUT105 = KEY) could be connected in parallel to both transmitter inputs (TX) on the communication equipment in *Figure 5.13*. Then output contact OUT107 can be used for another function.

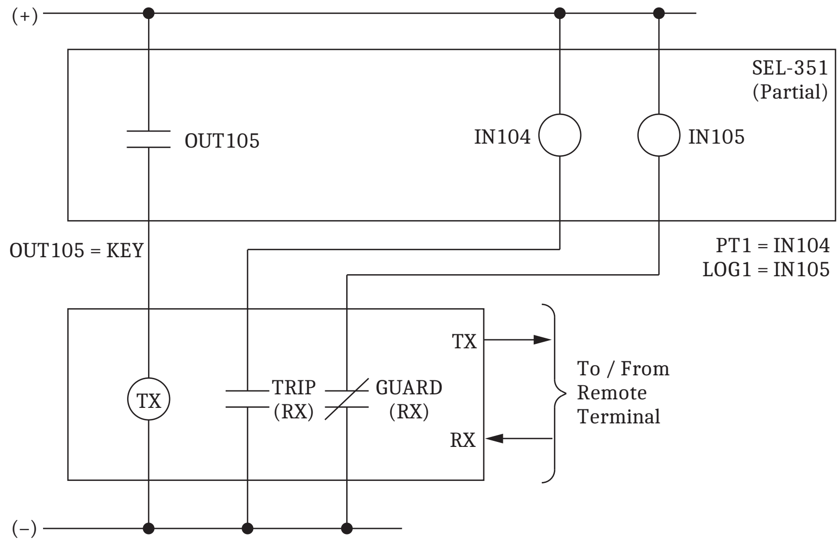


Figure 5.12 Connections to Communications Equipment for a Two-Terminal Line DCUB Scheme (Setting ECOMM = DCUB1)

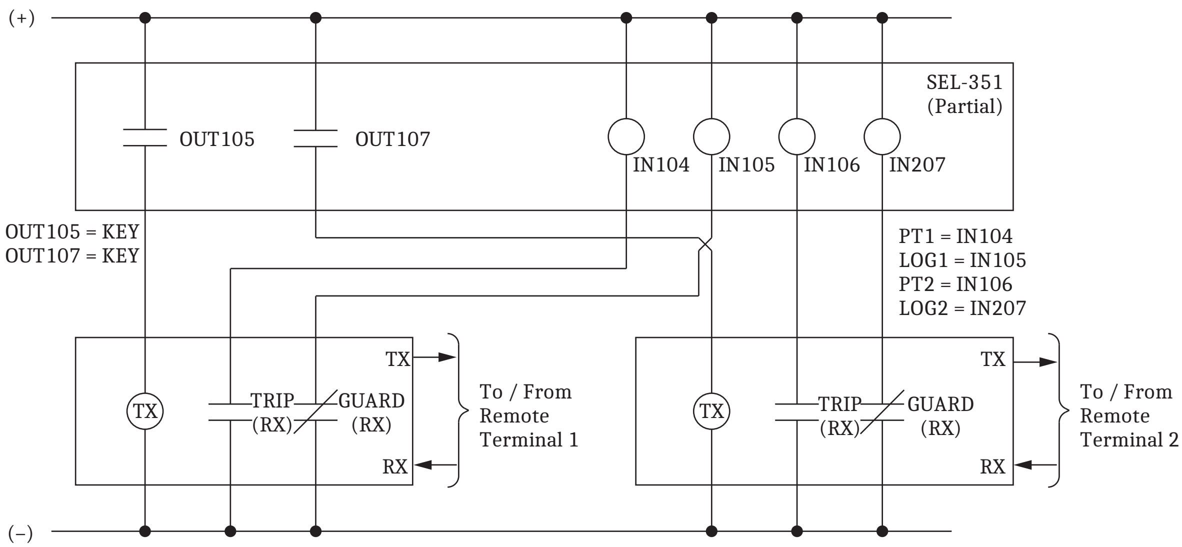


Figure 5.13 Connections to Communications Equipment for a Three-Terminal Line DCUB Scheme (Setting ECOMM = DCUB2)

Directional Comparison Blocking (DCB) Logic

Enable the DCB logic by setting ECOMM = DCB. The DCB logic in *Figure 5.14* performs the following tasks:

- Provides the individual carrier coordination timers for the Level 2 directional overcurrent elements 67P2S, 67N2S, 67G2S, and 67Q2S. These delays allow time for the block trip signal to arrive from the remote terminal.
- Instantaneously keys the communications equipment to transmit block trip for reverse faults and extends this signal for a settable time following the dropout of all Level 3 directional overcurrent elements 67P3, 67N3, 67G3, and 67Q3.

- Latches the block trip send condition by the directional overcurrent following a close-in zero-voltage three-phase fault where the polarizing memory expires. Latch is removed when the polarizing memory voltage returns or current is removed.
- Extends the received block signal by a settable time.

Use Existing SEL-321 DCB Application Guide for the SEL-351

Use the existing SEL-321 DCB application guide (AG93-06) to help set up the SEL-351 in a DCB scheme (see *Use Existing SEL-321 Application Guides for the SEL-351* on page 5.16 for more setting comparison information on the SEL-321/SEL-351 Relays).

External Inputs

See *Optoisolated Inputs* on page 7.1 for more information on optoisolated inputs.

BT—Received Block Trip Signal(s)

In two-terminal line DCB applications, a block trip signal is received from *one* remote terminal. One optoisolated input on the SEL-351 (e.g., input **IN104**) is driven by a communications equipment receiver output (see *Figure 5.15*). Make SELOGIC control equation setting BT:

BT = **IN104** (two-terminal line application)

In three-terminal line DCB applications, block trip signals are received from *two* remote terminals. Two optoisolated inputs on the SEL-351 (e.g., input **IN104** and **IN106**) are driven by communications equipment receiver outputs (see *Figure 5.16*). Make SELOGIC control equation setting BT as follows:

BT = **IN104 + IN106** (three-terminal line application)

SELOGIC control equation setting BT is routed through a dropout timer (BTXD) in the DCB logic in *Figure 5.14*. The timer output, Relay Word bit BTX, is routed to the trip logic in *Figure 5.1*.

Timer Settings

See *Section 9: Setting the Relay* for setting ranges.

Z3XPU—Zone (Level) 3 Reverse Pickup Time Delay

Current-reversal guard pickup timer—typically set at 1 cycle.

Z3XD—Zone (Level) 3 Reverse Dropout Extension

Current-reversal guard dropout timer—typically set at 5 cycles.

BTXD—Block Trip Receive Extension

Sets reset time of block trip received condition (BTX) after the reset of block trip input BT.

67P2SD, 67N2SD, 67G2SD, 67Q2SD—Level 2 Short Delay

Carrier coordination delays for the output of Level 2 overreaching overcurrent elements 67P2S, 67N2S, 67G2S, and 67Q2S, respectively—typically set at 1 cycle.

Logic Outputs

The following logic outputs can be tested by assigning them to output contacts. See *Output Contacts* on page 7.33 for more information on output contacts.

DSTRT—Directional Carrier Start

Program an output contact for directional carrier start. For example, SELOGIC control equation setting **OUT105** is set:

OUT105 = **DSTRT**

Output contact **OUT105** drives a communications equipment transmitter input in a two-terminal line application (see *Figure 5.15*).

In a three-terminal line scheme, output contact **OUT107** is set the same as **OUT105** (see *Figure 5.16*):

OUT107 = **DSTRT**

DSTRT includes current reversal guard logic.

NSTRT—Nondirectional Carrier Start

Program an output contact to include nondirectional carrier start, in addition to directional start. For example, SELOGIC control equation setting **OUT105** is set:

OUT105 = **DSTRT + NSTRT**

Output contact **OUT105** drives a communications equipment transmitter input in a two-terminal line application (see *Figure 5.15*).

In a three-terminal line scheme, output contact **OUT107** is set the same as **OUT105** (see *Figure 5.16*):

OUT107 = **DSTRT + NSTRT**

STOP—Stop Carrier

Program to an output contact to stop carrier. For example, SELOGIC control equation setting OUT106 is set:

OUT106 = **STOP**

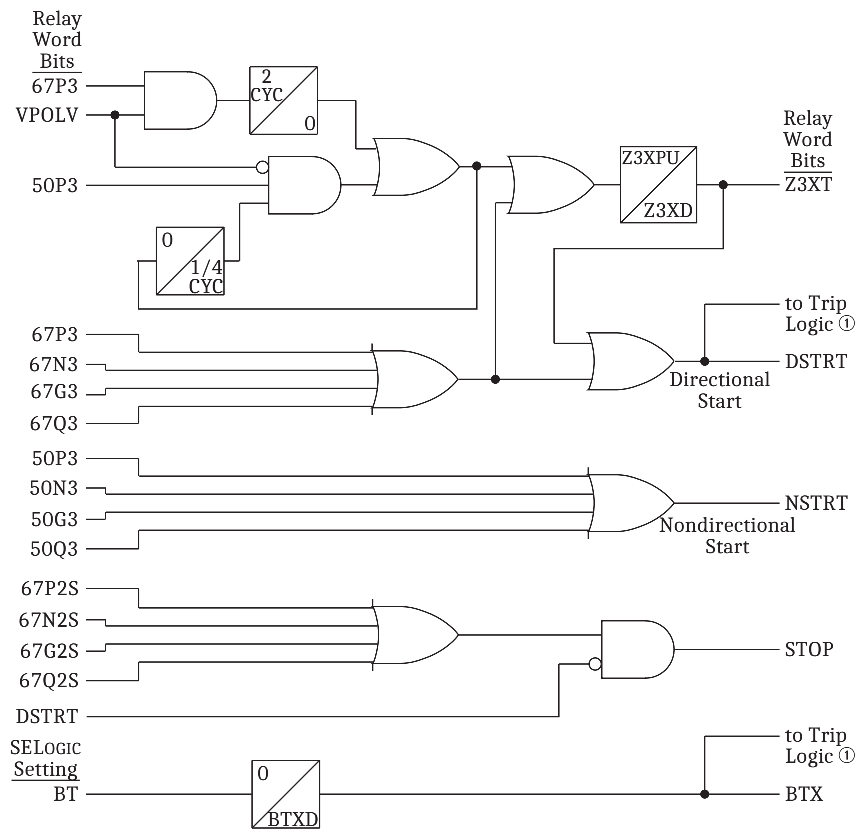
Output contact **OUT106** drives a communications equipment transmitter input in a two-terminal line application (see *Figure 5.15*).

In a three-terminal line scheme, output contact **OUT208** is set the same as **OUT106** (see *Figure 5.16*):

OUT208 = **STOP**

BTX—Block Trip Extension

The received block trip input (e.g., BT = IN104) is routed through a dropout timer (BTXD) in the DCB logic in *Figure 5.14*. The timer output (BTX) is routed to the trip logic in *Figure 5.1*.



① *Figure 5.1.*

Figure 5.14 DCB Logic

Installation Variations

Figure 5.16 shows output contacts OUT105, OUT106, OUT107, and OUT208 connected to separate communication equipment, for the two remote terminals. Both output contact pairs are programmed the same:

OUT105 = **DSTRT + NSTRT**

OUT107 = **DSTRT + NSTRT**

OUT106 = **STOP**

OUT208 = **STOP**

Depending on the installation, perhaps one output contact (e.g., OUT105 = DSTRT + NSTRT) can be connected in parallel to both START inputs on the communication equipment in *Figure 5.16*. Then output contact OUT107 can be used for another function.

Depending on the installation, perhaps one output contact (e.g., OUT106 = STOP) can be connected in parallel to both STOP inputs on the communication equipment in *Figure 5.16*. Then output contact OUT208 can be used for another function.

Figure 5.16 also shows communication equipment **RX** (receive) output contacts from each remote terminal connected to separate inputs **IN104** and **IN106** on the SEL-351. The inputs operate as block trip receive inputs for the two remote terminals and are used in the SELOGIC control equation setting:

BT = **IN104 + IN106**

Depending on the installation, perhaps one input (e.g., **IN104**) can be connected in parallel to both communication equipment **RX** (receive) output contacts in *Figure 5.16*. Then setting BT would be programmed as:

BT = **IN104**

and input **IN106** can be used for another function.

In *Figure 5.15* and *Figure 5.16*, the carrier scheme cutout switch contact (85CO) should be closed when the communications equipment is taken out of service so that the **BT** input of the relay remains asserted. An alternative to asserting the **BT** input is to change to a setting group where the DCB logic is not enabled.

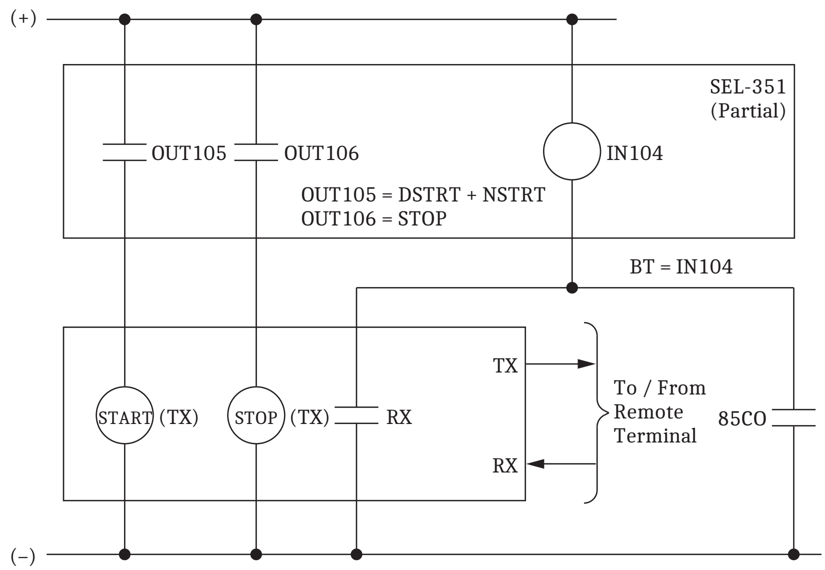


Figure 5.15 Connections to Communications Equipment for a Two-Terminal Line DCB Scheme

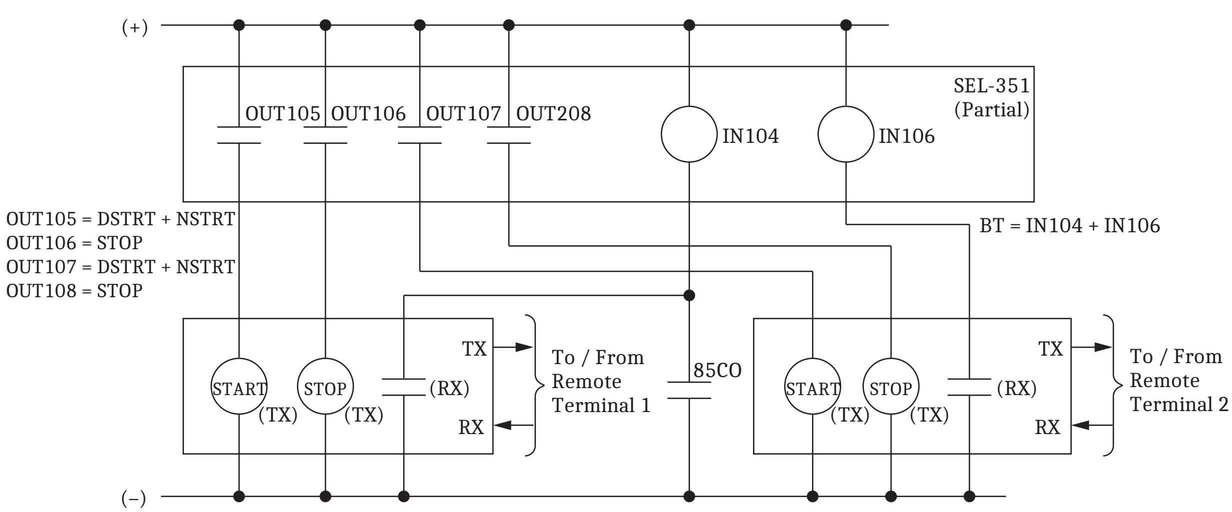


Figure 5.16 Connections to Communications Equipment for a Three-Terminal Line DCB Scheme

Breaker Failure Protection

Breaker failure protection provides local back-up protection when a circuit breaker fails to trip during a fault. In breaker failure schemes, it is important to quickly detect the dropout of fault-detecting overcurrent elements. Fault detector dropout can be delayed by the presence of subsidence current, which results from the energy trapped in the CT magnetizing branch after the circuit breaker opens to clear a fault or interrupt load. Subsidence current decays exponentially and delays the dropout of filtered instantaneous overcurrent elements. The open pole detection logic of the SEL-351 uses unfiltered data to identify a breaker open pole and reset the breaker failure logic in less than one cycle, even when subsidence current is present.

Breaker Failure Current Detectors

Figure 5.17 shows how the A-phase open pole detection logic controls the breaker failure current detector. Logic for phases B and C is similar. When a breaker fails to trip during a fault, the A-phase open pole detection logic remains deasserted. If the phase current, IA, is greater than breaker failure current pickup threshold, 50BFP, Relay Word bits 50BFA and 50BFT assert. If the breaker trips, phase current IA may remain above the breaker failure current pickup threshold 50BFP for some time because of subsidence. The open pole detection logic detects this and asserts, causing 50BFA and 50BFT to deassert. B-phase and C-phase logic is similar.

The breaker failure current pickup is usually set above maximum load.

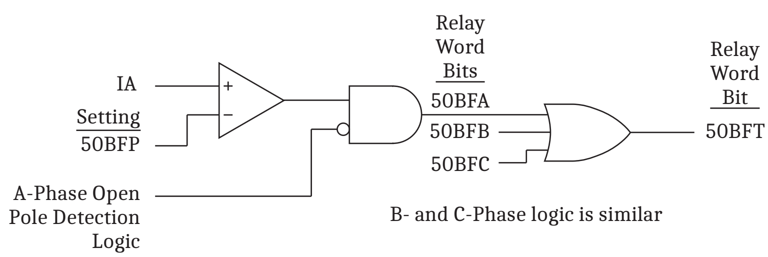


Figure 5.17 Breaker Failure Current Detector Logic for A-Phase

Breaker Failure Logic

Figure 5.18 shows the breaker failure logic. Fault current causes 50BFT to assert immediately following fault inception and just prior to the assertion of SELOGIC control equation BFI (Breaker Failure Initiate). Program BFI with internal breaker failure initiate conditions, such as the Relay Word bit TRIP, or breaker failure initiate signals from external devices communicated to the relay through contact inputs or MIRRORED BITS. When BFI asserts, timer BFPU (Breaker Failure Trip Timer) starts timing. If 50BFT remains asserted when the BFPU timer expires, Relay Word bit BFT asserts. Use this Relay Word bit in the circuit breaker failure tripping logic to cause a circuit breaker failure trip (see *Breaker Failure Trip Logic* on page 5.33). If the protected circuit breaker opens successfully, 50BFT deasserts before the BFPU timer expires and BFT does not assert.

If the Breaker Failure Logic of *Figure 5.18* does not match your preferred breaker failure scheme, Relay Word bits 50BFA, 50BFB, 50BFC, and 50BFT may be used along with SELOGIC control equation variables to create custom schemes. Use the breaker failure trip logic (*Figure 5.19*) to ensure that breaker failure trip signals are properly latched.

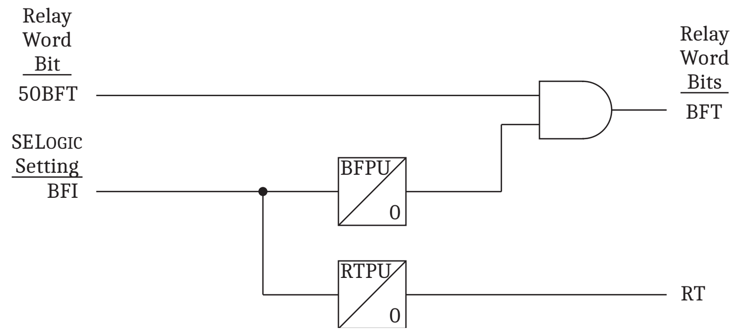


Figure 5.18 Breaker Failure Logic

Retrip Logic

Some three-pole circuit breakers have two separate trip coils. If one trip coil fails, the local protection can energize the second trip coil to attempt to trip the breaker again. Configure your protection system to attempt a local retrip using the second trip coil before the circuit breaker failure pickup timer expires.

RTPU (Breaker Failure Retrip Timer) begins timing when BFI asserts. Relay Word bit RT asserts when RTPU times out. Program a contact output to energize the second circuit breaker trip coil when Relay Word bit RT asserts.

Breaker Failure Trip Logic

Usually, SELOGIC control equation BFTR (Breaker Failure Trip Equation) includes Relay Word bit BFT. When BFTR evaluates to logical 1, Relay Word bit BFTRIP asserts and seals in. Include BFTRIP in an output contact equation to transmit breaker failure status to remote relays for backup protection. For example,

OUT106 = **BFTRIP**

Relay Word bit TRGTR and SELOGIC control equation BFULTR reset BFTRIP. The minimum trip duration of BFTRIP is controlled by Group setting TDURD. See *Trip Logic* on page 5.1 for a description of minimum trip duration timers, trip unlatch conditions, and operation of Relay Word bit TRGTR.

The breaker failure logic does not automatically trigger an event report. Modify the SELOGIC event report trigger equation ER to trigger an event when a breaker failure trip occurs. For example:

ER = **/51P1 + /51G1 + /BFTRIP + ...**

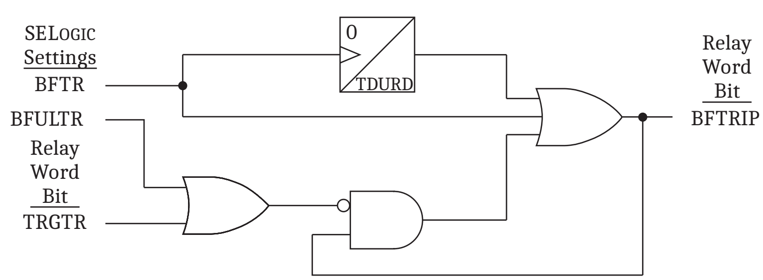


Figure 5.19 Breaker Failure Trip Logic

Table 5.1 Breaker Failure Protection Settings

Setting	Definition	Range
E50BF	Enable Breaker Failure	Y, N
50BFP	Breaker Failure Current Pickup Threshold	OFF, 0.25–100 A, sec {5 A nominal phase current inputs, IA, IB, IC} OFF, 0.05–20 A, sec {1 A nominal phase current inputs, IA, IB, IC}
BFI	Breaker Failure Initiate	SELOGIC control equation
BFPU	Breaker Failure Trip Timer Pickup	0–16,000 cycles
RTPU	Breaker Failure Retrip Timer Pickup	0–16,000 cycles
BFTR	Breaker Failure Trip Equation	SELOGIC control equation
BFULTR	Breaker Failure Unlatch Trip Equation	SELOGIC control equation
TDURD	Minimum Trip Duration Time	4–16,000 cycles

Table 5.2 Breaker Failure Protection Logic Outputs

Relay Word Bit	Definition	Application
50BFA	Phase A current threshold exceeded	Phase A breaker failure detection
50BFB	Phase B current threshold exceeded	Phase B breaker failure detection
50BFC	Phase C current threshold exceeded	Phase C breaker failure detection
50BFT	Any phase current threshold exceeded	Breaker failure detection
BFT	Any phase circuit breaker failure	
RT	Retrip	
BFTRIP	Circuit breaker failure trip	

Front-Panel Target LEDs

Table 5.3 Front-Panel Target LED Definitions (Sheet 1 of 2)

LED Number	LED Label	Definition
1	EN	Relay Enabled—see *Relay Self-Tests* on page 13.7
2	TRIP	Indication that a trip occurred, by overcurrent element, frequency element, or otherwise
3	INST	Instantaneous trip
4	COMM	Communications-assisted trip
5	SOTF	Switch-onto-fault trip
6	50	Instantaneous/definite-time overcurrent element generated trip
7	51	Time-overcurrent element generated trip
8	81	Frequency element generated trip
9	A	A-Phase involved in the fault
10	B	B-Phase involved in the fault
11	C	C-Phase involved in the fault
12	G	Residual-ground overcurrent element trips for the fault
13	N	Neutral-ground overcurrent element trips for the fault

Table 5.3 Front-Panel Target LED Definitions (Sheet 2 of 2)

LED Number	LED Label	Definition
14	RS	Reclosing relay is in the Reset State (follows Relay Word bit 79RS)
15	CY	Reclosing relay is in the Cycle State (follows Relay Word bit 79CY)
16	LO	Reclosing relay is in the Lockout State (follows Relay Word bit 79LO)

Target LEDs numbered 2 through 13 in *Table 5.3* are updated and then latched for every new assertion (rising edge) of the TRIP Relay Word bit. The TRIP Relay Word bit is the output of the trip logic (see *Figure 5.1*).

Further target LED information follows. Refer also to *Figure 2.2* through *Figure 2.6* for the placement of the target LEDs on the front panel.

Additional Target LED Information

TRIP Target LED

The TRIP target LED illuminates at the rising edge of trip (the new assertion of the TRIP Relay Word bit).

The TRIP target LED is especially helpful in providing front-panel indication for tripping that does not involve overcurrent or frequency elements. If the trip is not an overcurrent or frequency element generated trip, none of the target LEDs numbered 3 through 13 in *Table 5.3* illuminate, but the TRIP target LED still illuminates. Thus, tripping via the front-panel local control (local bits), serial port (remote bits or **OPEN** command), or voltage elements is indicated only by the illumination of the TRIP target LED.

INST Target LED

The INST target LED illuminates at the rising edge of trip if SELOGIC control equation setting FAULT has been asserted for less than three cycles. FAULT is usually set with time-overcurrent element pickups (e.g., FAULT = 51P + 51G) to detect fault inception. If tripping occurs within three cycles of fault inception, the INST target illuminates.

SELOGIC control equation setting FAULT also controls other relay functions. See *SELOGIC Control Equation Setting FAULT* on page 5.39.

COMM Target LED

The COMM target LED illuminates at the rising edge of trip if the trip is the result of SELOGIC control equation setting TRCOMM and associated communications-assisted trip logic, Relay Word bit ECTT, or SELOGIC control equation setting DTT (see *Figure 5.1*, top half of figure).

Another Application for the COMM Target LED

If none of the traditional communications-assisted trip logic is used (i.e., SELOGIC control equation setting TRCOMM is not used; see *Figure 5.4* and accompanying text), consideration can be given to using the COMM target LED to indicate tripping via remote communications channels (e.g., via serial port commands or SCADA asserting optoisolated inputs). Use SELOGIC control equation setting DTT (Direct Transfer Trip) to accomplish this (see *Figure 5.1*).

For example, if the **OPEN** command or remote bit RB1 (see **CON *(Control Remote Bit)*** on page 10.43) are used to trip via the serial port and they should illuminate the **COMM** target LED, set them in SELOGIC control equation setting DTT:

DTT = **... + OC + RB1**

Additionally, if SCADA asserts optoisolated input **IN104** to trip and it should illuminate the **COMM** target LED, set it in SELOGIC control equation setting DTT also:

DTT = **... + IN104 + ...**

Relay Word bits set in SELOGIC control equation setting DTT do not have to be set in SELOGIC control equation setting TR—both settings directly assert the TRIP Relay Word bit. The only difference between settings DTT and TR is that setting DTT causes the **COMM** target LED to illuminate.

Many other variations of the above DTT settings examples are possible.

SOTF Target LED

The **SOTF** target LED illuminates at the rising edge of the TRIP Relay Word bit if the trip is the result of the SELOGIC control equation setting TRSOTF and associated switch-onto-fault trip logic (see *Figure 5.3*).

50 Target LED

The **50** target LED illuminates at the rising edge of trip if an instantaneous or definite-time overcurrent element causes the trip.

51 Target LED

The **51** target LED illuminates at the rising edge of trip if a time-overcurrent element (51PT, 51AT, 51BT, 51CT, 51NT, 51GT, 51G2T, or 51QT) causes the trip.

81 Target LED

The **81** target LED illuminates at the rising edge of trip if a frequency element (81D1T–81D6T) causes the trip.

FAULT TYPE Target LEDs

A, B, and C Target LEDs

A (Phase A) target LED is illuminated at the rising edge of trip if an overcurrent element causes the trip and Phase A is involved in the fault [likewise for **B** (Phase B) and **C** (Phase C) target LEDs]. SELOGIC control equation FAULT has to be picked up for three-phase fault indication.

LEDs **A**, **B**, and **C** always latch in on trip, if the corresponding phase is involved with the fault. LEDs **A**, **B**, and **C** reset (unlatch) similar to the other target LEDs. SELOGIC control equation FAULT has to be picked up for three-phase fault indication (FAULT = 51P + 51G in the factory default settings—set with the pickup indicators of the time-overcurrent elements). Additionally, the fault must be present for at least one cycle after the relay trips for reliable targeting. This is most noticeable in relay testing when breaker opening times are not included in the test setup.

SELOGIC control equation setting FAULT also controls other relay functions. See *SELOGIC Control Equation Setting FAULT* on page 5.39.

If neutral channel IN is rated 0.2 A nominal and directional control is selected for a Petersen Coil-grounded or ungrounded/high-impedance grounded system (see *Table 4.4*), then A, B, and C target logic for ground faults uses Relay Word bits NSA, NSB, and NSC in determining the involved phase for forward-direction faults (both types of systems) and for reverse-direction faults (ungrounded system only).

If Global settings PTCONN = SINGLE and VSCONN = 3V0 (see *Settings for Voltage Input Configuration* on page 9.18), the fault type target LEDs may not operate for Petersen Coil grounded systems and will not operate for ungrounded/high-impedance grounded systems.

G Target LED

G target LED is illuminated at the rising edge of trip if a residual-ground overcurrent element causes the trip or was picked up and timing to trip.

N Target LED

N target LED is illuminated at the rising edge of trip if a neutral-ground overcurrent element causes the trip.

79 Target LEDs

If the reclosing relay is turned off (enable setting E79 = N or 79OI1 = 0), all the Device **79** (reclosing relay) target LEDs are extinguished.

Resetting Front-Panel Target LEDs

The front-panel target LEDs reset during the following conditions:

- TRIP newly asserts (/TRIP).
- The **TARGET RESET/LAMP TEST** pushbutton is pressed and TRIP is not asserted.
- The **TAR R** command is entered and TRIP is not asserted.
- A DNP or Modbus target reset command is received and TRIP is not asserted.
- The SELOGIC control equation RSTTRGT newly asserts and TRIP is not asserted.

When a new TRIP condition is present, the relay first clears the previous targets and then rapidly refreshes them with the updated target information. The relay locks-out the other target reset methods while TRIP is still active.

The **TARGET RESET/LAMP TEST** pushbutton, **TAR R** command, and Modbus/DNP target reset methods assert the TRGTR Relay Word bit for one processing interval.

Targets are maintained in nonvolatile memory so their status is available even after relay power is lost and then restored.

TARGET RESET/LAMP TEST Front-Panel Pushbutton

When the TARGET RESET/LAMP TEST front-panel pushbutton is pressed:

- All front-panel LEDs illuminate for one (1) second.
- All latched target LEDs (target LEDs numbered 2 through 13 in *Table 5.3*) are extinguished (unlatched), unless a trip condition is present in which case the latched target LEDs reappear in their previous state.

Other Applications for the Target Reset Function

Refer to the bottom of *Figure 5.1*. The combination of the TARGET RESET pushbutton, DNP and Modbus target reset inputs, and the **TAR R** (Target Reset) serial port command is available as Relay Word bit TRGTR. Relay Word bit TRGTR pulses to logical 1 for one processing interval when either the TARGET RESET pushbutton is pushed or the **TAR R** (Target Reset) serial port command is executed.

Relay Word bit TRGTR can be used to unlatch logic. For example, refer to the breaker failure logic in *Figure 7.26*. If a breaker failure trip occurs (SV7T asserts), the occurrence can be displayed on the front panel with seal-in logic and a rotating display (see *Rotating Display* on page 7.37 and *Rotating Display* on page 11.10):

SV8 = **(SV8 + SV7T) * !TRGTR**

DP3 = **SV8**

DP3_1 = **BREAKER FAILURE**

DP3_0 = NA (blank)

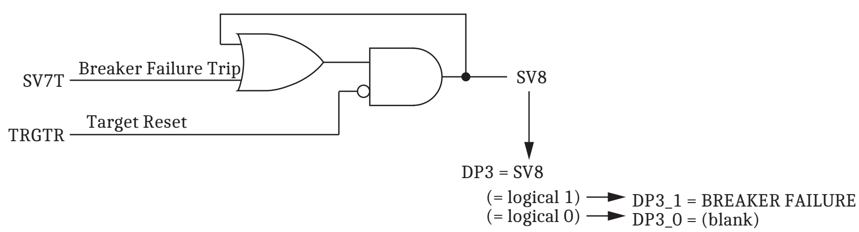
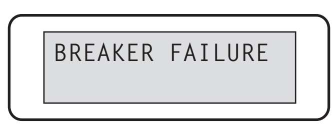


Figure 5.20 Seal-in of Breaker Failure Occurrence for Message Display

If a breaker failure trip has occurred, the momentary assertion of SV7T (breaker failure trip) will cause SV8 in *Figure 5.20* to seal-in. Asserted SV8 in turn asserts DP3, causing the message:



to display in the rotating default display.

This message can be removed from the display rotation by pushing the TARGET RESET pushbutton (Relay Word bit TRGTR pulses to logical 1, unlatching SV8 and in turn deasserting DP3). Thus, front-panel rotating default displays can be easily reset along with the front-panel targets by pushing the TARGET RESET pushbutton.

SELOGIC Control Equation Setting RSTTRGT

The SELOGIC control equation RSTTRGT may be used to perform a target reset on a programmable basis. The SEL-351 responds to the rising edge of the RSTTRGT equation, and resets the target LEDs provided that TRIP is not asserted.

For example, to reset the targets upon receipt of a control input pulse on IN106, set

RSTTRGT = **IN106**

The built-in rising edge requirement ensures that leaving IN106 asserted does not continually reset the targets.

However, if RSTTRGT is asserted at relay power-up, the relay resets the targets. If there is any chance the controlling condition can remain asserted, insert a rising-edge operator in the setting to eliminate the chance for an unwanted reset. Continuing with the same example, set

RSTTRGT = **/IN106**

Other control methods could use a SELOGIC timer or a remote bit to initiate the target reset.

NOTE: The RSTTRGT function does not assert the TRGTR Relay Word bit.

RSTTRGT is also available as a Relay Word bit, and can be added to the SER trigger settings and monitored in the SER. See *Sequential Events Recorder (SER) Report* on page 12.31.

Optional Logic to Clear Trip Seal-In and Reset Targets

As previously noted, if the ULTR (unlatch trip) setting is not asserted, a sealed-in TRIP Relay Word bit can be cleared by one of the target reset conditions that asserts the TRGTR Relay Word bit, as shown in *Figure 5.1*.

Note that the RSTTRGT SELOGIC control equation does not drive the TRGTR Relay Word bit. If an application requires a trip unlatch function based on the RSTTRGT setting, the logic used in the RSTTRGT SELOGIC control equation setting may be added to the ULTR setting. Continuing from the previous example with RSTTRGT = /IN106, an appropriate ULTR setting is:

ULTR = **IN106 + (existing unlatch trip settings)**

Because of the relay logic processing order, including Relay Word bit RSTTRGT in SELOGIC control equation ULTR will unlatch a sealed-in TRIP but will not reset the targets.

SELOGIC Control Equation Setting FAULT

SELOGIC control equation setting FAULT has control over or is used in the following:

- Front-panel target LEDs **INST**, **A**, **B**, and **C**. See *Front-Panel Target LEDs* on page 5.34.
- Demand Metering—FAULT is used to suspend demand metering peak recording. See *Demand Metering* on page 8.28.
- Maximum/Minimum Metering—FAULT is used to block Maximum/Minimum metering updating. See *Maximum/Minimum Metering* on page 8.39.
- Voltage Sag, Swell Interruption elements—FAULT is used to suspend the calculation of Vbase. See *Voltage Sag, Swell, and Interruption Elements* on page 3.66.

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SECTION 6

Close and Reclose Logic

Overview

This section is made up of the following topics:

Breaker Status Logic

Breaker status logic shows how the breaker status (Relay Word bit 52A) is derived.

Close Logic

This subsection describes the final logic that controls the close output contact (e.g., OUT102 = CLOSE). This output contact closes the circuit breaker for automatic reclosures and other close conditions (e.g., manual close initiation via serial port or optoisolated inputs).

If the SEL-351 Relay is to close the circuit breaker for other close conditions, such as manual close initiation via serial port or optoisolated inputs, but not for automatic reclosing, then this subsection is the only part of this section that you need to read (particularly the description of SELOGIC control equation setting CL).

Reclose Supervision Logic

This subsection describes the logic that supervises automatic reclosing when an open interval timer times out—a final condition check right before the close logic asserts the close output contact.

Reclosing Relay

This subsection describes all the reclosing relay settings and logic needed for automatic reclosing (besides the final close logic and reclose supervision logic described in the previous subsections).

NOTE: Setting E79 = N defeats the reclosing relay, but does not defeat the ability of the close logic described in the first subsection (*Figure 6.2*) to close the circuit breaker for other close conditions via SELOGIC control equation setting CL (e.g., manual close initiation via serial port or optoisolated inputs).

The reclose enable setting, E79, has setting choices N, 1, 2, 3, 4, C1, C2, C3, and C4. Setting E79 = N defeats the reclosing relay. Setting choices 1 through 4, and C1 through C4 are the number of desired automatic reclosures. Setting choices 1 through 4 have the reclosing relay go to the Lockout state upon Reclose Supervision Failure (refer to *Reclose Supervision Logic* on page 6.6). Setting choices C1 through C4, however, do not have the reclosing relay go to the Lockout state upon Reclose Supervision Failure. Instead, the reclosing relay increments the shot counter and starts timing on the next open interval. This operation emulates a rotating drum timer style reclosing relay—going onto the next open interval time and reclose opportunity if supervising conditions for the present reclose opportunity are not true.

Breaker Status Logic

The SEL-351 breaker status logic consists of a single SELOGIC control equation setting 52A, and the Relay Word bit 52A, as shown in *Figure 6.1*.

If 52A is set with numeral 0, all internal close logic is inoperable and the reclosing relay is defeated.

NOTE: The available SafeLock **CLOSE** pushbutton is electrically separate from the rest of the relay and not part of the close logic in *Figure 6.2*. It provides separate closing capability as shown in *Figure 2.29*.

The factory-default setting is:

52A = **IN101**

The pickup and dropout operation of Relay Word bit 52A is affected by the Global debounce timer setting IN101D, and the dropout operation is additionally affected by the 0.5 cycle timer shown in *Figure 6.1*.

See *Optoisolated Inputs* on page 7.1 for information on the debounce timers. See *Figure 2.14* for a typical breaker status input wiring connection.

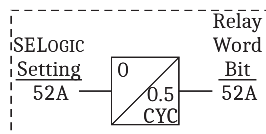


Figure 6.1 Breaker Status Logic

Close Logic

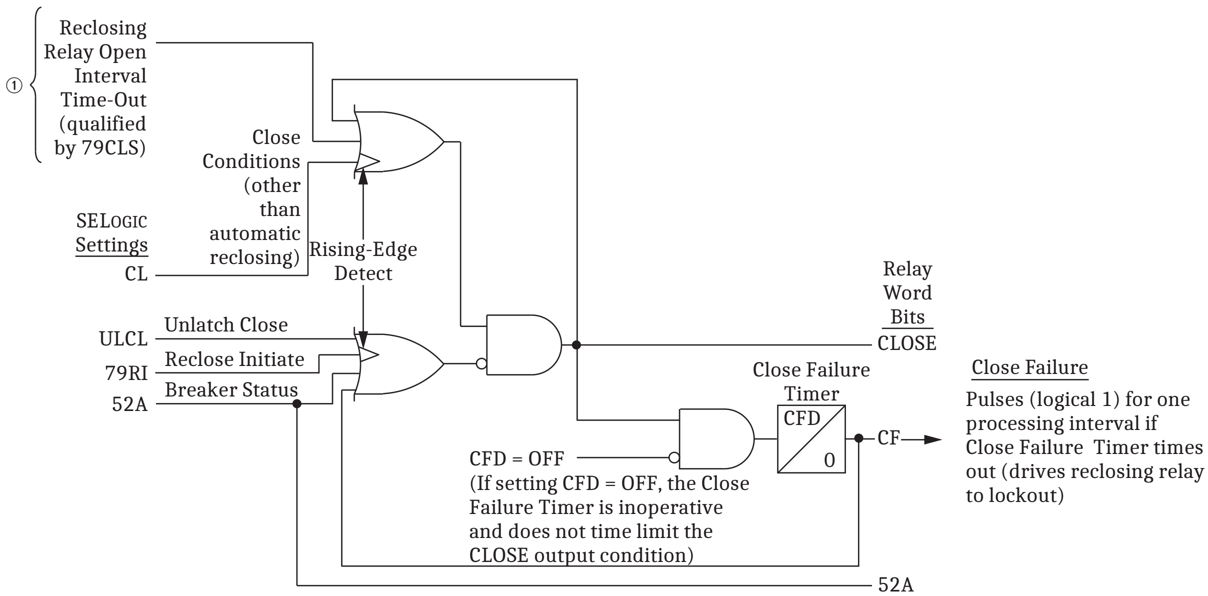
The close logic in *Figure 6.2* provides flexible circuit breaker closing/automatic reclosing with SELOGIC control equation settings:

- 52A (breaker status)
- CL (close conditions, other than automatic reclosing)
- ULCL (unlatch close conditions, other than circuit breaker status, close failure, or reclose initiation)

and setting:

- CFD (Close Failure Time)

See the *SEL-351-5, -6, -7 Relay Settings Sheets* for setting ranges.



① From *Figure 6.3*.

Figure 6.2 Close Logic

Set Close

If *all* the following are true:

- ➤ The unlatch close condition is not asserted (ULCL = logical 0).
- ➤ The circuit breaker is open (52A = logical 0).
- ➤ The reclose initiation condition (79RI) is not making a rising-edge (logical 0 to logical 1) transition.
- ➤ A close failure condition does not exist (Relay Word bit CF = 0).

Then the CLOSE Relay Word bit can be asserted to logical 1 if either of the following occurs:

- ➤ A reclosing relay open interval times out (qualified by SELOGIC control equation setting 79CLS—see *Figure 6.3*).
- ➤ SELOGIC control equation setting CL goes from logical 0 to logical 1 (rising-edge transition).

NOTE: The CLOSE command that asserts Relay Word bit CC for one processing interval is not embedded in the close logic. It is included in the factory SELOGIC control equation settings:
CL = ... + CC

Relay Word bit CC asserts for execution of the **CLOSE** command. See ***CLO (Close Breaker)*** on page 10.40 for more information on the **CLOSE** command. More discussion follows later on the factory settings for setting CL.

If a user wants to supervise the **CLOSE** command with optoisolated input **IN106**, the following setting is made:

CL = **... + CC * IN106**

NOTE: The SafeLock close pushbutton on model 0351xx/B/D is electrically separate from the rest of the relay and not part of the close logic in *Figure 6.2*. It provides separate closing capability as shown in *Figure 2.29*.

With this setting, the **CLOSE** command can provide a close only if optoisolated input **IN106** is asserted. This is just one **CLOSE** command supervision example—many variations are possible.

Unlatch Close

- ➤ If the CLOSE Relay Word bit is asserted at logical 1, it stays asserted at logical 1 until one of the following occurs:
- ➤ The unlatch close condition asserts (ULCL = logical 1).
- ➤ The circuit breaker closes (52A = logical 1).
- ➤ The reclose initiation condition (79RI) makes a rising-edge (logical 0 to logical 1) transition.
- ➤ The Close Failure Timer times out (Relay Word bit CF = 1).

The Close Failure Timer is inoperative if setting CFD = OFF.

Factory Settings Example

The factory settings for the close logic SELOGIC control equation settings are:

52A = **IN101**

CL = **CC + LB4**

ULCL = **TRIP**

The factory setting for the Close Failure Timer setting is:

CFD = **60.00 cycles**

See the *SEL-351-5, -6, -7 Relay Settings Sheets* for setting ranges.

Set Close

If the Reclosing Relay Open Interval Time-Out logic input at the top of *Figure 6.2* is ignored (reclosing is discussed in detail in a following subsection), then SELOGIC control equation setting CL is the only logic input that can set the CLOSE Relay Word bit.

In SELOGIC control equation setting CL = CC + LB4

- ➤ Local bit LB4 operates as a manual close switch via the front panel. See *Local Control Switches* on page 7.5 and *Local Control* on page 11.7 for more information on local control.
- ➤ Relay Word bit CC asserts for execution of the **CLOSE** command. See **CLO *(Close Breaker)*** on page 10.40 for more information on the **CLOSE** command.

Unlatch Close

SELOGIC control equation setting ULCL is set with the TRIP Relay Word bit. This prevents the CLOSE Relay Word bit from being asserted any time the TRIP Relay Word bit is asserted (TRIP takes priority). See *Trip Logic* on page 5.1.

SELOGIC control equation setting 52A is set with optoisolated input IN101. Input IN101 is connected to a 52a circuit breaker auxiliary contact. When a closed circuit breaker condition is detected, the CLOSE Relay Word bit is deasserted to logical 0. Setting 52A can handle a 52a or 52b circuit breaker auxiliary contact connected to an optoisolated input (see *Optoisolated Inputs* on page 7.1 for more 52A setting examples).

With setting CFD = 60.00 cycles, once the CLOSE Relay Word bit asserts, it remains asserted at logical 1 no longer than a *maximum* of 60 cycles. If the Close Failure Timer times out, Relay Word bit CF asserts to logical 1, forcing the CLOSE Relay Word bit to logical 0.

Defeat the Close Logic

The close logic is inoperable and the reclosing relay is defeated (see *Reclosing Relay* on page 6.12) if any of the following are true:

➤ SELOGIC control equation setting 52A is set with numeral 0 (52A = 0)

➤ Unlatch close logic SELOGIC setting ULCL is set with numeral 1 (ULCL = 1)

➤ SELOGIC setting ULCL is set to a SELOGIC condition that is always logical 1

Circuit Breaker Status

Refer to the bottom of *Figure 6.2*. Note that SELOGIC control equation setting 52A (circuit breaker status) is available as Relay Word bit 52A, which makes setting other SELOGIC control equations more convenient. For example, if the following setting is made:

52A = **IN101** (52a auxiliary contact wired to input **IN101**)

or

52A = **!IN101** (52b auxiliary contact wired to input **IN101**)

then if breaker status is used in other SELOGIC control equations, it can be entered as 52A—the user does not have to enter IN101 (for a 52a) or !IN101 (for a 52b). For example, refer to *Rotating Display* on page 7.37. In the factory settings, circuit breaker status indication is controlled by display point setting DP2:

DP2 = **IN101**

This can be entered instead as:

DP2 = **52A**

(presuming SELOGIC control equation setting 52A = IN101 is made).

Program an Output Contact for Closing

In the factory settings, the result of the close logic in *Figure 6.2* is routed to output contact **OUT102** with the following SELOGIC control equation:

OUT102 = **CLOSE**

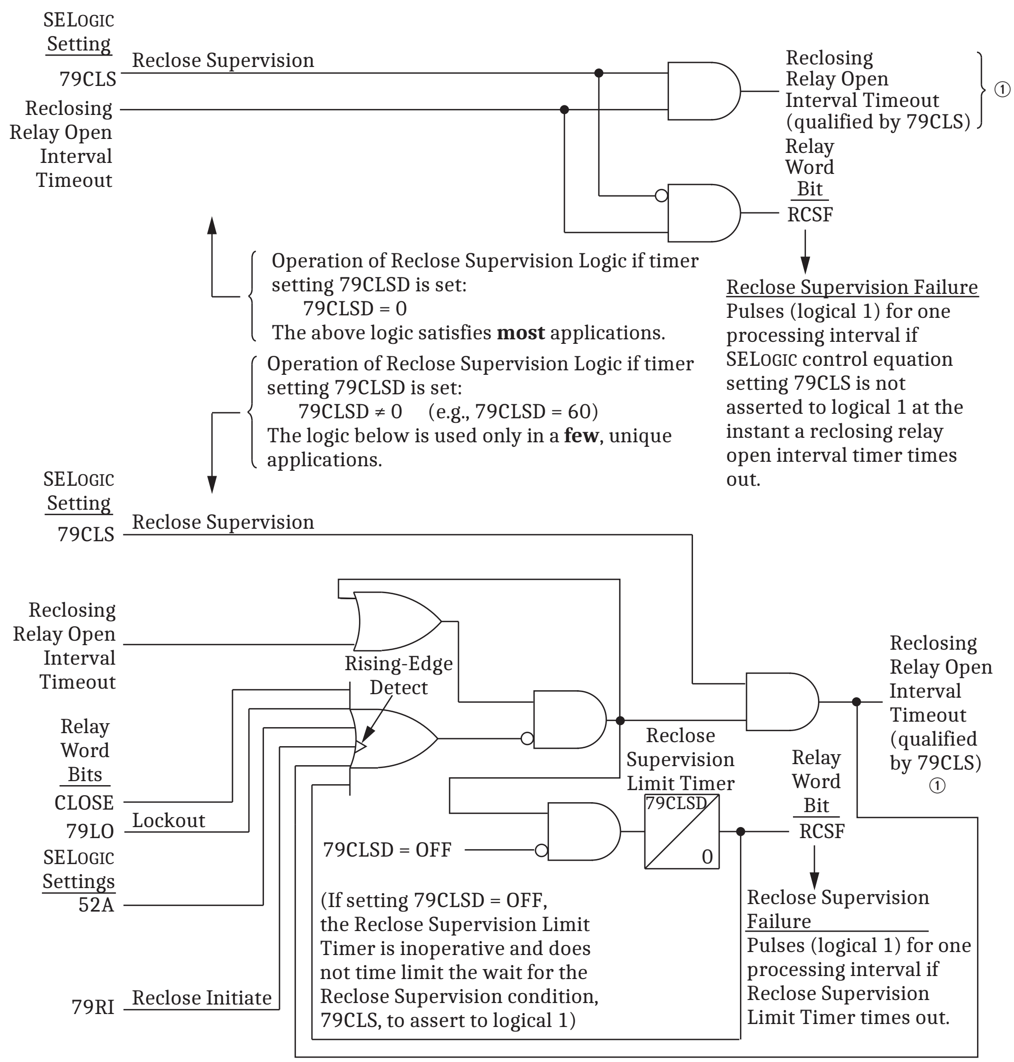
See *Output Contacts* on page 7.33 for more information on programming output contacts.

Reclose Supervision Logic

Note that one of the inputs into the close logic in *Figure 6.2* is:

Reclosing Relay Open Interval Time-Out (qualified by 79CLS)

This input into the close logic in *Figure 6.2* is the indication that a reclosing relay open interval has timed out (see *Figure 6.7*), a qualifying condition (SELOGIC control equation setting 79CLS) has been met, and thus automatic reclosing of the circuit breaker should proceed by asserting the CLOSE Relay Word bit to logical 1. This input into the close logic in *Figure 6.2* is an output of the reclose supervision logic in the following *Figure 6.3*.



① To *Figure 6.2*.

Figure 6.3 Reclose Supervision Logic (Following Open Interval Time-Out)

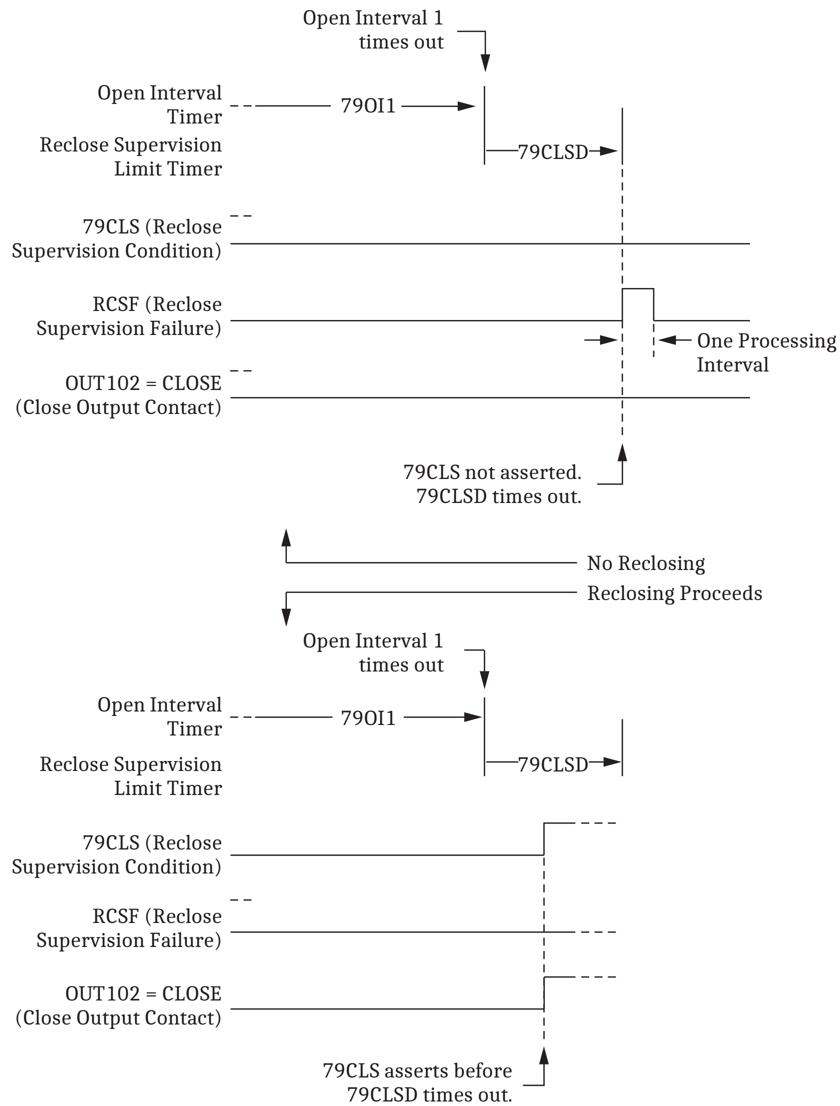


Figure 6.4 Reclose Supervision Limit Timer Operation (Refer to Bottom of *Figure 6.3*)

Settings and General Operation

Figure 6.3 contains the following SELOGIC control equation setting:

79CLS (reclose supervision conditions—checked after reclosing relay open interval time-out)

and setting:

79CLSD (Reclose Supervision Limit Time)

See the *SEL-351-5, -6, -7 Relay Settings Sheets* for setting ranges.

For Most Applications (Top of *Figure 6.3*)

For most applications, the Reclose Supervision Limit Time setting should be set to zero cycles:

79CLSD = **0.00**

With this setting, the logic in the top of *Figure 6.3* is operative. When an open interval times out, the SELOGIC control equation reclose supervision setting 79CLS is *checked just once*.

If 79CLS is *asserted* to logical 1 at the instant of an open interval time-out, then the now-qualified open interval time-out will propagate onto the final close logic in *Figure 6.2* to automatically reclose the circuit breaker.

If 79CLS is *deasserted* to logical 0 at the instant of an open interval time-out, the following occurs:

- No automatic reclosing takes place.
- Relay Word bit RCSF (Reclose Supervision Failure indication) asserts to logical 1 for one processing interval.
- If setting E79 = 1, 2, 3, or 4, the reclosing relay is driven to Lockout State.
- If setting E79 = C1, C2, C3, or C4, the reclosing relay increments the shot counter and starts timing on the next open interval. This operation emulates a rotating drum timer style reclosing relay—going onto the next open interval time and reclose opportunity if supervising conditions for the present reclose opportunity are not satisfied. If the reclosing relay increments to the last shot value (no more open intervals left; see *Figure 6.7* and *Table 6.3*), the reclosing relay is then driven to the Lockout State.

See *Factory Settings Example* on page 6.10 and *Additional Settings Example 1* on page 6.10.

For A Few, Unique Applications (Bottom of *Figure 6.3* and *Figure 6.4*)

For a few unique applications, the Reclose Supervision Limit Time setting is *not* set equal to zero cycles, e.g.,

79CLSD = **60.00**

With this setting, the logic in the bottom of *Figure 6.3* is operative. When an open interval times out, the SELOGIC control equation reclose supervision setting 79CLS is then *checked for a time window* equal to setting 79CLSD.

If 79CLS *asserts* to logical 1 at any time during this 79CLSD time window, then the now-qualified open interval time-out will propagate onto the final close logic in *Figure 6.2* to automatically reclose the circuit breaker.

If 79CLS remains *deasserted* to logical 0 during this entire 79CLSD time window, when the time window times out, the following occurs:

- No automatic reclosing takes place.
- Relay Word bit RCSF (Reclose Supervision Failure indication) asserts to logical 1 for one processing interval.
- If setting E79 = 1, 2, 3, or 4, the reclosing relay is driven to Lockout State.
- If setting E79 = C1, C2, C3, or C4, the reclosing relay increments the shot counter and starts timing on the next open interval. This operation emulates a rotating drum timer style reclosing relay—going onto the next open interval time and reclose opportunity if supervising conditions for the present reclose opportunity are not satisfied. If the reclosing relay increments to the last shot value (no more open intervals left; see *Figure 6.7* and *Table 6.3*), the reclosing relay is then driven to the Lockout State.

The logic in the bottom of *Figure 6.3* is explained in more detail in the following text.

Set Reclose Supervision Logic (Bottom of *Figure 6.3*)

Refer to the bottom of *Figure 6.3*. If *all* the following are true:

- The close logic output CLOSE (also see *Figure 6.2*) is *not* asserted (Relay Word bit CLOSE = logical 0).
- The reclosing relay is *not* in the Lockout State (Relay Word bit 79LO = logical 0).
- The circuit breaker is open (52A = logical 0).
- The reclose initiation condition (79RI) is *not* making a rising edge (logical 0 to logical 1) transition.
- The Reclose Supervision Limit Timer is *not* timed out (Relay Word bit RCSF = logical 0).

then a reclosing relay open interval time-out seals in as shown in *Figure 6.3*. Then, when 79CLS asserts to logical 1, the sealed-in reclosing relay open interval time-out condition will propagate through *Figure 6.3* and on to the close logic in *Figure 6.2*.

Unlatch Reclose Supervision Logic (Bottom of *Figure 6.3*)

Refer to the bottom of *Figure 6.3*. If the reclosing relay open interval time-out condition is sealed-in, it stays sealed-in until *one* of the following occurs:

- The close logic output CLOSE (also see *Figure 6.3*) asserts (Relay Word bit CLOSE = logical 1).
- The reclosing relay goes to the Lockout State (Relay Word bit 79LO = logical 1).
- The circuit breaker closes (52A = logical 1).
- The reclose initiation condition (79RI) makes a rising-edge (logical 0 to logical 1) transition.
- SELOGIC control equation setting 79CLS asserts (79CLS = logical 1).
- The Reclose Supervision Limit Timer times out (Relay Word bit RCSF = logical 1 for one processing interval).

⚠WARNING
Setting 79CLSD = OFF can create an infinite "standing close" condition. For example, if SELOGIC control equation 79CLS is deasserted with 79CLSD = OFF, manual action could cause 79CLS to assert, allowing the breaker to immediately reclose.

The Reclose Supervision Limit Timer is inoperative if setting 79CLSD = OFF. With 79CLSD = OFF, reclose supervision condition 79CLS is not time limited. When an open interval times out, reclose supervision condition 79CLS is checked indefinitely until one of the other above unlatch conditions comes true.

The unlatching of the sealed-in reclosing relay open interval time-out condition by the assertion of SELOGIC control equation setting 79CLS indicates successful propagation of a reclosing relay open interval time-out condition on to the close logic in *Figure 6.2*.

See *Additional Settings Example 2* on page 6.12.

Factory Settings Example

Refer to the top of *Figure 6.3*.

The factory setting for the SELOGIC control equation reclose supervision setting is:

79CLS = **1** (numeral 1)

The factory setting for the Reclose Supervision Limit Timer setting is:

79CLSD = **0.00 cycles**

Any time a reclosing relay open interval times out, it propagates immediately through *Figure 6.3* and then on to *Figure 6.2*, because SELOGIC control equation setting 79CLS is always asserted to logical 1. Effectively, there is no special reclose supervision.

Additional Settings Example 1

Refer to the top of *Figure 6.3* and *Figure 6.5*.

SEL-351 Relays are installed at both ends of a transmission line in a high-speed reclose scheme. After both circuit breakers open for a transmission line fault, the SEL-351(1) recloses circuit breaker 52/1 first, followed by the SEL-351(2) reclosing circuit breaker 52/2, after a synchronism check across circuit breaker 52/2.

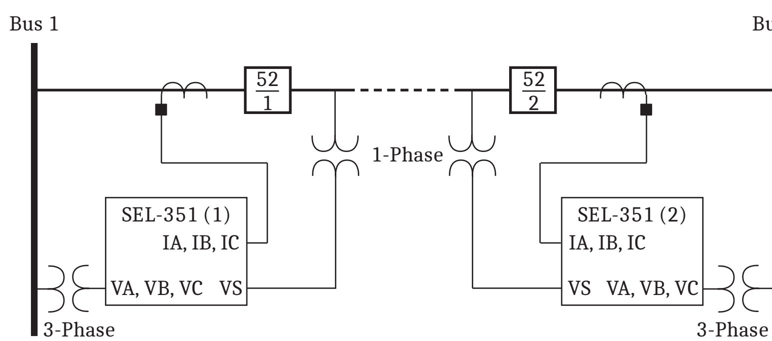


Figure 6.5 SEL-351 Relays Installed at Both Ends of a Transmission Line in a High-Speed Reclose Scheme

SEL-351(1) Relay

Before allowing circuit breaker 52/1 to be reclosed after an open interval time-out, the SEL-351(1) checks that Bus 1 voltage is hot and the transmission line voltage is dead. This requires reclose supervision settings:

79CLSD = **0.00 cycles** (only one check)

79CLS = **3P59 * 27S**

where:

3P59 = all three Bus 1 phase voltages (VA, VB, and VC) are hot

27S = monitored single-phase transmission line voltage (channel VS) is dead

SEL-351(2) Relay

The SEL-351(2) checks that Bus 2 voltage is hot, the transmission line voltage is hot, and both voltages satisfy the synchronism-check logic requirements after the reclosing relay open interval times out, before allowing circuit breaker 52/2 to be reclosed. This requires reclose supervision settings:

79CLSD = **0.00 cycles** (only one check)

79CLS = **25A1**

where:

25A1 = selected Bus 2 phase voltage (VA, VB, or VC) is in synchronism with monitored single-phase transmission line voltage (channel VS) and both are hot

Other Setting Considerations for SEL-351(1) and SEL-351(2) Relays

Refer to *Skip Shot and Stall Open-Interval Timing Settings (79SKP and 79STL, Respectively)* on page 6.24.

SELOGIC control equation setting 79STL stalls open interval timing if it asserts to logical 1. If setting 79STL is deasserted to logical 0, open interval timing can continue. The SEL-351(1) has no intentional open interval timing stall condition (circuit breaker 52/1 closes first after a transmission line fault):

79STL = **0** (numeral 0)

The SEL-351(2) starts open interval timing after circuit breaker 52/1 at the remote end has re-energized the line. The SEL-351(2) has to see Bus 2 hot, transmission line hot, and both voltages satisfy the synchronism-check logic requirements across open circuit breaker 52/2 for open interval timing to begin. Thus, SEL-351(2) open interval timing is stalled when the transmission line voltage and Bus 2 voltage are *not* in synchronism across open circuit breaker 52/2:

79STL = **!25A1** [=NOT(25A1)]

A transient condition that meets the synchronism-check requirements across open circuit breaker 52/2 could possibly occur if circuit breaker 52/1 recloses into a fault on one phase of the transmission line. The other two unfaulted phases would be briefly energized until circuit breaker 52/1 is tripped again. If channel VS of the SEL-351(2) is connected to one of these briefly energized phases, synchronism-check element 25A1 could momentarily assert to logical 1.

So that this possible momentary assertion of synchronism-check element 25A1 does not cause any inadvertent reclose of circuit breaker 52/2, make sure the open interval timers in the SEL-351(2) are set with some appreciable time greater than the momentary energization time of the faulted transmission line. Or, run the synchronism-check element 25A1 through a programmable timer before using it in the preceding 79CLS and 79STL settings for the SEL-351(2) (see *Figure 7.24* and *Figure 7.25*). Note the built-in 3 cycle qualification of the synchronism-check voltages shown in *Figure 3.29*.

Additional Settings Example 2

Refer to *Synchronism-Check Elements* on page 3.36. Also refer to *Figure 6.4* and *Figure 6.5*.

If the synchronizing voltages across open circuit breaker 52/2 are "slipping" with respect to one another, the Reclose Supervision Limit Timer setting 79CLSD should be set greater than zero so there is time for the slipping voltages to come into synchronism. For example:

79CLSD = **60.00 cycles**

79CLS = **25A1**

The status of synchronism-check element 25A1 is checked continuously during the 60-cycle window. If the slipping voltages come into synchronism while timer 79CLSD is timing, synchronism-check element 25A1 asserts to logical 1 and reclosing proceeds.

If E79 = 1, 2, 3, or 4 (which allows one to four automatic reclose attempts) and the slipping voltages fail to come into synchronism while timer 79CLSD is timing (resulting in a reclose supervision failure, causing RCSF to assert for one processing interval), then the reclosing relay goes to the Lockout State.

If E79 = C1, C2, C3, or C4 (which allows one to four automatic reclose attempts) and the slipping voltages fail to come into synchronism while timer 79CLSD is timing (resulting in a reclose supervision failure, causing RCSF to assert for one processing interval), then the reclosing relay increments the shot counter and starts timing on the next open interval. This operation emulates a rotating drum timer style reclosing relay-going onto the next open interval time and reclose opportunity if supervising conditions for the present reclose opportunity are not true. If the reclosing relay increments to the last shot value (no more open intervals left; see *Figure 6.7* and *Table 6.3*), the reclosing relay is then driven to the Lockout State.

In *Synchronism-Check Elements*, note item 3 under *Synchronism-Check Element Outputs* on page 3.53, Voltages V_P and V_S are "Slipping." Item 3 describes a last attempt for a synchronism-check reclose before timer 79CLSD times out (or setting 79CLSD = 0.00 and only one check is made).

Reclosing Relay

Note that input:

Reclosing Relay Open Interval Time-Out

in *Figure 6.3* is the logic input that is qualified by SELOGIC control equation setting 79CLS, and then propagated on to the close logic in *Figure 6.2* to automatically reclose a circuit breaker. The explanation that follows in this reclosing relay subsection describes all the reclosing relay settings and logic that eventually result in this open interval time-out logic input into *Figure 6.3*. Other aspects of the reclosing relay are also explained. As many as four (4) automatic reclosures (shots) are available.

The reclose enable setting, E79, has setting choices N, 1, 2, 3, 4, C1, C2, C3, and C4. Setting E79 = N defeats the reclosing relay. Setting choices 1 through 4 are the number of desired automatic reclosures (see *Open Interval Timers* on page 6.16). Setting choices 1 through 4 also have the reclosing relay go to the Lockout state upon reclose supervision failure (refer to *Reclose Supervision Logic* on page 6.6).

Setting choice C1 through C4 similarly are the number of desired automatic reclosures (C1 for one reclosure, C2 for two reclosures, etc.). Setting choices C1 through C4, however, do not have the reclosing relay go to the Lockout state upon reclose supervision failure. Instead, the reclosing relay increments the shot counter and starts timing on the next open interval. This operation emulates a rotating drum timer style reclosing relay—going onto the next open interval time and reclose opportunity if supervising conditions for the present reclose opportunity are not satisfied. If the reclosing relay increments to the last shot value (no more open intervals left; see *Figure 6.7* and *Table 6.3*), the reclosing relay is then driven to the Lockout State.

Reclosing Relay States and General Operation

Figure 6.6 explains in general the different states of the reclosing relay and its operation.

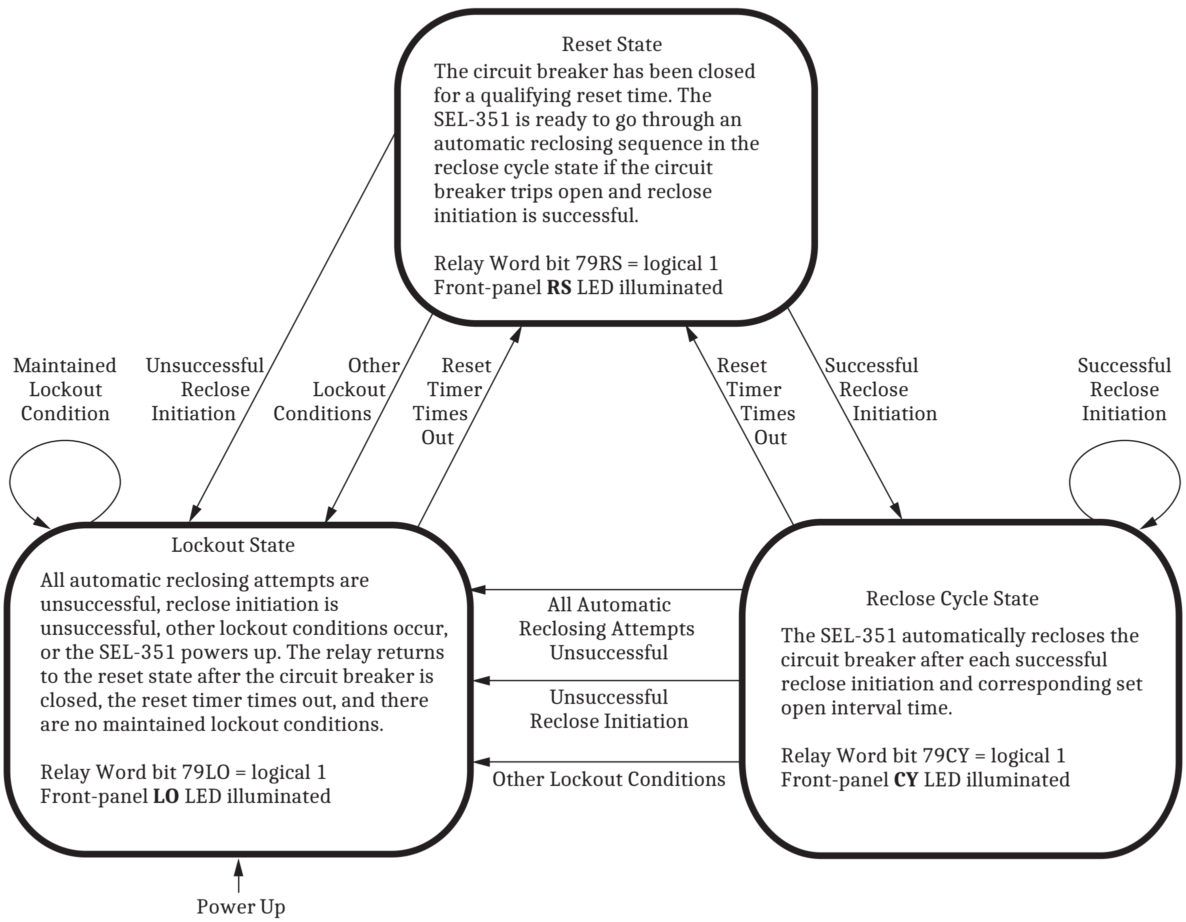


Figure 6.6 Reclosing Relay States and General Operation

Table 6.1 Relay Word Bit and Front-Panel Correspondence to Reclosing Relay States

Reclosing Relay State	Corresponding Relay Word Bit	Corresponding Front-Panel LED
Reset	79RS	RS
Reclose Cycle	79CY	CY
Lockout	79LO	LO

The reclosing relay is in one (and only one) of these states (listed in *Table 6.1*) at any time. When in a given state, the corresponding Relay Word bit asserts to logical 1, and the LED illuminates. Automatic reclosing only takes place when the relay is in the Reclose Cycle State.

Lockout State

The reclosing relay goes to the Lockout State if any *one* of the following occurs:

- The shot counter is equal to or greater than the last shot at time of reclose initiation (e.g., all automatic reclosing attempts are unsuccessful—see *Figure 6.7*).
- Reclose initiation is unsuccessful because of SELOGIC control equation setting 79RIS (see *Reclose Initiate and Reclose Initiate Supervision Settings (79RI and 79RIS, Respectively)* on page 6.20).
- The circuit breaker opens without reclose initiation (e.g., an external trip).

  If a trip is issued via the front-panel SafeLock trip pushbutton (model 0351*xx*B/D) and it is wired similar to *Figure 2.29*, then this trip appears as an external trip to the relay and the relay goes to the lockout state.
- The shot counter is equal to or greater than last shot, and the circuit breaker is open (e.g., the shot counter is driven to last shot with SELOGIC control equation setting 79DLS while open interval timing is in progress. See *Drive-to-Lockout and Drive-to-Last Shot Settings (79DTL and 79DLS, Respectively)* on page 6.22).
- The close failure timer (setting CFD) times out (see *Figure 6.2*).
- SELOGIC control equation setting 79DTL = logical 1 (see *Drive-to-Lockout and Drive-to-Last Shot Settings (79DTL and 79DLS, Respectively)*).
- The Reclose Supervision Limit Timer (setting 79CLSD) times out (see *Figure 6.3* and top of *Figure 6.4*) and the reclose enable setting, E79, is set to 1, 2, 3, or 4.
- A normal reclose initiation (e.g., SELOGIC control equation 79RI = TRIP) occurs and properly loads up an open-interval time (e.g., 79OI2 = 600 cycles; see *Figure 6.7*). Then, before the open-interval time has timed out completely (or even started timing), a subsequent unexpected reclose initiation occurs (e.g., flashover inside the circuit breaker tank while it is open).
- This lockout condition occurs when the open interval timer expires and CLOSE is asserted. If the SELOGIC control equation setting ULCL deasserts CLOSE before the breaker status indication, 52A, Relay Word bit asserts, then the relay will consider the close operation unsuccessful and go to lockout.

The **OPEN** command is included in the reclosing relay logic via the factory SELOGIC control equation settings:

79DTL = **... + OC** (drive-to-lockout)

Relay Word bit OC asserts for execution of the **OPEN** command. See ***OPE (Open Breaker)*** on page 10.63 for more information on the **OPEN** command. Also, see *Drive-to-Lockout and Drive-to-Last Shot Settings (79DTL and 79DLS, Respectively)* on page 6.22.

If the **OPEN** command is set to trip (TR = … + OC), then the following reclosing relay SELOGIC control equation settings should also be made (presuming that an **OPEN** command trip should not initiate reclosing):

79RI = **TRIP** (reclose initiate)

79DTL = **... + OC** (drive-to-lockout)

This is how the SEL-351 is set at the factory.

Reclosing Relay States and Settings/Setting Group Changes

If individual settings are changed for the active setting group *or* the active setting group is changed, *all* of the following occur:

- ➤ The reclosing relay remains in the state it was in before the settings change.
- ➤ The shot counter is driven to last shot (last shot corresponding to the new settings; see discussion on last shot that follows).
- ➤ The reset timer is loaded with reset time setting 79RSLD (see discussion on reset timing later in this section).

If the relay happened to be in the Reclose Cycle State and was timing on an open interval before the settings change, the relay would be in the Reclose Cycle State after the settings change, but the relay would immediately go to the Lockout State. This is because the breaker is open, and the relay is at last shot after the settings change, and thus no more automatic reclosures are available.

If the circuit breaker remains closed through the settings change, the reset timer times out on reset time setting 79RSLD after the settings change and goes to the Reset State (if it is not already in the Reset State), and the shot counter returns to shot = 0. If the relay happens to trip during this reset timing, the relay will immediately go to the Lockout State, because shot = last shot.

Defeat the Reclosing Relay

If *any one* of the following reclosing relay settings are made:

- ➤ Reclose enable setting E79 = N.
- ➤ Open Interval 1 time setting 79OI1 = 0.00.

then the reclosing relay is defeated, and no automatic reclosing can occur. These settings are explained later in this section. See also the *SEL-351-5, -6, -7 Relay Settings Sheets*.

If the reclosing relay is defeated, the following also occur:

➤ All three reclosing relay state Relay Word bits (79RS, 79CY, and 79LO) are forced to logical 0 (see *Table 6.1*).

➤ All shot counter Relay Word bits (SH0, SH1, SH2, SH3, and SH4) are forced to logical 0 (the shot counter is explained later in this section).

➤ The front-panel LEDs RS, CY, and LO are all extinguished, providing a visible indication that the recloser is defeated.

Close Logic Can Still Operate When the Reclosing Relay Is Defeated

If the reclosing relay is defeated, the close logic (see *Figure 6.2*) can still operate if the following settings are *not* true:

➤ 52A = 0

➤ ULCL = logical 1

Making 52A = 0 or ULCL = 1 (or setting ULCL to a SELOGIC condition that is always logical 1) defeats the close logic *and* also defeats the reclosing relay.

For example, if 52A = IN101, a 52a circuit breaker auxiliary contact is connected to input IN101. If the reclosing relay does not exist, the close logic still operates, allowing closing to take place via SELOGIC control equation setting CL (close conditions, other than automatic reclosing). See *Close Logic* on page 6.2 for more discussion on SELOGIC control equation settings 52A and CL. Also see *Optoisolated Inputs* on page 7.1 for more discussion on SELOGIC control equation setting 52A.

Reclosing Relay Timer Settings

The open interval and reset timer factory settings are shown in *Table 6.2*.

Table 6.2 Reclosing Relay Timer Settings and Setting Ranges

Timer Setting (range)	Factory Setting (in cycles)	Definition
79OI1 (0.00–999999 cyc)	300.00	open interval 1 time
79OI2 (0.00–999999 cyc)	0.00	open interval 2 time
79OI3 (0.00–999999 cyc)	0.00	open interval 3 time
79OI4 (0.00–999999 cyc)	0.00	open interval 4 time
79RSD (0.00–999999 cyc)	1800.00	reset time from reclose cycle state
79RSLD (0.00–999999 cyc)	300.00	reset time from lockout state

The operation of these timers is affected by SELOGIC control equation settings discussed later in this section. Also, see the *SEL-351-5, -6, -7 Relay Settings Sheets*.

Open Interval Timers

The reclose enable setting, E79, determines the number of open interval time settings that can be set. For example, if setting E79 = 3 or C3, the first three open interval time settings in *Table 6.2* are made available for setting.

If an open interval time is set to zero, then that open interval time is not operable, *and* neither are the open interval times that follow it.

In the factory settings in *Table 6.2*, the open interval 3 time setting 79OI2 is the first open interval time setting set equal to zero:

79OI2 = **0.00 cycles**

Thus, open interval times 79OI2, 79OI3, and 79OI4 are not operable. In the factory settings, both open interval times 79OI3 and 79OI4 are set to zero. But if the settings were:

79OI2 = **0.00 cycles**

79OI3 = **900.00 cycles** (set to some value other than zero)

open interval time 79OI3 would still be inoperative, because a preceding open interval time is set to zero (i.e., 79OI2 = 0.00).

If open interval 1 time setting, 79OI1, is set to zero (79OI1 = 0.00 cycles), no open interval timing takes place, and the reclosing relay is defeated.

The open interval timers time consecutively; they do not have the same beginning time reference point. For example, with settings 79OI1 = 30.00 cycles, and 79OI2 = 600.00 cycles, open interval 1 time setting, 79OI1, times first. If subsequent first reclosure is not successful, then open interval 2 time setting, 79OI2, starts timing. If the subsequent second reclosure is not successful, the relay goes to the Lockout State. See the example time line in *Figure 6.7*. The open interval timer starts timing when the 52A status deasserts (logical 0) following a valid reclose initiation, unless the open interval timing is suspended because the SELOGIC control equation 79STL is asserted (logical 1).

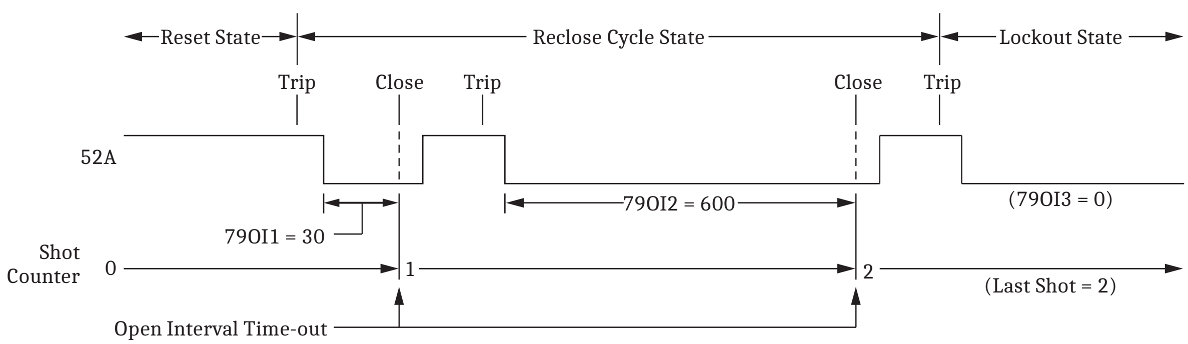


Figure 6.7 Reclosing Sequence From Reset to Lockout With Example Settings

SELOGIC control equation setting 79STL (stall open interval timing) can be set to control open interval timing (see *Skip Shot and Stall Open-Interval Timing Settings (79SKP and 79STL, Respectively)* on page 6.24).

Determination of Number of Reclosures (Last Shot)

The number of reclosures is equal to the number of open interval time settings that precede the first open interval time setting set equal to zero. The “last shot” value is also equal to the number of reclosures.

In the above example settings, two set open interval times precede open interval 3 time, which is set to zero (79OI3 = 0.00):

79OI1 = **30.00**

79OI2 = **600.00**

79OI3 = **0.00**

For this example:

Number of reclosures (last shot) = 2 = the number of set open interval times that precede the first open interval set to zero.

Observe Shot Counter Operation

Observe the reclosing relay shot counter operation, especially during testing, with the front-panel shot counter screen (accessed via the OTHER pushbutton). See *Functions Unique to the Front-Panel Interface* on page 11.5.

Reset Timer

The reset timer qualifies circuit breaker closure before taking the relay to the Reset State from the Reclose Cycle State or the Lockout State. Circuit breaker status is determined by the SELOGIC control equation setting 52A. (See *Close Logic* on page 6.2 and *Optoisolated Inputs* on page 7.1 for more discussion on SELOGIC control equation setting 52A.)

Setting 79RSD

Qualifies closures when the relay is in the Reclose Cycle State. These closures are usually automatic reclosures resulting from open interval time-out.

It is also the reset time used in sequence coordination schemes (see *Sequence Coordination Setting (79SEQ)* on page 6.27).

Setting 79RSLD

Qualifies closures when the relay is in the Lockout State. These closures are usually manual closures. These manual closures can originate external to the relay, via the **CLOSE** command, or via the SELOGIC control equation setting CL (see *Figure 6.2*).

Setting 79RSLD is also the reset timer used when the relay powers up, when settings are changed in the active setting group, or the active setting group is changed (see *Reclosing Relay States and Settings/Setting Group Changes* on page 6.15).

Setting 79RSD and Setting 79RSLD Are Independent

Typically, setting 79RSLD is set less than setting 79RSD. Setting 79RSLD emulates reclosing relays with motor-driven timers that have a relatively short reset time from the lockout position to the reset position.

The 79RSD and 79RSLD settings are set independently (setting 79RSLD can even be set greater than setting 79RSD, if desired). SELOGIC control equation setting 79BRS (block reset timing) can be set to control reset timing (see *Block Reset Timing Setting (79BRS)* on page 6.26).

Monitoring Open-Interval and Reset Timing

Open-interval and reset timing can be monitored with the following Relay Word bits:

Relay Word Bits	Definition
OPTMN	Indicates that the open interval timer is *actively* timing
RSTMN	Indicates that the reset timer is *actively* timing

If the open-interval timer is actively timing, OPTMN asserts to logical 1. When the relay is not timing on an open interval (e.g., it is in the Reset State or in the Lockout State), OPTMN deasserts to logical 0. The relay can only time on an open interval when it is in the Reclose Cycle State, but just because the relay is in the Reclose Cycle State does not necessarily mean the relay is timing on an open interval. When the next open interval is enabled, the relay only times on the open interval after successful reclose initiation, the breaker is open (52A = logical 0), and no stall conditions are present (see *Skip Shot and Stall Open-Interval Timing Settings (79SKP and 79STL, Respectively)* on page 6.24).

If the reset timer is actively timing, RSTMN asserts to logical 1. If the reset timer is not timing, RSTMN deasserts to logical 0. See *Block Reset Timing Setting (79BRS)* on page 6.26.

Reclosing Relay Shot Counter

Refer to *Figure 6.7*.

The shot counter increments for each reclose operation. For example, when the relay is timing on open interval 1, 79OI1, it is at shot = 0. When the open interval times out, the shot counter increments to shot = 1 and so forth for the set open intervals that follow. The shot counter cannot increment beyond the last shot for automatic reclosing (see *Determination of Number of Reclosures (Last Shot)* on page 6.17). The shot counter resets back to shot = 0 when the reclosing relay returns to the Reset State.

Table 6.3 Shot Counter Correspondence to Relay Word Bits and Open Interval Times

Shot	Corresponding Relay Word Bit	Corresponding Open Interval
0	SH0	79OI1
1	SH1	79OI2
2	SH2	79OI3
3	SH3	79OI4
4	SH4	

When the shot counter is at a particular shot value (e.g., shot = 2), the corresponding Relay Word bit asserts to logical 1 (e.g., SH2 = logical 1).

The shot counter also increments for sequence coordination operation. The shot counter can increment beyond the last shot for sequence coordination (see *Sequence Coordination Setting (79SEQ)* on page 6.27).

Reclosing Relay SELOGIC Control Equation Settings Overview

Table 6.4 Reclosing Relay SELOGIC Control Equation Settings

SELOGIC Control Equation Setting	Factory Setting	Definition
79RI	TRIP	Reclose Initiate
79RIS	52A + 79CY	Reclose Initiate Supervision
79DTL	OC + !IN102 + LB3	Drive-to-Lockout
79DLS	79LO	Drive-to-Last Shot
79SKP	0	Skip Shot
79STL	TRIP	Stall Open Interval Timing
79BRS	TRIP	Block Reset Timing
79SEQ	0	Sequence Coordination
79CLS	1	Reclose Supervision

These settings are discussed in detail in the remainder of this subsection.

Reclose Initiate and Reclose Initiate Supervision Settings (79RI and 79RIS, Respectively)

The reclose initiate setting 79RI is a rising-edge detect setting. The reclose initiate supervision setting 79RIS supervises setting 79RI. When setting 79RI senses a rising edge (logical 0 to logical 1 transition), setting 79RIS has to be at logical 1 (79RIS = logical 1) in order for open interval timing to be initiated.

If 79RIS = logical 0 when setting 79RI senses a rising edge (logical 0 to logical 1 transition), the relay goes to the Lockout State.

Factory Settings Example

With factory settings:

79RI = **TRIP**

79RIS = **52A + 79CY**

the transition of the TRIP Relay Word bit from logical 0 to logical 1 enables the next open-interval only if Relay Word bits 52A or 79CY are logical 1. Input **IN101** is assigned as the breaker status input in the factory settings (52A = IN101).

The circuit breaker has to be closed (circuit breaker status 52A = logical 1) at the instant of the first trip of the autoreclose cycle in order for the SEL-351 to successfully initiate reclosing and start timing on the first open interval. The SEL-351 is not yet in the reclose cycle state (79CY = logical 0) at the instant of the first trip.

Then for any subsequent trip operations in the autoreclose cycle, the SEL-351 is in the reclose cycle state (79CY = logical 1) and the SEL-351 successfully initiates reclosing for each trip. Because of factory setting 79RIS = 52A + 79CY, successful reclose initiation in the reclose cycle state (79CY = logical 1) is not dependent on the circuit breaker status (52A). This allows successful reclose initiation for the case of an instantaneous trip, but the circuit breaker status indication is slow—the instantaneous trip (reclose initiation) occurs before the SEL-351 sees the circuit breaker close.

If a flashover occurs in a circuit breaker tank during an open interval (circuit breaker open and the SEL-351 calls for a trip), the SEL-351 goes immediately to lockout.

Additional Settings Example

The preceding settings example initiates open interval timing on rising edge of the TRIP Relay Word bit. The following is an example of reclose initiation on the opening of the circuit breaker.

Presume input **IN101** is connected to a 52a circuit breaker auxiliary contact (52A = IN101).

With setting:

79RI = **!52A**

the transition of the 52A Relay Word bit from logical 1 to logical 0 (breaker opening) enables the next open interval. Setting 79RI looks for a logical 0 to logical 1 transition, thus Relay Word bit 52A is inverted in the 79RI setting [!52A = NOT(52A)].

The reclose initiate supervision setting 79RIS supervises setting 79RI. With settings:

79RI = **!52A**

79RIS = **TRIP**

the transition of the 52A Relay Word bit from logical 1 to logical 0 enables the next open interval only if the TRIP Relay Word bit is at logical 1 (TRIP = logical 1). Thus, the TRIP Relay Word bit has to be asserted when the circuit breaker opens in order to initiate open interval timing. With a long enough setting of the Minimum Trip Duration Timer (TDURD), the TRIP Relay Word bit will still be asserted to logical 1 when the circuit breaker opens (see *Figure 5.1* and *Figure 5.2*).

If the TRIP Relay Word bit is at logical 0 (TRIP = logical 0) when the circuit breaker opens (79RI transitions from logical 0 to logical 1), the relay goes to the Lockout State. This helps prevent reclose initiation for circuit breaker openings caused by trips external to the relay.

If circuit breaker status indication (52A) is slow, the TRIP Relay Word bit should be removed from unlatch close setting ULCL (*Figure 6.4*) when setting 79RI = !52A. This keeps the SEL-351 from going to lockout prematurely for an instantaneous trip after an autoreclose by allowing CLOSE to remain asserted until the circuit breaker status indication confirms that the breaker is closed. The circuit breaker anti-pump circuitry should take care of the TRIP and CLOSE being on together for a short period of time.

Other Settings Considerations

1. In the preceding additional setting example, the reclose initiate setting (79RI) includes input **IN101**, that is connected to a 52a breaker auxiliary contact (52A = IN101).

   79RI = **!52A**

   If a 52b breaker auxiliary contact is connected to input **IN101** (52A = !IN101), the reclose initiate setting (79RI) remains the same.
2. If no reclose initiate supervision is desired, make the following setting:

79RIS = **1** (numeral 1)

Setting 79RIS = logical 1 at all times. Any time a logical 0 to logical 1 transition is detected by setting 79RI, the next open interval will be enabled (unless prevented by other means).

3. If the following setting is made:

   79RI = **0** (numeral 0)

   reclosing will never take place. The reclosing relay is effectively inoperative because there is no way to initiate the autoreclose cycle. However, the relay reclose state might still transition between RESET (79RS = 1) and LOCKOUT (79LO = 1), depending on 52A status.

4. If the following setting is made:

   79RIS = **0** (numeral 0)

   reclosing will never take place (the reclosing relay goes directly to the lockout state any time reclosing is initiated). The reclosing relay is effectively inoperative.

Drive-to-Lockout and Drive-to-Last Shot Settings (79DTL and 79DLS, Respectively)

When 79DTL = logical 1, the reclosing relay goes to the Lockout State (Relay Word bit 79LO = logical 1), and the front-panel **LO** (Lockout) LED illuminates.

79DTL has a 60-cycle dropout time. This keeps the drive-to-lockout condition up 60 more cycles after 79DTL has reverted back to 79DTL = logical 0. This is useful for situations where both of the following are true:

- ➤ Any of the trip and drive-to-lockout conditions are “pulsed” conditions (e.g., the **OPEN** command Relay Word bit, OC, asserts for only 1/4 cycle—refer to *Factory Settings Example* on page 6.22).
- ➤ Reclose initiation is by the breaker contact opening (e.g., 79RI = !52A—refer to *Additional Settings Example* on page 6.21).

Then the drive-to-lockout condition overlaps reclose initiation and the SEL-351 stays in lockout after the breaker trips open.

When 79DLS = logical 1, the reclosing relay goes to the last shot, if the shot counter is not at a shot value greater than or equal to the calculated last shot (see *Reclosing Relay Shot Counter* on page 6.19).

Factory Settings Example

The drive-to-lockout factory setting is:

79DTL = **OC + !IN102 + LB3**

Optoisolated input **IN102** is set to operate as a reclose enable switch (see *Optoisolated Inputs* on page 7.1). When Relay Word bit IN102 = logical 1 (reclosing enabled), the relay is *not* driven to the Lockout State (assuming local bit LB3 = logical 0, too):

!IN102 = **!(logical 1)** = NOT(logical 1) = logical 0

79DTL = **OC + !IN102 + LB3** = OC + (logical 0) + LB3 = OC + LB3

When Relay Word bit IN102 = logical 0 (reclosing disabled), the relay is driven to the Lockout State:

!IN102 = **!(logical 0)** = NOT(logical 0) = logical 1

79DTL = **OC + !IN102 + LB3** = OC + (logical 1) + LB3 = logical 1

Local bit LB3 is set to operate as a manual trip switch (see *Local Control Switches* on page 7.5 and *Trip Logic* on page 5.1). When Relay Word bit LB3 = logical 0 (no manual trip), the relay is *not* driven to the Lockout State (assuming optoisolated input IN102 = logical 1, too):

79DTL = **OC + !IN102 + LB3** = OC + NOT(IN102) + (logical 0) = OC + NOT(IN102)

When Relay Word bit LB3 = logical 1 (manual trip), the relay is driven to the Lockout State:

79DTL = **OC + !IN102 + LB3** = OC + NOT(IN102) + (logical 1) = logical 1

Relay Word bit OC asserts for execution of the **OPEN** command. See the Note in the Lockout State discussion, following *Table 6.1*.

The drive-to-last shot factory setting is:

79DLS = **79LO**

One open interval is also set in the factory settings, resulting in last shot = 1. Any time the relay is in the lockout state (Relay Word bit 79LO = logical 1), the relay is driven to last shot (if the shot counter is not already at a shot value greater than or equal to shot = 1):

79DLS = **79LO** = logical 1

Thus, if optoisolated input IN102 (reclose enable switch) is in the "disable reclosing" position (Relay Word bit IN102 = logical 0) or local bit LB3 (manual trip switch) is operated, then the relay is driven to the Lockout State (by setting 79DTL) and, subsequently, last shot (by setting 79DLS).

Additional Settings Example 1

The preceding drive-to-lockout factory settings example drives the relay to the Lockout State immediately when the reclose enable switch (optoisolated input IN102) is put in the "reclosing disabled" position (Relay Word bit IN102 = logical 0):

79DTL = **!IN102 + ...** = NOT(IN102) + ... = NOT(logical 0) + ... = logical 1

To disable reclosing, but not drive the relay to the Lockout State until the relay trips, make settings similar to the following:

79DTL = **!IN102 * TRIP + ...**

Additional Settings Example 2

To drive the relay to the Lockout State for fault current above a certain level when tripping (e.g., level of phase instantaneous overcurrent element 50P3), make settings similar to the following:

79DTL = **TRIP * 50P3 + ...**

Additionally, if the reclosing relay should go to the Lockout State for an underfrequency trip, make settings similar to the following:

79DTL = **TRIP * 81D1T + ...**

Other Settings Considerations

If no special drive-to-lockout or drive-to-last shot conditions are desired, make the following settings:

79DTL = **0** (numeral 0)

79DLS = **0** (numeral 0)

With settings 79DTL and 79DLS inoperative, the relay still goes to the Lockout State (and to last shot) if an entire automatic reclose sequence is unsuccessful.

Overall, settings 79DTL or 79DLS are needed to take the relay to the Lockout State (or to last shot) for immediate circumstances.

Skip Shot and Stall Open-Interval Timing Settings (79SKP and 79STL, Respectively)

The skip shot setting 79SKP causes a reclose shot to be skipped. Thus, an open interval time is skipped, and the next open interval time is used instead.

If 79SKP = logical 1 at the instant of successful reclose initiation (see preceding discussion on settings 79RI and 79RIS), the relay increments the shot counter to the next shot and then loads the open interval time corresponding to the new shot (see *Table 6.3*). If the new shot is the "last shot," no open interval timing takes place, and the relay goes to the Lockout State if the circuit breaker is open (see *Lockout State* on page 6.14).

After successful reclose initiation, open interval timing does not start until allowed by the stall open interval timing setting 79STL. If 79STL = logical 1, open interval timing is stalled. If 79STL = logical 0, open interval timing can proceed.

If an open interval time has not yet started timing (79STL = logical 1 still), the 79SKP setting is still processed. In such conditions (open interval timing has not yet started), if 79SKP = logical 1, the relay increments the shot counter to the next shot and then loads the open interval time corresponding to the new shot (see *Table 6.3*). If the new shot turns out to be the "last shot," no open interval timing takes place, and the relay goes to the Lockout State if the circuit breaker is open (see *Lockout State* on page 6.14).

If the relay is in the middle of timing on an open interval and 79STL changes state to 79STL = logical 1, open interval timing stops where it is. If 79STL changes state back to 79STL = logical 0, open interval timing resumes where it left off. Use the OPTMN Relay Word bit to monitor open interval timing (see *Monitoring Open-Interval and Reset Timing* on page 6.18).

Factory Settings Example

The skip shot function is not enabled in the factory settings:

79SKP = **0** (numeral 0)

The stall open interval timing factory setting is:

79STL = **TRIP**

After successful reclose initiation, open interval timing does not start as long as the trip condition is present (Relay Word bit TRIP = logical 1). As discussed previously, if an open interval time has not yet started timing (79STL = logical 1 still), the 79SKP setting is still processed. Once the trip condition goes away (Relay Word bit TRIP = logical 0), open interval timing can proceed.

Additional Settings Example 1

With skip shot setting:

79SKP = **50P2 * SH0**

if shot = 0 (Relay Word bit SH0 = logical 1) and phase current is above the phase instantaneous overcurrent element 50P2 threshold (Relay Word bit 50P2 = logical 1), at the instant of successful reclose initiation, the shot counter is incremented from shot = 0 to shot = 1. Then, open interval 1 time (setting 79OI1) is skipped, and the relay times on the open interval 2 time (setting 79OI2) instead.

Table 6.5 Open Interval Time Example Settings

Shot	Corresponding Relay Word Bit	Corresponding Open Interval	Open Interval Time Example Setting
0	SH0	79OI1	30 cycles
1	SH1	79OI2	600 cycles

In *Table 6.5*, note that the open interval 1 time (setting 79OI1) is a short time, while the following open interval 2 time (setting 79OI2) is significantly longer. For a high magnitude fault (greater than the phase instantaneous overcurrent element 50P2 threshold), open interval 1 time is skipped, and open interval timing proceeds on the following open interval 2 time.

Once the shot is incremented to shot = 1, Relay Word bit SH0 = logical 0 and then setting 79SKP = logical 0, regardless of Relay Word bit 50P2.

Additional Settings Example 2

If the SEL-351 Relay is used on a feeder with a line-side independent power producer (cogenerator), the utility should not reclose into a line still energized by an islanded generator. To monitor line voltage and block reclosing, connect a line-side single-phase potential transformer to channel VS on the SEL-351 as shown in *Figure 6.8*.

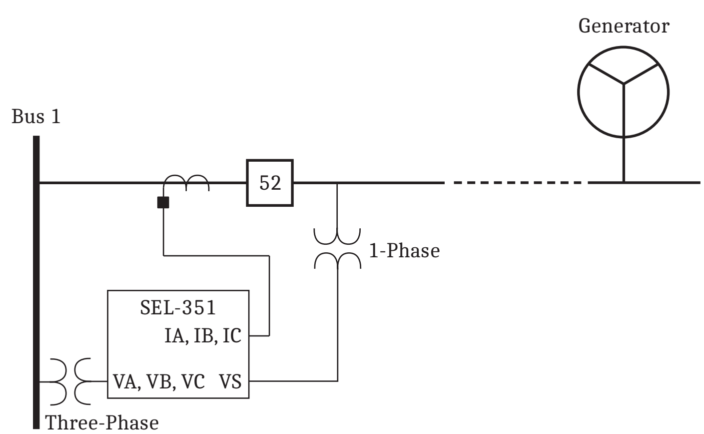


Figure 6.8 Reclose Blocking for Islanded Generator

If the line is energized, channel VS overvoltage element 59S1 can be set to assert. Make the following setting:

79STL = **59S1 + ...**

If line voltage is present, Relay Word bit 59S1 asserts, stalling open interval timing (reclose block). If line voltage is not present, Relay Word bit 59S1 deasserts, allowing open interval timing to proceed (unless some other set condition stalls open interval timing).

Additional Settings Example 3

Refer to *Figure 6.5* and accompanying setting example, showing an application for setting 79STL.

Other Settings Considerations

If no special skip shot or stall open interval timing conditions are desired, make the following settings:

79SKP = **0** (numeral 0)

79STL = **0** (numeral 0)

Block Reset Timing Setting (79BRS)

The block reset timing setting 79BRS keeps the reset timer from timing. Depending on the reclosing relay state, the reset timer can be loaded with either reset time:

79RSD (Reset Time from Reclose Cycle)

or

79RSLD (Reset Time from Lockout)

Depending on how setting 79BRS is set, none, one, or both of these reset times can be controlled. If the reset timer is timing and then 79BRS asserts to:

79BRS = logical 1

reset timing is stopped and does not begin timing again until 79BRS deasserts to:

79BRS = logical 0

When reset timing starts again, the reset timer is fully loaded. Thus, successful reset timing has to be continuous. Use the RSTMN Relay Word bit to monitor reset timing (see *Monitoring Open-Interval and Reset Timing* on page 6.18).

Factory Settings Example

The block reset timing factory setting is:

79BRS = **TRIP** (numeral 0)

The block reset timing factory setting (79BRS = TRIP) keeps the reset timer (setting 79RSD) from starting to time during the brief interval that the circuit breaker is in the process of opening after the trip coil is energized.

At the instant of reclose initiation (factory reclose initiate setting 79RI = TRIP), one of the following starts timing, unless otherwise inhibited:

- Reset timing (setting 79RSD) if the circuit breaker is closed

➤ Open interval timing (setting 79OIn) if the circuit breaker is open

At the instant of tripping/reclose initiation, the circuit breaker is still closed and thus reset timer setting 79RSD starts timing, however briefly, if 79BRS = logical 0. This is mostly a nuisance in the Time column of the event report, where an “r” appears for a few cycles in the column (indicating the reset timer is timing), until the circuit breaker opens. Once the circuit breaker opens, the reset timer stops timing. When the circuit breaker recloses later, the reset timer starts timing anew, with full setting value 79RSD.

TRIP remains asserted for at least TDURD time (see *Figure 5.2*)—long enough to encompass this brief time period (waiting for the circuit breaker to open after the trip coil is energized). Thus, factory setting 79BRS = TRIP is used in most applications.

Additional Settings Example 1

The block reset timing setting is:

79BRS = **(51P + 51G) * 79CY**

Relay Word bit 79CY corresponds to the Reclose Cycle State. The reclosing relay is in one of the three reclosing relay states at any one time (see *Figure 6.6* and *Table 6.1*).

When the relay is in the Reset or Lockout States, Relay Word bit 79CY is deasserted to logical 0. Thus, the 79BRS setting has no effect when the relay is in the Reset or Lockout States. When a circuit breaker is closed from lockout, there could be cold load inrush current that momentarily picks up a time-overcurrent element (e.g., phase time-overcurrent element 51PT pickup (51P) asserts momentarily). But, this assertion of pickup 51P has no effect on reset timing because the relay is in the Lockout State (79CY = logical 0). The relay will time immediately on reset time 79RSLD and take the relay from the Lockout State to the Reset State with no additional delay because 79BRS is deasserted to logical 0.

When the relay is in the Reclose Cycle State, Relay Word bit 79CY is asserted to logical 1. Thus, the factory 79BRS setting can function to block reset timing if time-overcurrent pickup 51P or 51G is picked up while the relay is in the Reclose Cycle State. This helps prevent repetitive “trip-reclose” cycling for low-magnitude faults where the inverse time-overcurrent tripping time might be greater than the reset time from reclose cycle, 79RSD.

Additional Settings Example 2

If the block reset timing setting is:

79BRS = **51P + 51G**

then reset timing is blocked if time-overcurrent pickup 51P or 51G is picked up, regardless of the reclosing relay state.

Sequence Coordination Setting (79SEQ)

The sequence coordination setting 79SEQ keeps the relay in step with a downstream line recloser in a sequence coordination scheme, which prevents overreaching SEL-351 overcurrent elements from tripping for faults beyond the line recloser. This is accomplished by incrementing the shot counter and supervising overcurrent elements with resultant shot counter elements.

In order for the sequence coordination setting 79SEQ to increment the shot counter, *both* the following conditions must be true:

- No trip present (Relay Word bit TRIP = logical 0)
- Circuit breaker closed (SELOGIC control equation setting 52A = logical 1, effectively)

The sequence coordination setting 79SEQ is usually set with some overcurrent element pickups. If the above two conditions are both true, and a set overcurrent element pickup asserts for at least 1.25 cycles and then deasserts, the shot counter increments by one count. This assertion/deassertion indicates that a downstream device (e.g., line recloser—see *Figure 6.9*) has operated to clear a fault. Incrementing the shot counter keeps the SEL-351 "in step" with the downstream device, as is shown in *Additional Settings Example 1* on page 6.28 and *Additional Settings Example 2* on page 6.30.

Every time a sequence coordination operation occurs, the shot counter is incremented, and the reset timer is loaded up with reset time 79RSD. Sequence coordination can increment the shot counter beyond last shot, but no further than shot = 4. The shot counter returns to shot = 0 after the reset timer times out. Reset timing is subject to SELOGIC control equation setting 79BRS (see *Block Reset Timing Setting (79BRS)* on page 6.26).

Sequence coordination operation does not change the reclosing relay state. For example, if the relay is in the Reset State and there is a sequence coordination operation, it remains in the Reset State.

Factory Settings Example

Sequence coordination is not enabled in the factory settings:

79SEQ = **0**

Additional Settings Example 1

With sequence coordination setting:

79SEQ = **79RS * 51P**

sequence coordination is operable only when the relay is in the Reset State (79RS = logical 1). Refer to *Figure 6.9* and *Figure* .

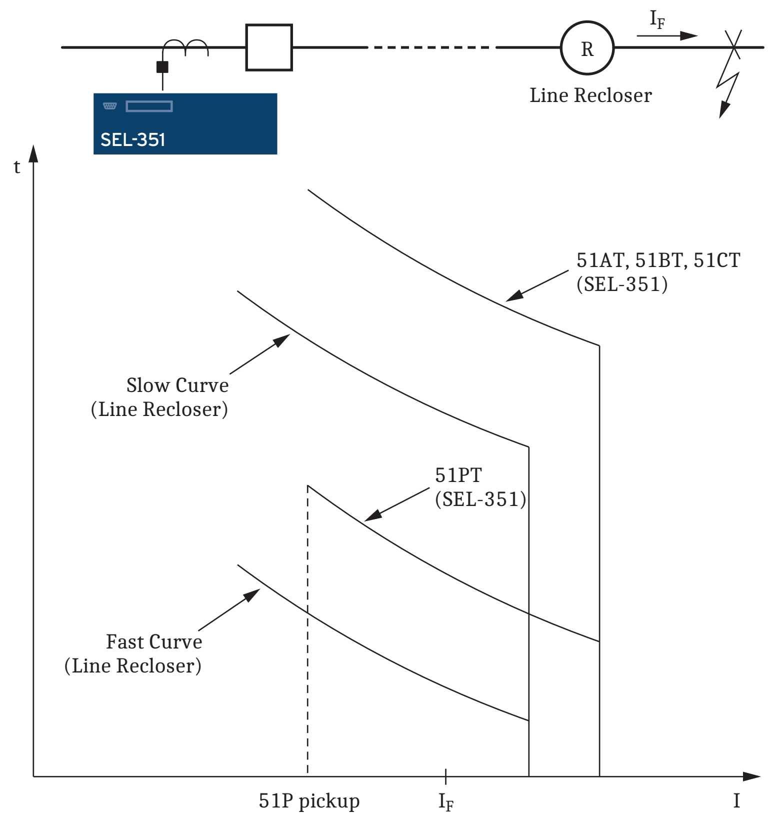
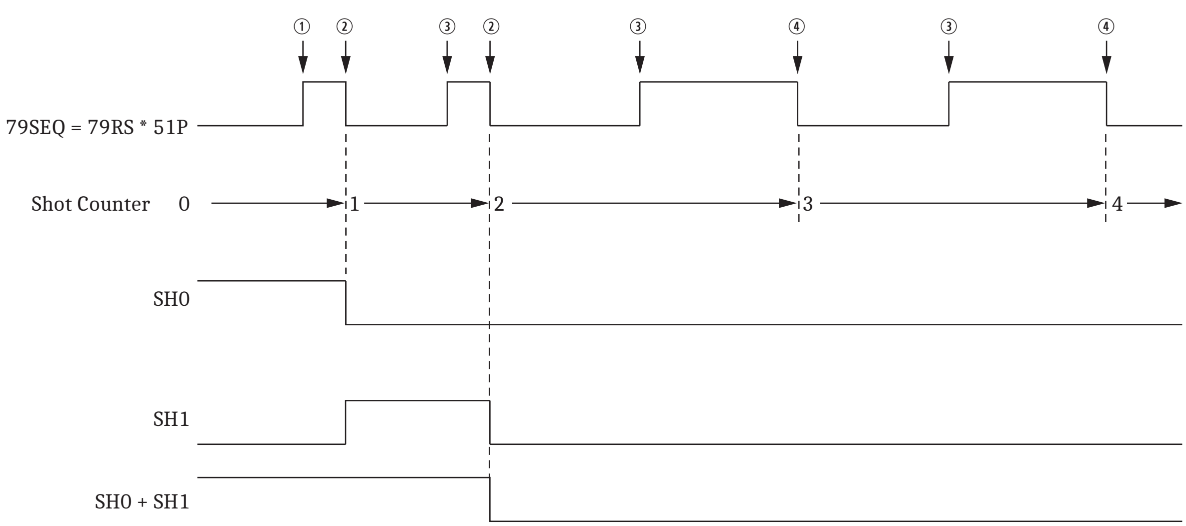


Figure 6.9 Sequence Coordination Between the SEL-351 and a Line Recloser

Assume that the line recloser is set to operate twice on the fast curve and then twice on the slow curve. The slow curve is allowed to operate after two fast curve operations because the fast curves are then inoperative for tripping. The SEL-351 phase time-overcurrent element 51PT is coordinated with the line recloser fast curve. The SEL-351 single-phase time-overcurrent elements 51AT, 51BT, and 51CT are coordinated with the line recloser slow curve.



① Fault occurs beyond line recloser. ② Fault cleared by line recloser fast curve. ③ Line recloser recloses into fault. ④ Fault cleared by line recloser slow curve.

Figure 6.10 Operation of SEL-351 Shot Counter for Sequence Coordination With Line Recloser (Additional Settings Example 1)

If the SEL-351 is in the Reset State (79RS = logical 1) and then a permanent fault beyond the line recloser occurs (fault current I_F in *Figure 6.9*), the line recloser fast curve operates to clear the fault. The SEL-351 also sees the fault. The phase time-overcurrent pickup 51P asserts and then deasserts without tripping, incrementing the relay shot counter from:

shot = 0 to shot = 1

When the line recloser recloses its circuit breaker, the line recloser fast curve operates again to clear the fault. The SEL-351 also sees the fault again. The phase time-overcurrent pickup 51P asserts and then deasserts without tripping, incrementing the relay shot counter from:

shot = 1 to shot = 2

The line recloser fast curve is now disabled after operating twice. When the line recloser recloses its circuit breaker, the line recloser slow curve operates to clear the fault. The relay does not operate on its faster-set phase time-overcurrent element 51PT (51PT is "below" the line recloser slow curve) because the shot counter is now at shot = 2. For this sequence coordination scheme, the SELOGIC control equation trip equation is:

TR = **51PT * (SH0 + SH1) + 51AT + 51BT + 51CT**

NOTE: Sequence coordination can increment the shot counter beyond last shot in this example (last shot = 2 in this factory setting example) but no further than shot = 4.

The following Example 2 limits sequence coordination shot counter incrementing.

With the shot counter at shot = 2, Relay Word bits SH0 (shot = 0) and SH1 (shot = 1) are both deasserted to logical 0. This keeps the 51PT phase time-overcurrent element from tripping. The 51PT phase time-overcurrent element is still operative, and its pickup (51P) can still assert and then deassert, thus continuing the sequencing of the shot counter to shot = 3, etc. The 51PT phase time-overcurrent element cannot cause a trip because shot ≥ 2, and SH0 and SH1 both are deasserted to logical 0.

The shot counter returns to shot = 0 after the reset timer (loaded with reset time 79RSD) times out.

Additional Settings Example 2

Review preceding Example 1.

Assume that the line recloser in *Figure 6.9* is set to operate twice on the fast curve and then twice on the slow curve for faults beyond the line recloser.

Assume that the SEL-351 is set to operate once on 51PT and then twice on 51AT, 51BT, or 51CT for faults between the SEL-351 and the line recloser. This results in the following trip setting:

TR = **51PT * SH0 + 51AT + 51BT + 51CT**

This requires that two open interval settings be made (see *Table 6.2* and *Figure 6.7*). This corresponds to the last shot being:

last shot = 2

If the sequence coordination setting is:

79SEQ = **79RS * 51P**

and there is a permanent fault beyond the line recloser, the shot counter of the SEL-351 will increment all the way to shot = 4 (see *Figure 6.10*). If there is a coincident fault *between* the SEL-351 and the line recloser, the SEL-351 will trip and go to the Lockout State. Any time the shot counter is at a value equal to or greater than last shot and the relay trips, it goes to the Lockout State.

To avoid this problem, make the following sequence coordination setting:

79SEQ = **79RS * 51P * SH0**

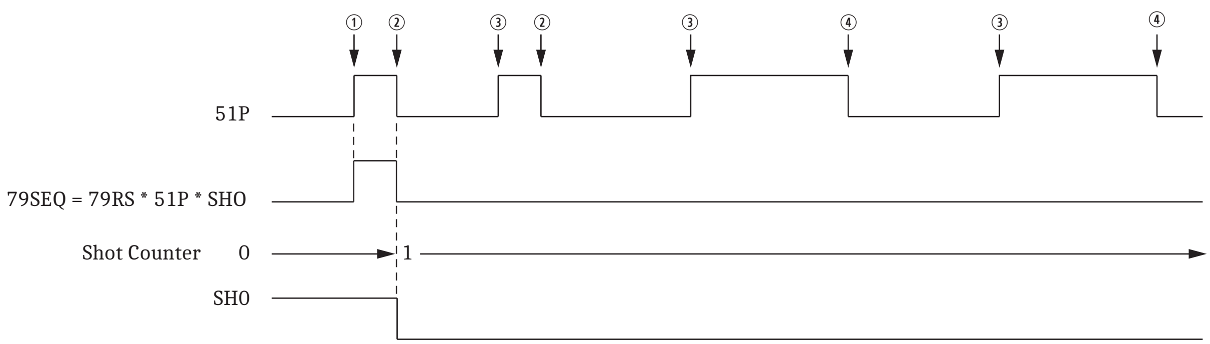
Refer to *Figure 6.11*.

If the SEL-351 is in the Reset State (79RS = logical 0) with the shot counter reset (shot = 0; SH0 = logical 1) and then a permanent fault beyond the line recloser occurs (fault current I_F in *Figure 6.9*), the line recloser fast curve operates to clear the fault. The SEL-351 also sees the fault. The phase time-overcurrent pickup 51P asserts and then deasserts without tripping, incrementing the relay shot counter from:

shot = 0 to shot = 1

Now the SEL-351 cannot operate on its faster-set phase time-overcurrent element 51PT because the shot counter is at shot = 1 (SH0 = logical 0):

TR = **51PT * SH0 + 51AT + 51BT + 51CT** = 51PT * (logical 0) + 51AT + 51BT + 51CT = 51AT + 51BT + 51CT



① Fault occurs beyond line recloser. ② Fault cleared by line recloser fast curve. ③ Line recloser recloses into fault. ④ Fault cleared by line recloser slow curve.

Figure 6.11 Operation of SEL-351 Shot Counter for Sequence Coordination With Line Recloser (Additional Settings Example 2)

The line recloser continues to operate for the permanent fault beyond it, but the SEL-351 shot counter does not continue to increment. Sequence coordination setting 79SEQ is effectively disabled by the shot counter incrementing from shot = 0 to shot = 1.

79SEQ = **79RS * 51P * SH0** = 79RS * 51P * (logical 0) = logical 0

The shot counter stays at shot = 1.

Thus, if there is a coincident fault between the SEL-351 and the line recloser, the SEL-351 will operate on 51AT, 51BT, or 51CT and then reclose once, instead of going straight to the Lockout State (shot = 1 < last shot = 2).

As stated earlier, the reset time setting 79RSD takes the shot counter back to shot = 0 after a sequence coordination operation increments the shot counter. Make sure that reset time setting 79RSD is set long enough to maintain the shot counter at shot = 1 as shown in *Figure 6.11*.

When sequence coordination setting 79SEQ is set to a value other than zero, include Relay Word bits SH0, SH1, SH2, SH3, and SH4 in the SER to help indicate when Sequence Coordination operates.

Reclose Supervision Setting (79CLS)

See *Reclose Supervision Logic* on page 6.6.

SECTION 7

Inputs, Outputs, Timers, and Other Control Logic

Overview

This section contains the following topics:

This section explains the settings and operation of all the programmable logic functions of the relay, including control input and output functions. They are combined with the overcurrent, voltage, frequency, and reclosing elements in SELOGIC control equation settings to realize numerous protection and control schemes.

Relay Word bits and SELOGIC control equation setting examples are used throughout this section.

See *Section 9: Setting the Relay* for more information on relay setting procedures, and see *Appendix D: Relay Word Bits* for a list of Relay Word bits in the SEL-351.

See *Section 10: Communications* for more information on viewing and making SELOGIC control equation settings (commands **SHO L** and **SET L**).

Optoisolated Inputs

NOTE: Optoisolated inputs are level-sensitive, meaning that they require more than one-half of rated voltage to assert. Refer to *Specifications* on page 1.4 for proper ac and dc voltages required for secure and dependable input operation.

Figure 7.1 and *Figure 7.2* show the resultant Relay Word bits (e.g., Relay Word bits IN101–IN106 in *Figure 7.1*) that follow corresponding optoisolated inputs (e.g., optoisolated inputs IN101–IN106 in *Figure 7.1*) for the different SEL-351 Relay models. The figures show examples of energized and de-energized optoisolated inputs and corresponding Relay Word bit states. To assert an input, apply rated control voltage to the appropriate terminal pair (see *Figure 2.2*–*Figure 2.6*).

Figure 7.1, showing main board inputs IN101 to IN106, is used for the following discussion and examples. The optoisolated inputs on the extra I/O board operate similarly. *Figure 7.2* shows the eight inputs IN201–IN208 available with extra I/O board options 2 and 6. Extra I/O board option 4 provides 16 inputs IN201–IN216.

NOTE: Optoisolated inputs are not polarity sensitive.

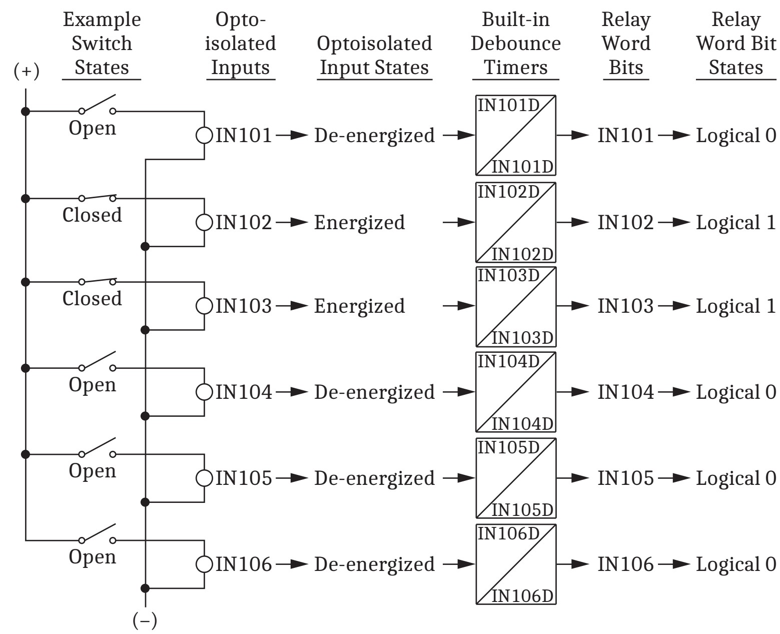


Figure 7.1 Example Operation of Optoisolated Inputs IN101–IN106 (All Models)

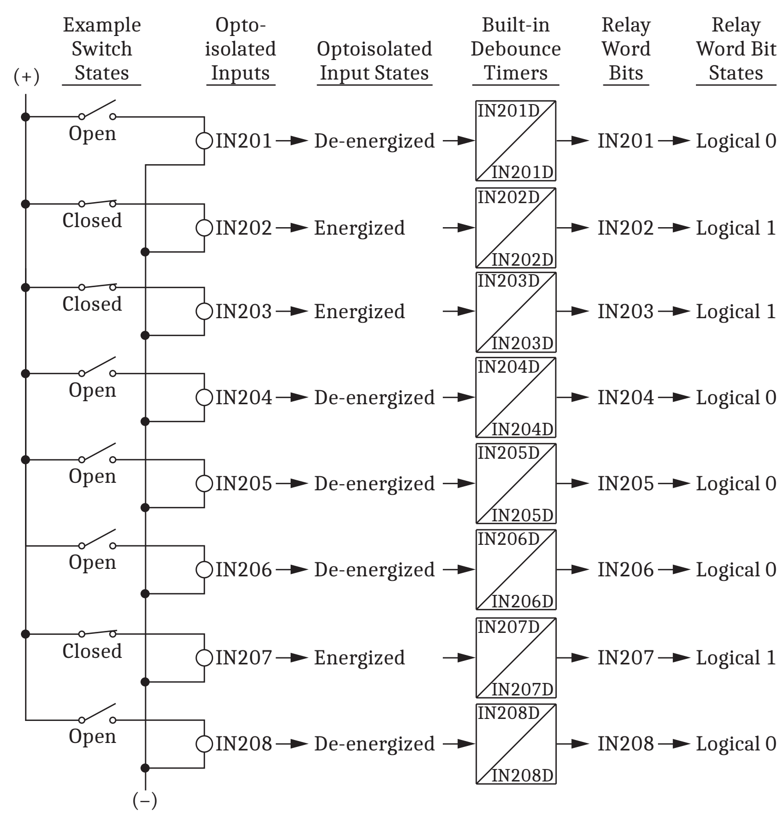


Figure 7.2 Example Operation of Optoisolated Inputs IN201–IN208

Input Debounce Timers

See *Figure 7.1*.

Each input has settable pickup/dropout timers for input energization/de-energization debounce. These timers are IN101D–IN106D for the main board. IN201D–IN208D for extra I/O board options 2 and 6, and IN201D–IN216D for extra I/O board option 4. The setting is applied to both the pickup and dropout time for the corresponding input.

Debounce timer settings are adjustable from 0.00 to 2.00 cycles, or AC. The relay takes the entered time setting and internally runs the timer at the nearest 1/16 cycle. For example, if setting IN105D = 0.80, internally the timer runs at the nearest 1/16 cycle: 13/16 cycles (13/16 = 0.8125).

For *most dc applications*, the input pickup/dropout debounce timers should be set in 1/4 cycle increments. For example, in the *factory default settings*, all the optoisolated input pickup/dropout debounce timers are set at 1/2 cycle (e.g., IN104D = 0.50). See **SHO** ***(Show/View Settings)*** on page 10.68 for a list of the factory default settings.

Only a *few applications* (e.g., communications-assisted tripping schemes) might require input pickup/dropout debounce timers set less than 1/4 cycle [e.g., if setting IN105D = 0.13, internally the timer runs at the nearest 1/16 cycle: 2/16 cycles (2/16 = 0.1250)].

Relay Word bits IN101–IN106 and IN201–IN216 are updated on the next 1/4 cycle processing interval after the debounce timer expires.

If more than two cycles of debounce are needed, run the Relay Word bit (for example, IN101) through a SELOGIC control equation variable timer and use the output of the timer for input functions (see *Figure 7.24* and *Figure 7.25*).

The AC setting allows the input to sense ac control signals. When you use the AC setting, the input has a maximum pickup time of 0.75 cycles and a maximum dropout time of 1.25 cycles. The AC setting qualifies the input by not asserting until two successive 1/16 cycle samples are higher than the optoisolated input voltage threshold and not deasserting until 16 successive 1/16 cycle samples are lower than the optoisolated input voltage threshold.

See SEL Application Guide *Guidelines for Using Optoisolated Inputs in SEL Relays* (AG2003-08) on the SEL website for more information about debounce timers and optoisolated input security.

View Raw Input Status

For system testing and analysis, the status of IN101 through IN106 and IN201 through IN216 before the debounce timer is applied can be viewed in an event report by using the **EVE R** or **CEV R** commands. This type of event report is helpful for analyzing contact bounce problems with connected equipment. See *Filtered and Unfiltered Event Reports* on page 12.18 for more information.

Input Functions

Optoisolated inputs are used by including the corresponding Relay Word bits (for example, IN101 or IN102) in SELOGIC control equations.

Factory Settings Examples

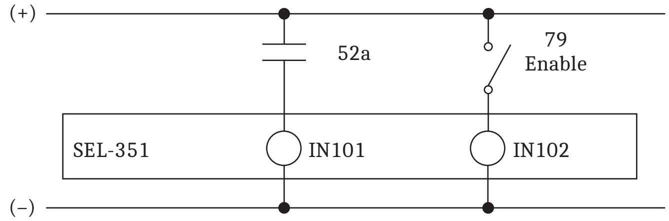


Figure 7.3 Circuit Breaker Auxiliary Contact and Reclose Enable Switch Connected to Optoisolated Inputs IN101 and IN102

The functions for inputs **IN101** and **IN102** are described in the following discussions.

Input IN101

Relay Word bit IN101 is used in the factory settings for the SELOGIC control equation circuit breaker status setting:

52A = **IN101**

Connect input **IN101** to a 52a circuit breaker auxiliary contact.

If a 52b circuit breaker auxiliary contact is connected to input **IN101**, the setting is changed to:

52A = **!IN101** [!IN101 = NOT(IN101)]

See *Close Logic* on page 6.2 for more information on SELOGIC control equation setting 52A.

The pickup/dropout timer for input **IN101** (IN101D) is set at:

IN101D = **0.50 cycles**

to provide input energization/de-energization debounce.

Input **IN101** is indirectly used via the 52A Relay Word bit for other factory settings (i.e., SELOGIC control equation settings BSYNCH (see *Section 3: Overcurrent, Harmonic Blocking, Voltage, Synchronism Check, Frequency, and Power Elements*), 79RIS (see *Section 6: Close and Reclose Logic*), and DP2 (see *Rotating Display* on page 7.37)). Using Relay Word bit IN101 for the circuit breaker status setting 52A does *not* prevent using Relay Word bit IN101 in other SELOGIC control equation settings.

Input IN102

Relay Word bit IN102 is used in the factory settings for the SELOGIC control equation drive-to-lockout setting:

79DTL = **!IN102 + ...** [=NOT(IN102) + ...]

Connect input **IN102** to a reclose enable switch.

When the reclose enable switch is open, input **IN102** is de-energized and the reclosing relay is driven to lockout:

79DTL = **!IN102 + ...** = NOT(IN102) + ... = NOT(logical 0) +... = logical 1

When the reclose enable switch is closed, input **IN102** is energized and the reclosing relay is enabled, if no other setting condition is driving the reclosing relay to lockout:

79DTL = **!IN102 + ...** = NOT(IN102) + ... = NOT(logical 1) +... = logical 0 + ...

See *Section 6: Close and Reclose Logic* for more information on SELOGIC control equation setting 79DTL.

The pickup/dropout timer for input **IN102** (IN102D) is set at:

IN102D = **0.50 cycles**

to provide input energization/de-energization debounce.

Local Control Switches

The local control switch feature of this relay replaces traditional panel-mounted control switches. Operate the 16 local control switches using the **CNTRL** pushbutton on the front-panel keyboard/display (see *Section 11: Front-Panel Interface*).

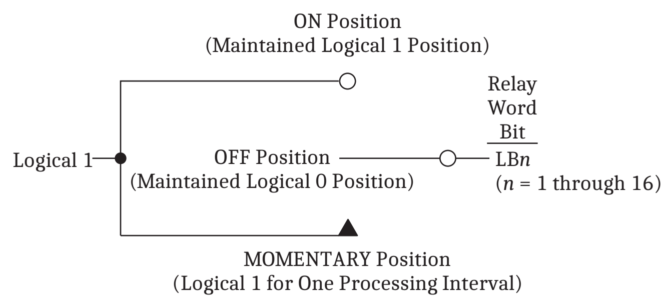


Figure 7.4 Local Control Switches Drive Local Bits LB1 Through LB16

NOTE: When one or more local switch label settings are entered, the front-panel rotating display will include the message `Push CNTRL for Local Control`. This message is not displayed when all local control switches are disabled.

The output of the local control switch in *Figure 7.4* is a Relay Word bit LB*n* (*n* = 1 through 16), called a local bit. The local control switch logic in *Figure 7.4* repeats for each local bit LB1–LB16. Use these local bits in SELOGIC control equations. For a given local control switch, the local control switch positions are enabled by making corresponding label settings. Pressing the **CNTRL** button on the front panel displays a menu of local control switch functions. Follow the display menu to operate (set, pulse, or clear) the local bit associated with desired local control switch. The local bit must be used in the appropriate SELOGIC control equation to produce the desired result.

Table 7.1 Correspondence Between Local Control Switch Positions and Label Settings

Switch Position	Label Setting	Setting Definition	Logic State
not applicable	NLB*n*	Name of Local Control Switch	not applicable
ON	SLB*n*	“Set” Local bit LB*n*	logical 1
OFF	CLB*n*	“Clear” Local bit LB*n*	logical 0
MOMENTARY	PLB*n*	“Pulse” Local bit LB*n*	logical 1 for one processing interval

Note the first setting in *Table 7.1* (NLB*n*) is the overall switch name setting that appears in the front-panel **CNTRL** display menu. Make each label setting through the serial port using the command **SET T**. View these settings using the serial port command **SHO T** (see *Section 9: Setting the Relay* and *Section 10: Communications*) or by reading the Text settings with ACSELERATOR QuickSet SEL-5030 software.

Local Control Switch Types

Configure any local control switch as one of the following three switch types:

ON/OFF Switch

Local bit LB*n* is in either the ON (LB*n* = logical 1) or OFF (LB*n* = logical 0) position.

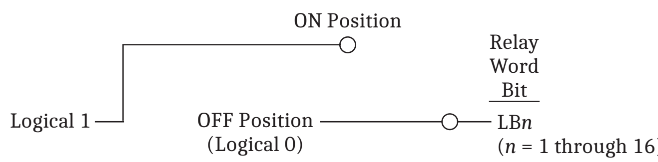


Figure 7.5 Local Control Switch Configured as an ON/OFF Switch

OFF/MOMENTARY Switch

The local bit LB*n* is maintained in the OFF (LB*n* = logical 0) position and pulses to the MOMENTARY (LB*n* = logical 1) position for one processing interval (1/4 cycle).

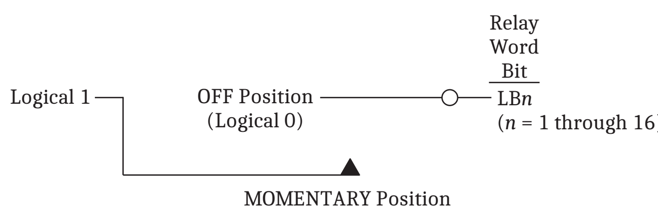


Figure 7.6 Local Control Switch Configured as an OFF/MOMENTARY Switch

ON/OFF/MOMENTARY Switch

The local bit LB*n*:

> is in either the ON (LB*n* = logical 1) or OFF (LB*n* = logical 0) position

or

> is in the OFF (LB*n* = logical 0) position and pulses to the MOMENTARY (LB*n* = logical 1) position for one processing interval (1/4 cycle).

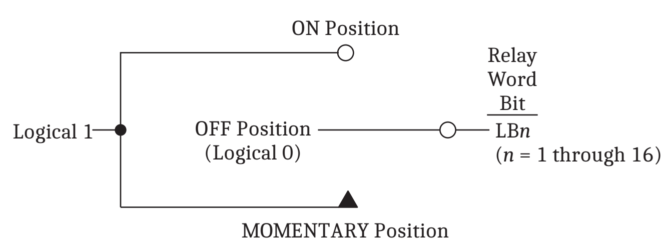


Figure 7.7 Local Control Switch Configured as an ON/OFF/MOMENTARY Switch

Table 7.2 Correspondence Between Local Control Switch Types and Required Label Settings

Local Switch Type	Label NLBn	Label CLBn	Label SLBn	Label PLBn
ON/OFF	X	X	X	
OFF/MOMENTARY	X	X		X
ON/OFF/MOMENTARY	X	X	X	X

Disable local control switches by entering NA at the prompt for all the label settings for that switch (see *Section 9: Setting the Relay*). The local bit associated with this disabled local control switch is then fixed at logical 0.

Factory Settings Examples

Local bits LB3 and LB4 are used in a few of the factory SELOGIC control equation settings for manual trip and close functions. Their corresponding local control switch position labels are set to configure the switches as OFF/ MOMENTARY switches:

Local Bit	Label Settings	Function
LB3	NLB3 = MANUAL TRIP	trips breaker and drives reclosing relay to lockout
	CLB3 = RETURN	OFF position (“return” from MOMENTARY position)
	SLB3 =	ON position—not used (left “blank”)
	PLB3 = TRIP	MOMENTARY position
LB4	NLB4 = MANUAL CLOSE	closes breaker, separate from automatic reclosing
	CLB4 = RETURN	OFF position (“return” from MOMENTARY position)
	SLB4 =	ON position—not used (left “blank”)
	PLB4 = CLOSE	MOMENTARY position

Following *Figure 7.8* and *Figure 7.9* show local control switches with factory settings.

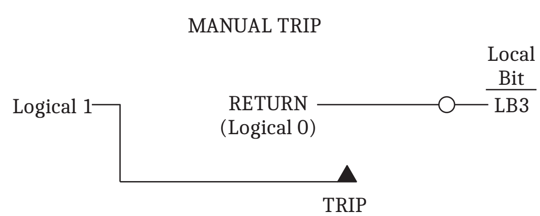


Figure 7.8 Configured Manual Trip Switch Drives Local Bit LB3

Local bit LB3 is set to trip in the following SELOGIC control equation trip setting (see *Figure 5.1*):

TR = **... + LB3 + ...**

To keep reclosing from being initiated for this trip, set local bit LB3 to drive the reclosing relay to lockout for a manual trip (see *Section 6: Close and Reclose Logic*):

79DTL = **... + LB3**

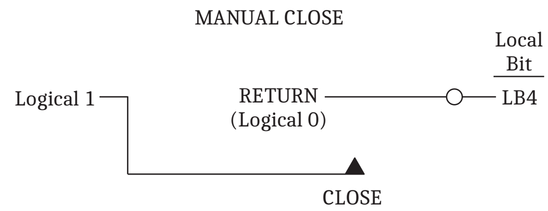


Figure 7.9 Configured Manual Close Switch Drives Local Bit LB4

Local bit LB4 is set to close the circuit breaker in the following SELOGIC control equation setting:

CL = **CC + LB4**

SELOGIC control equation setting CL is for close conditions other than automatic reclosing (see *Figure 6.2*).

Additional Local Control Switch Application Ideas

The preceding factory settings examples are OFF/MOMENTARY switches. Local control switches configured as ON/OFF switches can be used for such applications as:

- Reclosing relay enable/disable
- Ground relay enable/disable
- Remote control supervision
- Sequence coordination enable/disable

Local control switches can also be configured as ON/OFF/MOMENTARY switches for applications that require such. Local control switches can be applied to almost any control scheme that traditionally requires front-panel switches.

Local Control Switch States Retained

Power Loss

The states of the local bits (Relay Word bits LB1–LB16) are retained if power to the relay is lost and then restored. If a local control switch is in the ON position (corresponding local bit is asserted to logical 1) when power is lost, it comes back in the ON position (corresponding local bit is still asserted to logical 1) when power is restored. If a local control switch is in the OFF position (corresponding local bit is deasserted to logical 0) when power is lost, it comes back in the OFF position (corresponding local bit is still deasserted to logical 0) when power is restored. This feature makes the local bit feature behave the same as a traditional installation with panel-mounted control switches. If power is lost to the panel, the front-panel control switch positions remain unchanged.

If a local bit is routed to a programmable output contact and control power is lost, the state of the local bit is stored in nonvolatile memory but the output contact will go to its de-energized state. When the control power is reapplied to the relay, the programmed output contact will go back to the state of the local bit after relay initialization.

Settings Change or Active Setting Group Change

If settings are changed (for the active setting group or one of the other setting groups) or the active setting group is changed, the states of the local bits (Relay Word bits LB1–LB16) are retained, much like in the preceding *Power Loss* explanation.

If settings are changed for a setting group other than the active setting group, there is no interruption of the local bits (the relay is not momentarily disabled).

If a local control switch is made inoperable because of a settings change (i.e., the corresponding label settings are nulled), the corresponding local bit is then fixed at logical 0, regardless of the local bit state before the settings change. If a local control switch is made newly operable because of a settings change (i.e., the corresponding label settings are set), the corresponding local bit starts out at logical 0.

Remote Control Switches

Remote control switches are operated via the communications ports (see ***CON (Control Remote Bit)*** on page 10.43), *Appendix J: Configuration, Fast Meter, and Fast Operate Commands*, *Appendix L: DNP3 Communications*, *Appendix O: Modbus RTU and TCP Communications*), and *Appendix P: IEC 61850*.

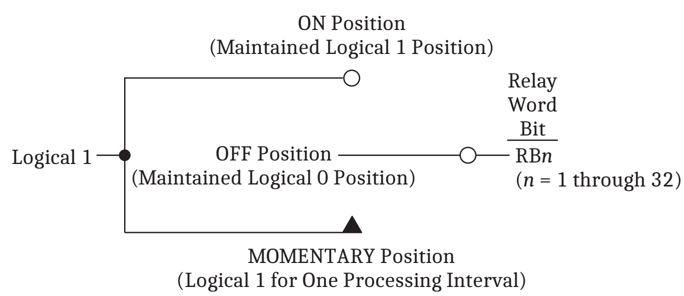


Figure 7.10 Remote Control Switches Drive Remote Bits RB1–RB32

The outputs of the remote control switches in *Figure 7.10* are Relay Word bits RB*n* (*n* = 1 to 32), called remote bits. Use these remote bits in SELOGIC control equations.

Any given remote control switch can be put in one of the following three positions:

ON (logical 1)

OFF (logical 0)

MOMENTARY (logical 1 for one processing interval)

Remote Bit Application Ideas

With SELOGIC control equations, the remote bits can be used in applications similar to those that local bits are used in (see preceding local control switch discussion).

Also, remote bits can be used much as optoisolated inputs are used in operating latch control switches (see discussion following *Figure 7.15*). Pulse (momentarily operate) the remote bits for this application.

Remote Bit States Not Retained When Power Is Lost

The states of the remote bits are not retained if power to the relay is lost and then restored. The remote control switches always come back in the OFF position (corresponding remote bit is deasserted to logical 0) when power is restored to the relay.

Remote Bit States Retained When Settings Changed or Active Setting Group Changed

The state of each remote bit is retained if relay settings are changed (for the active setting group or one of the other setting groups) or the active setting group is changed. If a remote control switch is in the ON position (corresponding remote bit is asserted to logical 1) before a setting change or an active setting group change, it comes back in the ON position (corresponding remote bit is still asserted to logical 1) after the change. If a remote control switch is in the OFF position (corresponding remote bit is deasserted to logical 0) before a settings change or an active setting group change, it comes back in the OFF position (corresponding remote bit is still deasserted to logical 0) after the change.

If settings are changed for a setting group other than the active setting group, there is no interruption of the remote bits (the relay is not momentarily disabled).

Details on the Remote Control Switch MOMENTARY Position

This subsection describes remote control switch 3, which is also called Remote Bit 3 (RB3). All of the remote bits operate in the same way.

See **CON** ***(Control Remote Bit)*** on page 10.43.

The **CON 3** command and **PRB 3** subcommand place the remote control switch 3 into the MOMENTARY position for one processing interval, regardless of its initial state. Remote Control Switch 3 is then placed in the OFF position.

If RB3 is initially at logical 0, pulsing it with the **CON 3** command and **PRB 3** subcommand will change RB3 to a logical 1 for one processing interval, and then return it to a logical 0. In this situation, the /RB3 (rising-edge operator) will also assert for one processing interval, followed by the \RB3 (falling-edge operator) one processing interval later.

If RB3 is initially at logical 1 instead, pulsing it with the **CON 3** command and **PRB 3** subcommand will change RB3 to a logical 0. In this situation, the /RB3 (rising-edge operator) will *not* assert, but the \RB3 (falling-edge operator) will assert for one processing interval.

See *Appendix F: Setting SELOGIC Control Equations* for more details on using the rising- and falling-edge operators in SELOGIC control equations.

Latch Control Switches

The latch control switch feature of this relay replaces latching relays. Traditional latching relays maintain their output contact state when set. The SEL-351 latch control switches retain their states even when control power is lost. If the latch bit is set to a programmable output contact and control power is lost, the state of the latch bit is stored in nonvolatile memory but the output contact will go to its de-energized state. When the control power is applied back to the relay, the programmed output contact will go back to the state of the latch bit after relay initialization.

The state of a traditional latching relay output contact is changed by pulsing the latching relay inputs (see *Figure 7.11*). Pulse the set input to close ("set") the latching relay output contact. Pulse the reset input to open ("reset") the latching relay output contact. Often the external contacts wired to the latching relay inputs are from remote control equipment (e.g., SCADA, RTU).

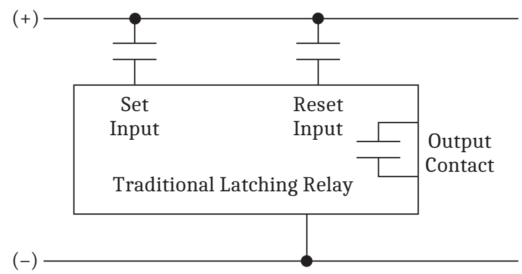


Figure 7.11 Traditional Latching Relay

The 16 latch control switches in the SEL-351 provide latching relay type functions.

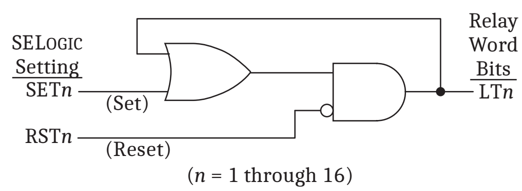


Figure 7.12 Latch Control Switches Drive Latch Bits LT1–LT16

The output of the latch control switch in *Figure 7.12* is a Relay Word bit LT*n* (*n* = 1 through 16), called a latch bit. The latch control switch logic in *Figure 7.12* repeats for each latch bit LT1–LT16. Use these latch bits in SELOGIC control equations.

These latch control switches each have the following SELOGIC control equation settings:

SET*n* (set latch bit LT*n* to logical 1)

RST*n* (reset latch bit LT*n* to logical 0)

If setting SET*n* asserts to logical 1, latch bit LT*n* asserts to logical 1. If setting RST*n* asserts to logical 1, latch bit LT*n* deasserts to logical 0. If both settings SET*n* and RST*n* assert to logical 1, setting RST*n* has priority and latch bit LT*n* deasserts to logical 0.

Latch Control Switch Application Ideas

Latch control switches can be used for such applications as:

- Reclosing relay enable/disable
- Ground relay enable/disable
- Sequence coordination enable/disable

Latch control switches can be applied to almost any control scheme. The following is an example of using a latch control switch to enable/disable the reclosing relay in the SEL-351.

Reclosing Relay Enable/Disable Setting Example

Use a latch control switch to enable/disable the reclosing relay in the SEL-351. In this example, a SCADA contact is connected to optoisolated input **IN104**. Each pulse of the SCADA contact changes the state of the reclosing relay. The SCADA contact is not maintained, just pulsed to enable/disable the reclosing relay.

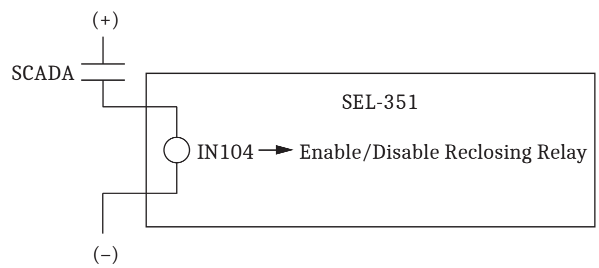


Figure 7.13 SCADA Contact Pulses Input IN104 to Enable/Disable Reclosing Relay

If the reclosing relay is enabled and the SCADA contact is pulsed, the reclosing relay is then disabled. If the SCADA contact is pulsed again, the reclosing relay is enabled again. The control operates in a cyclic manner:

pulse to enable ... pulse to disable ... pulse to enable ... pulse to disable ...

This reclosing relay logic is implemented in the following SELOGIC control equation settings and displayed in *Figure 7.14*.

SET1 = **/IN104 * !LT1** [= (rising edge of input IN104) AND NOT(LT1)]

RST1 = **/IN104 * LT1** [= (rising edge of input IN104) AND LT1]

79DTL = **!LT1** [= NOT(LT1); drive-to-lockout setting]

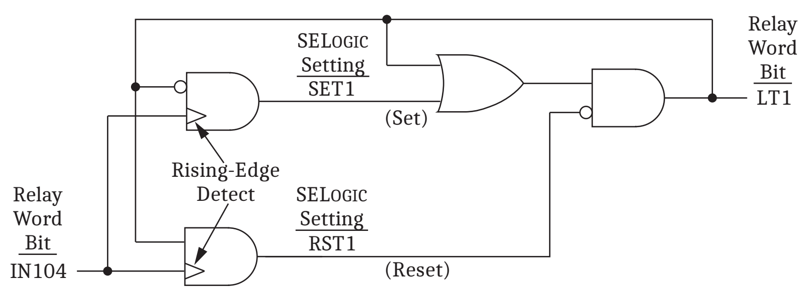


Figure 7.14 Latch Control Switch Controlled by a Single Input to Enable/Disable Reclosing

Feedback Control

Note in *Figure 7.14* that the latch control switch output (latch bit LT1) is effectively used as feedback for SELOGIC control equation settings SET1 and RST1. The feedback of latch bit LT1 “guides” input **IN104** to the correct latch control switch input.

If latch bit LT1 = logical 0, input **IN104** is routed to setting SET1 (set latch bit LT1):

SET1 = **/IN104 * !LT1** = /IN104 * NOT(LT1) = /IN104 * NOT(logical 0) = /IN104 = rising edge of input IN104

RST1 = **/IN104 * LT1** = /IN104 * (logical 0) = logical 0

If latch bit LT1 = logical 1, input **IN104** is routed to setting RST1 (reset latch bit LT1):

SET1 = **/IN104 * !LT1** = /IN104 * NOT(LT1) = /IN104 * NOT(logical 1) = /IN104 * (logical 0) = logical 0

RST1 = **/IN104 * LT1** = /IN104 * (logical 1) = /IN104 = rising edge of input IN104

Rising-Edge Operators

Refer to *Figure 7.14* and *Figure 7.15*.

The rising-edge operator in front of Relay Word bit IN104 (/IN104) sees a logical 0 to logical 1 transition as a “rising edge,” and /IN104 asserts to logical 1 for one processing interval. For more details on rising-edge operators, see *Appendix F: Setting SELOGIC Control Equations*.

The rising-edge operator on input **IN104** is necessary because any single assertion of optoisolated input **IN104** by the SCADA contact will last for at least a few cycles, and each individual assertion of input **IN104** should only change the state of the latch control switch once (e.g., latch bit LT1 changes state from logical 0 to logical 1).

For example in *Figure 7.14*, if:

LT1 = logical 0

input **IN104** is routed to setting SET1 (as discussed previously):

SET1 = **/IN104** = rising edge of input **IN104**

If input IN104 is then asserted for a few cycles by the SCADA contact (see Pulse 1 in *Figure 7.15*), SET1 is asserted to logical 1 for one processing interval. This causes latch bit LT1 to change state to:

LT1 = logical 1

the next processing interval.

NOTE: Refer to *Optoisolated Inputs* on page 7.1 and *Figure 7.1*. Relay Word bit IN104 shows the state of optoisolated input **IN104 after** the input pickup/dropout debounce timer IN104D. Thus, when using Relay Word bit IN104 in *Figure 7.13* and *Figure 7.14* and associated SELOGIC control equations, keep in mind any time delay produced by the input pickup/dropout debounce timer IN104D.

With latch bit LT1 now at logical 1 for the next processing interval, input IN104 is routed to setting RST1 (as discussed previously):

RST1 = **/IN104** = rising edge of input **IN104**

This would then appear to enable the “reset” input (setting RST1) the next processing interval. But the “rising-edge” condition occurred the preceding processing interval. /IN104 is now at logical 0, so setting RST1 does not assert, even though input **IN104** remains asserted for at least a few cycles by the SCADA contact.

If the SCADA contact deasserts and then asserts again (new rising edge—see Pulse 2 in *Figure 7.15*), the "reset" input (setting RST1) asserts and latch bit LT1 deasserts back to logical 0 again. Thus, each individual assertion of input IN104 (Pulse 1, Pulse 2, Pulse 3, and Pulse 4 in *Figure 7.15*) changes the state of latch control switch just once.

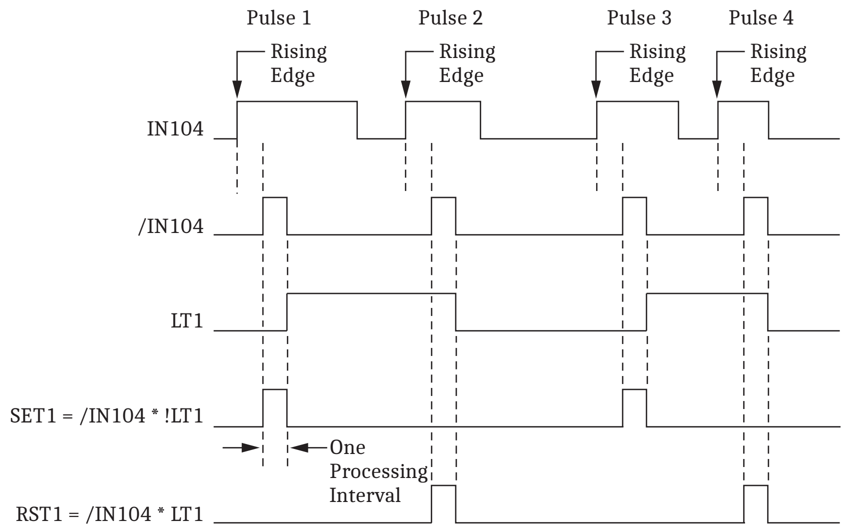


Figure 7.15 Latch Control Switch Operation Time Line

Use a Remote Bit Instead to Enable/Disable the Reclosing Relay

Use a remote bit to enable/disable the reclosing relay, instead of an optoisolated input. For example, substitute remote bit RB1 for optoisolated input **IN104** in the settings accompanying *Figure 7.14*:

SET1 = **/RB1 * !LT1** [= (rising edge of remote bit RB1) AND NOT(LT1)]

RST1 = **/RB1 * LT1** [= (rising edge of remote bit RB1) AND LT1]

79DTL = **!LT1** [= NOT(LT1); drive-to-lockout setting]

Pulse remote bit RB1 to enable reclosing, pulse remote bit RB1 to disable reclosing, etc.—much like the operation of optoisolated input **IN104** in the previous example. Remote bits (Relay Word bits RB1–RB32) are operated through the communications port. See *Remote Control Switches* on page 7.9 for more information on remote bits.

These are just a few control logic examples—many variations are possible.

Latch Control Switch States Retained

Power Loss

NOTE: If a latch bit is set to a programmable output contact (e.g., OUT103 = LT2) and power to the relay is lost, the state of the latch bit is stored in nonvolatile memory but the output contact will go to its de-energized state. When power to the relay is restored, the programmable output contact will go back to the state of the latch bit after relay initialization.

The states of the latch bits (LT1–LT16) are retained if power to the relay is lost and then restored. If a latch bit is asserted (e.g., LT2 = logical 1) when power is lost, it comes back asserted (LT2 = logical 1) when power is restored. If a latch bit is deasserted (e.g., LT3 = logical 0) when power is lost, it comes back deasserted (LT3 = logical 0) when power is restored. This feature makes the latch bit feature behave the same as traditional latching relays. In a traditional installation, if power is lost to the panel, the latching relay output contact position remains unchanged.

Settings Change or Active Setting Group Change

If individual settings are changed (for the active setting group or one of the other setting groups) or the active setting group is changed, the states of the latch bits (Relay Word bits LT1–LT16) are retained, much like in the preceding *Power Loss* on page 7.14 explanation.

If individual settings are changed for a setting group other than the active setting group, there is no interruption of the latch bits (the relay is not momentarily disabled).

If the individual settings change or active setting group change causes a change in SELOGIC control equation settings SET*n* or RST*n* (*n* = 1 through 16), the retained states of the latch bits can be changed, subject to the newly enabled settings SET*n* or RST*n*.

Reset Latch Bits for Active Setting Group Change

If desired, the latch bits can be reset to logical 0 right after a settings group change, using SELOGIC control equation setting RST*n* (*n* = 1 through 16). Relay Word bits SG1–SG6 indicate the active setting Group 1 through 6, respectively (see *Table 7.3*).

For example, an application requires that when setting Group 4 becomes the active setting group, latch bit LT2 gets reset. Make the following SELOGIC control equation settings in setting Group 4:

RST2 = **/SG4 + ...** [other logic]

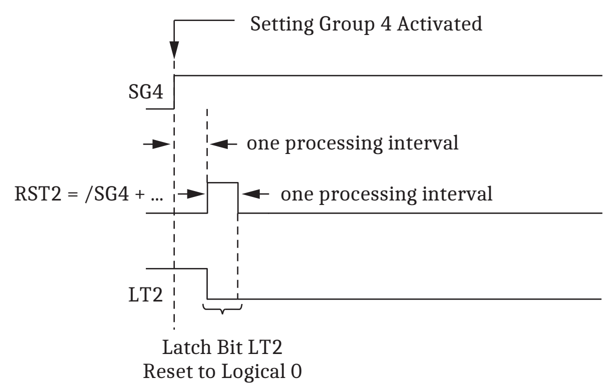


Figure 7.16 Time Line for Reset of Latch Bit LT2 After Active Setting Group Change

In *Figure 7.16*, the rising edge operator /SG4 creates a pulse (logical 1) for one quarter-cycle after setting group 4 is newly entered. Latch bit LT2 is reset (deasserted to logical 0) when setting RST2 briefly asserts to logical 1 right after setting Group 4 is activated. This logic only clears LT2 after a setting group change from another group to Group 4—it does not clear the latch when the relay is powered up into setting Group 4. This logic can be repeated for other latch bits.

Note: Make Latch Control Switch Settings With Care

The latch bit states are stored in nonvolatile memory so they can be retained during power loss, settings change, or active setting group change. The nonvolatile memory is rated for a finite number of “writes” for all cumulative latch bit state changes. Exceeding the limit can result in an eventual self-test failure. *An average of 70 cumulative latch bit state changes per day can be made for a 25-year relay service life.*

This requires that SELOGIC control equation settings SETn and RSTn for any given latch bit LTn (n = 1 through 16) be set with care. Settings SET*n* and RST*n* cannot result in continuous cyclical operation of latch bit LT*n*. Use timers to qualify conditions set in settings SET*n* and RST*n*. If any optoisolated inputs **IN101–IN106** are used in settings SET*n* and RST*n*, the inputs have their own debounce timer that can help in providing the necessary time qualification (see *Figure 7.1*).

In the preceding reclosing relay enable/disable example application (*Figure 7.14* and *Figure 7.15*), the SCADA contact cannot be asserting/deasserting continuously, thus causing latch bit LT1 to change state continuously. Note that the rising-edge operators in the SET1 and RST1 settings keep latch bit LT1 from cyclically operating for any single assertion of the SCADA contact.

Another variation to the example application in *Figure 7.14* and *Figure 7.15* that adds more security is a timer with pickup/dropout times set the same (see *Figure 7.17* and *Figure 7.18*). Suppose that SV6PU and SV6DO are both set to 300 cycles. Then the SV6T timer keeps the state of latch bit LT1 from being able to be changed at a rate faster than once every 300 cycles (5 seconds).

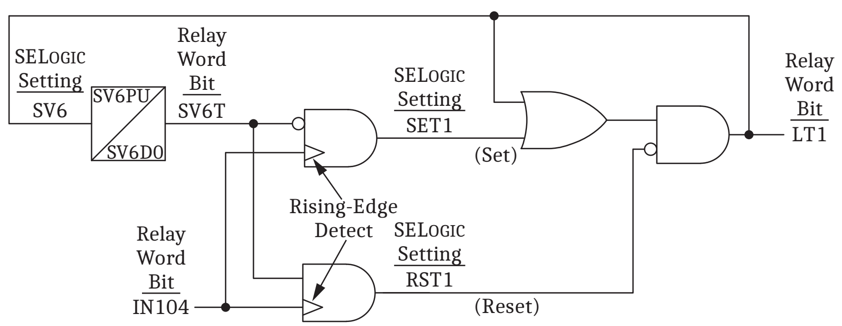


Figure 7.17 Latch Control Switch (With Time Delay Feedback) Controlled by a Single Input to Enable/Disable Reclosing

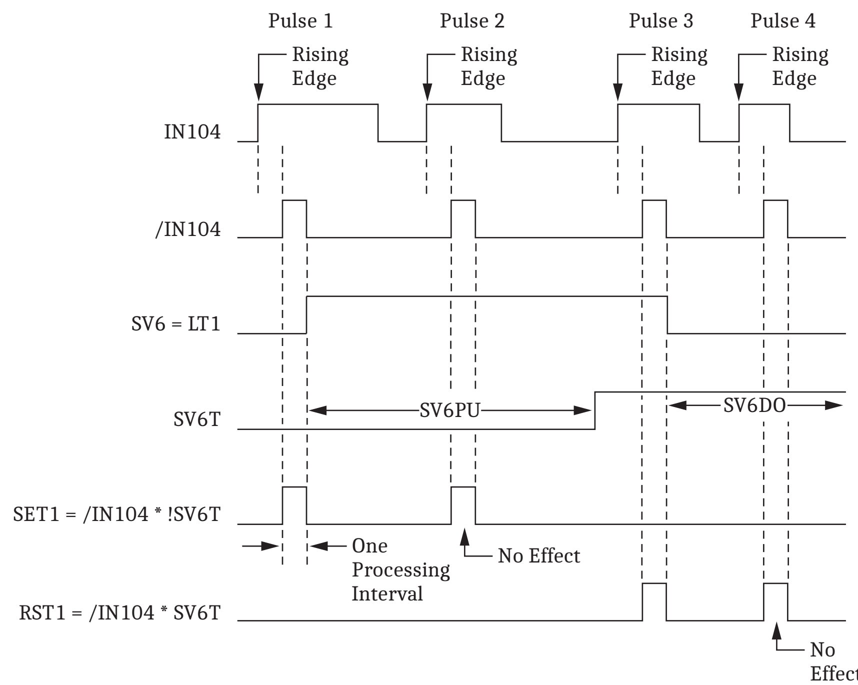


Figure 7.18 Latch Control Switch (With Time Delay Feedback) Operation Time Line

Multiple Setting Groups

The relay has six (6) independent setting groups. Each setting group has complete relay (overcurrent, reclosing, frequency, etc.) and SELOGIC control equation settings.

Active Setting Group Indication

Only one setting group can be active at a time. Relay Word bits SG1–SG6 indicate the active setting group:

Table 7.3 Definitions for Active Setting Group Indication Relay Word Bits SG1 Through SG6

Relay Word Bit	Definition
SG1	Indication that setting Group 1 is the active setting group
SG2	Indication that setting Group 2 is the active setting group
SG3	Indication that setting Group 3 is the active setting group
SG4	Indication that setting Group 4 is the active setting group
SG5	Indication that setting Group 5 is the active setting group
SG6	Indication that setting Group 6 is the active setting group

For example, if setting Group 4 is the active setting group, Relay Word bit SG4 asserts to logical 1, and the other Relay Word bits SG1, SG2, SG3, SG5, and SG6 are all deasserted to logical 0.

Selecting the Active Setting Group

The active setting group is selected with:

- SELOGIC control equation settings SS1–SS6
- The serial port **GROUP** command (see *Section 10: Communications*)
- The front-panel **GROUP** pushbutton (see *Section 11: Front-Panel Interface*)
- DNP analog output ACTGRP (see *Appendix L: DNP3 Communications*)
- Modbus function code 06 or 10 write to ACTGRP (see *Appendix O: Modbus RTU and TCP Communications*)

SELOGIC control equation settings SS1–SS6 have priority over the serial port **GROUP** command, the front-panel **GROUP** pushbutton, and the DNP and Modbus controls in selecting the active setting group.

Operation of SELOGIC Control Equation Settings SS1–SS6

Each setting group has its own set of SELOGIC control equation settings SS1–SS6.

Table 7.4 Definitions for Active Setting Group Switching SELOGIC Control Equation Settings SS1 Through SS6

Setting	Definition
SS1	go to (or remain in) setting Group 1
SS2	go to (or remain in) setting Group 2
SS3	go to (or remain in) setting Group 3
SS4	go to (or remain in) setting Group 4
SS5	go to (or remain in) setting Group 5
SS6	go to (or remain in) setting Group 6

The operation of these settings is explained with the following example.

Assume the active setting group starts out as setting Group 3. Corresponding Relay Word bit SG3 is asserted to logical 1 as an indication that setting Group 3 is the active setting group (see *Table 7.3*).

With setting Group 3 as the active setting group, setting SS3 has priority. If setting SS3 is asserted to logical 1, setting Group 3 remains the active setting group, regardless of the activity of settings SS1, SS2, SS4, SS5, and SS6. With settings SS1 through SS6 all deasserted to logical 0, setting Group 3 still remains the active setting group.

With setting Group 3 as the active setting group, if setting SS3 is deasserted to logical 0 and one of the other settings (e.g., setting SS5) asserts to logical 1, the relay switches from setting Group 3 as the active setting group to another setting group (e.g., setting Group 5) as the active setting group, after qualifying time setting TGR:

TGR Group Change Delay Setting (settable from 0.00 to 16000.00 cycles)

In this example, TGR qualifies the assertion of setting SS5 before it can change the active setting group.

Operation of Serial Port GROUP Command and Front-Panel GROUP Pushbutton

SELOGIC control equation settings SS1–SS6 have priority over the serial port **GROUP** command and the front-panel **GROUP** pushbutton in selecting the active setting group. If any *one* of SS1–SS6 asserts to logical 1, neither the serial port **GROUP** command nor the front-panel **GROUP** pushbutton can be used to switch the active setting group. But if SS1–SS6 *all* deassert to logical 0, the serial port **GROUP** command or the front-panel **GROUP** pushbutton can be used to switch the active setting group.

See *Section 10: Communications* for more information on the serial port **GROUP** command. See *Section 11: Front-Panel Interface* for more information on the front-panel **GROUP** pushbutton.

Relay Disabled Momentarily During Active Setting Group Change

The relay is disabled for a *few seconds* while the relay is in the process of changing active setting groups. Relay elements, timers, and logic are reset, unless indicated otherwise in specific logic description [e.g., local bit (LB1– LB16), remote bit (RB1–RB32), and latch bit (LT1– LT16) states are retained during an active setting group change]. The output contacts do not change state until the relay enables in the new settings group and the SELOGIC control equations are processed to determine the output contact status for the new group. For instance, if setting OUT105 = logical 1 in Group 2, and setting OUT105 = logical 1 in Group 3, and the relay is switched from Group 2 to Group 3, **OUT105** stays energized before, during, and after the group change. However, if the Group 3 setting was OUT105 = logical 0 instead, then **OUT105** remains energized until the relay enables in Group 3, solves the SELOGIC control equations, and causes **OUT105** to de-energize. See *Figure 7.28* and *Figure 7.29* for examples of output contacts in the de-energized state (i.e., corresponding output contact coils de-energized).

Group Switch Indication

When the active settings group is switched, Relay Word bit GRPSW asserts for approximately one second, and a Group Switch entry is automatically inserted in the SER.

Active Setting Group Switching Example 1

Use a single optoisolated input to switch between two setting groups in the SEL-351. In this example, optoisolated input **IN105** on the relay is connected to a SCADA contact in *Figure 7.19*. Each pulse of the SCADA contact changes the active setting group from one setting group (e.g., setting Group 1) to another (e.g., setting Group 4). The SCADA contact is not maintained, just pulsed to switch from one active setting group to another.

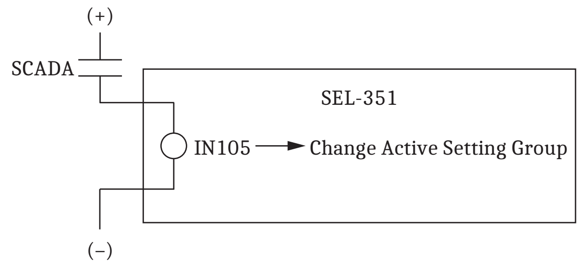


Figure 7.19 SCADA Contact Pulses Input IN105 to Switch Active Setting Group Between Setting Groups 1 and 4

If setting Group 1 is the active setting group and the SCADA contact is pulsed, setting Group 4 becomes the active setting group. If the SCADA contact is pulsed again, setting Group 1 becomes the active setting group again. The setting group control operates in a cyclical manner:

> pulse to activate setting Group 4 ... pulse to activate setting Group 1 ... pulse to activate setting Group 4 ... pulse to activate setting Group 1 ...

This logic is implemented in the SELOGIC control equation settings in *Table 7.5*.

Table 7.5 SELOGIC Control Equation Settings for Switching Active Setting Group Between Setting Groups 1 and 4

Setting Group 1	Setting Group 4
SV8PU = 1.5 • SCADA pulse width (in cycles)	SV8PU = 1.5 • SCADA pulse width (in cycles)
SV8DO = 0.00	SV8DO = 0.00
SV8 = SG1 * !/SG1	SV8 = SG4 * !/SG4
SS1 = 0	SS1 = IN105 * SV8T
SS2 = 0	SS2 = 0
SS3 = 0	SS3 = 0
SS4 = IN105 * SV8T	SS4 = 0
SS5 = 0	SS5 = 0
SS6 = 0	SS6 = 0
Global Setting	
TGR = 1.00 cycle	

SELOGIC control equation timer input setting SV8 in *Table 7.5* has logic output SV8T, shown in operation in *Figure 7.20* for both setting Groups 1 and 4.

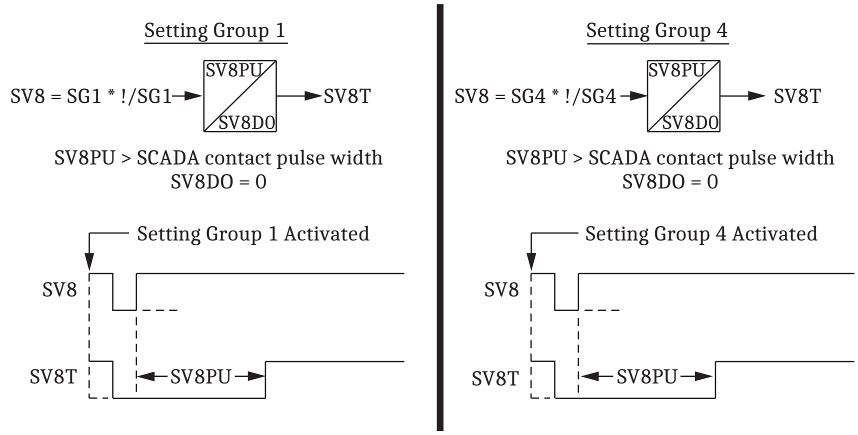


Figure 7.20 SELOGIC Control Equation Variable Timer SV8T Used in Setting Group Switching

In this example, timer SV8T is used in both setting groups; different timers could have been used with the same operational result. The SELOGIC variables do not reset during the setting group change, so special programming considerations are required to allow the same timer to be used in both setting groups.

Timer pickup setting SV8PU is set greater than the pulse width of the SCADA contact (*Figure 7.19*). This allows only one active setting group change (e.g., from setting Group 1 to 4) for each pulse of the SCADA contact (and subsequent assertion of input IN105). The function of the SELOGIC control equations in *Table 7.5* becomes more apparent in the following example scenario.

Start Out in Setting Group 1

Refer to *Figure 7.21*.

The relay has been in setting Group 1 for some time, with timer logic output SV8T asserted to logical 1, thus enabling SELOGIC control equation setting SS4 for the assertion of input IN105.

Switch to Setting Group 4

Refer to *Figure 7.21*.

The SCADA contact pulses input IN105, and the active setting group changes to setting Group 4 after qualifying time setting TGR (set at 1.00 cycle to qualify the assertion of setting SS4). Optoisolated input IN105 also has its own built-in debounce timer (IN105D) available (see *Figure 7.1*).

Note that *Figure 7.21* shows both setting Group 1 and setting Group 4 settings. The setting Group 1 settings (top of *Figure 7.21*) are enabled only when setting Group 1 is the active setting group and likewise for the setting Group 4 settings at the bottom of the figure.

Setting Group 4 is now the active setting group, and Relay Word bit SG4 asserts to logical 1. One processing interval later, the expression /SG4 asserts to logical 1 for one processing interval, and then deasserts to logical 0. The expression SV8 = SG4 * !/SG4 deasserts for once processing interval because the NOT operator “!” is inverting the rising edge operator “/”. This action resets the timer SV8T, which must then time for SV8PU cycles in order to assert again. See *Appendix F: Setting SELOGIC Control Equations* for more details on the rising edge operator.

The TGR setting of 1.00 cycle prevents the brief assertion of SV8T in setting Group 4 from prematurely initiating a group change.

After the relay has been in setting Group 4 for a time period equal to SV8PU, the timer logic output SV8T asserts to logical 1, thus enabling SELOGIC control equation setting SS1 for a new assertion of input IN105.

Note that input IN105 is still asserted as setting Group 4 is activated. Pickup time SV8PU keeps the continued assertion of input IN105 from causing the active setting group to revert back again to setting Group 1 for a single assertion of input IN105. This keeps the active setting group from being changed at a time interval less than time SV8PU.

Switch Back to Setting Group 1

Refer to *Figure 7.21*.

The SCADA contact pulses input IN105 a second time, and the active setting group changes back to setting Group 1 after qualifying time setting TGR (set at 1.00 cycle to qualify the assertion of setting SS1). Optoisolated input IN105 also has its own built-in debounce timer (IN105D) available (see *Figure 7.1*).

Similar logic settings operate in setting Group 1 to deassert SV8T quickly, before the TGR timer expires, and then allow IN105 to deassert before SV8T asserts again.

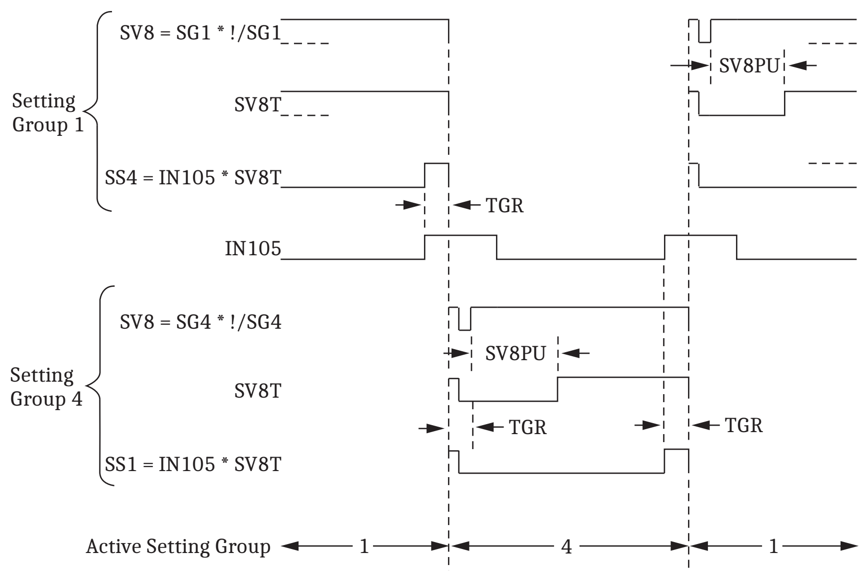


Figure 7.21 Active Setting Group Switching (With Single Input) Time Line

Active Setting Group Switching Example 2

Previous SEL relays (e.g., SEL-321 and SEL-251 relays) have multiple settings groups controlled by the assertion of three optoisolated inputs (e.g., IN101, IN102, and IN103) in different combinations as shown in *Table 7.6*.

Table 7.6 Active Setting Group Switching Input Logic

Input States			Active Setting Group
IN103	IN102	IN101	
0	0	0	Remote
0	0	1	Group 1
0	1	0	Group 2
0	1	1	Group 3
1	0	0	Group 4
1	0	1	Group 5
1	1	0	Group 6

The SEL-351 can be programmed to operate similarly. Use three optoisolated inputs to switch between the six setting groups in the SEL-351. In this example, optoisolated inputs IN101, IN102, and IN103 on the relay are connected to a rotating selector switch in *Figure 7.22*.

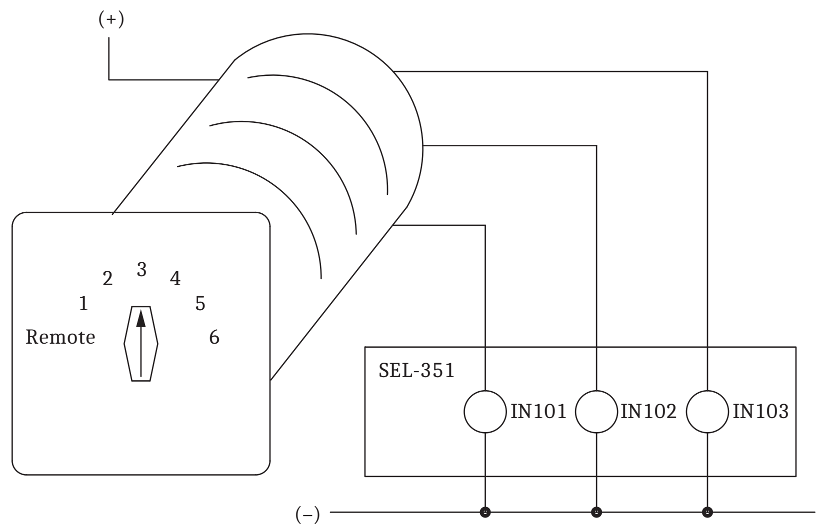


Figure 7.22 Rotating Selector Switch Connected to Inputs IN101, IN102, and IN103 for Active Setting Group Switching

The selector switch has multiple internal contacts arranged to assert inputs IN101, IN102, and IN103, dependent on the switch position. As shown in *Table 7.7*, as the selector switch is moved from one position to another, a different setting group is activated. The logic in *Table 7.6* is implemented in the SELOGIC control equation settings in *Table 7.7*.

Table 7.7 SELOGIC Control Equation Settings for Rotating Selector Switch Active Setting Group Switching

SS1 = !IN103 * !IN102 * IN101	= NOT(IN103) * NOT(IN102) * IN101
SS2 = !IN103 * IN102 * !IN101	= NOT(IN103) * IN102 * NOT(IN101)
SS3 = !IN103 * IN102 * IN101	= NOT(IN103) * IN102 * IN101
SS4 = IN103 * !IN102 * !IN101	= IN103 * NOT(IN102) * NOT(IN101)
SS5 = IN103 * !IN102 * IN101	= IN103 * NOT(IN102) * IN101
SS6 = IN103 * IN102 * !IN101	= IN103 * IN102 * NOT(IN101)

The settings in *Table 7.7* are made in each setting Group 1 through 6.

Selector Switch Starts Out in Position 3

Refer to *Table 7.7* and *Figure 7.23*.

If the selector switch is in position 3 in *Figure 7.22*, setting Group 3 is the active setting group (Relay Word bit SG3 = logical 1). Inputs IN101 and IN102 are energized and IN103 is de-energized:

SS3 = **!IN103 * IN102 * IN101** = NOT(IN103) * IN102 * IN101 = NOT(logical 0) * logical 1 * logical 1 = logical 1

To get from position 3 to position 5 on the selector switch, the switch passes through position 4. The switch is only briefly in position 4:

SS4 = **IN103 * !IN102 * !IN101** = IN103 * NOT(IN102) * NOT(IN101) = logical 1 * NOT(logical 0) * NOT(logical 0) = logical 1

but not long enough to be qualified by time setting TGR in order to change the active setting group to setting Group 4. For such a rotating selector switch application, qualifying time setting TGR is typically set at 180 to 300 cycles. Set TGR long enough to allow the selector switch to pass through intermediate positions without changing the active setting group, until the switch rests on the desired setting group position.

Selector Switch Switched to Position 5

Refer to *Figure 7.23*.

If the selector switch is rested on position 5 in *Figure 7.22*, setting Group 5 becomes the active setting group (after qualifying time setting TGR; Relay Word bit SG5 = logical 1). Inputs IN101 and IN103 are energized and IN102 is de-energized:

SS5 = **IN103 * !IN102 * IN101** = IN103 * NOT(IN102) * IN101 = logical 1 * NOT(logical 0) * logical 1 = logical 1

To get from position 5 to position REMOTE on the selector switch, the switch passes through the positions 4, 3, 2, and 1. The switch is only briefly in these positions, but not long enough to be qualified by time setting TGR in order to change the active setting group to any one of these setting groups.

Selector Switch Now Rests on Position REMOTE

Refer to *Figure 7.23*.

If the selector switch is rested on position REMOTE in *Figure 7.22*, all inputs IN101, IN102, and IN103 are de-energized and all settings SS1 through SS6 in *Table 7.7* are at logical 0. The last active setting group (Group 5 in this example) remains the active setting group (Relay Word bit SG5 = logical 1).

With settings SS1–SS6 all at logical 0, the serial port **GROUP** command or the front-panel GROUP pushbutton can be used to switch the active setting group from Group 5, in this example, to another desired setting group.

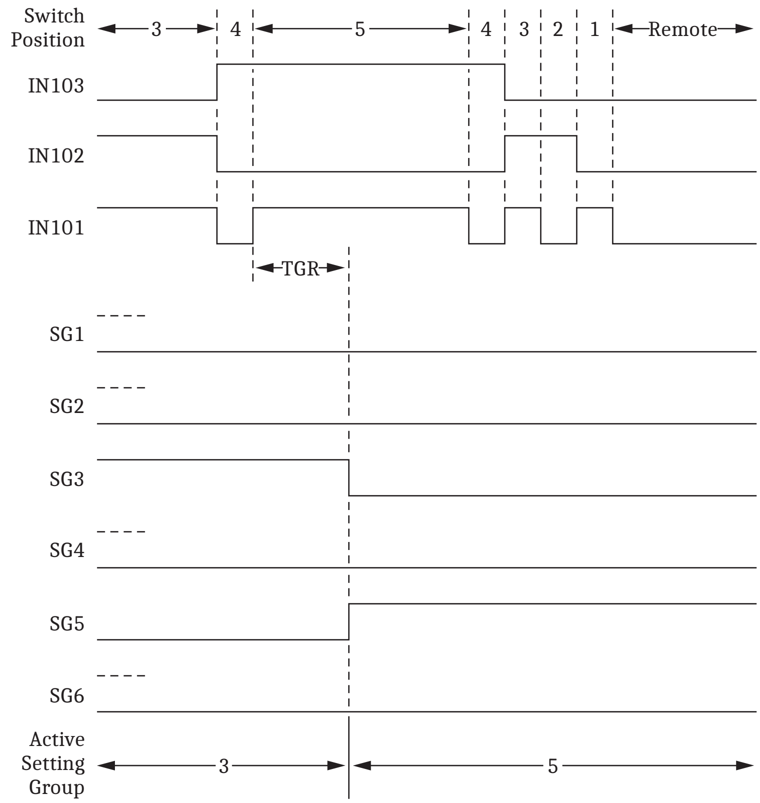


Figure 7.23 Active Setting Group Switching (With Rotating Selector Switch) Time Line

Active Setting Group Retained

Power Loss

The active setting group is retained if power to the relay is lost and then restored. If a particular setting group is active (e.g., setting Group 5) when power is lost, it comes back with the same setting group active when power is restored.

Settings Change

If individual settings are changed (for the active setting group or one of the other setting groups), the active setting group is retained, much like in the preceding *Power Loss* explanation.

If individual settings are changed for a setting group other than the active setting group, there is no interruption of the active setting group (the relay is not momentarily disabled).

If the individual settings change causes a change in one or more SELOGIC control equation settings SS1–SS6, the active setting group can be changed, subject to the newly enabled SS1–SS6 settings.

Note: Make Active Setting Group Switching Settings With Care

The active setting group is stored in nonvolatile memory so it can be retained during power loss or settings change. The nonvolatile memory is rated for a finite number of “writes” for all setting group changes. Exceeding the limit can result in an eventual self-test failure. *An average of one (1) setting group change per day can be made for a 25-year relay service life.*

This requires that SELOGIC control equation settings SS1 through SS6 (see Table 7.4) be set with care. Settings SS1–SS6 cannot result in continuous cyclical changing of the active setting group. Time setting TGR qualifies settings SS1–SS6 before changing the active setting group. If optoisolated inputs IN101 through IN106 are used in settings SS1–SS6, the inputs have their own built-in debounce timer that can help in providing the necessary time qualification (see *Figure 7.1*).

SELOGIC Control Equation Variables/Timers

NOTE: The SEL-351 ESV setting does not hide the Logic settings class SV1–SV16 SELOGIC control equation settings. All of the SELOGIC control equation settings (SV1–SV16) may be used, even when the associated timer settings are hidden by the ESV setting.

There are 16 SELOGIC control equation variables/timers available. Each SELOGIC control equation variable/timer has a SELOGIC control equation setting input and variable/timer outputs as shown in *Figure 7.24* and *Figure 7.25*.

Timers SV1T–SV6T in *Figure 7.24* have a setting range of a little over 4.5 hours:

0.00–999999.00 cycles in 0.25-cycle increments

Timers SV7T–SV16T in *Figure 7.25* have a setting range of almost 4.5 minutes:

0.00–16000.00 cycles in 0.25-cycle increments

These timer setting ranges apply to both pickup and dropout times (SV*n*PU and SV*n*DO, *n* = 1 through 16).

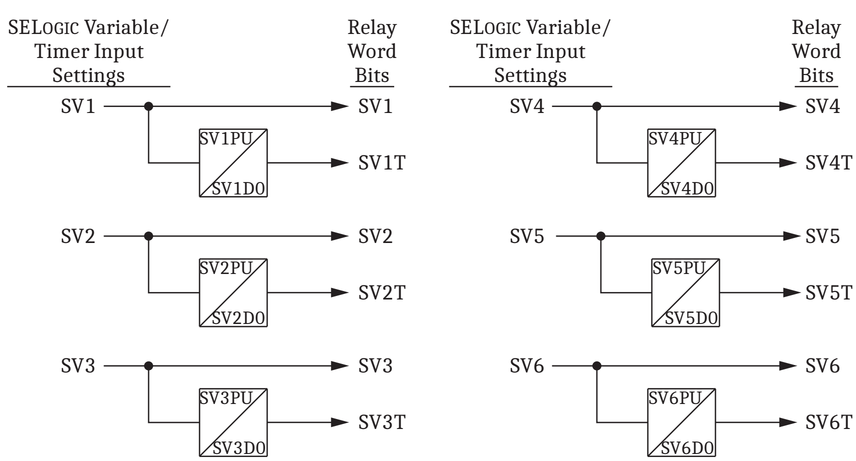


Figure 7.24 SELOGIC Control Equation Variables/Timers SV1/SV1T Through SV6/SV6T

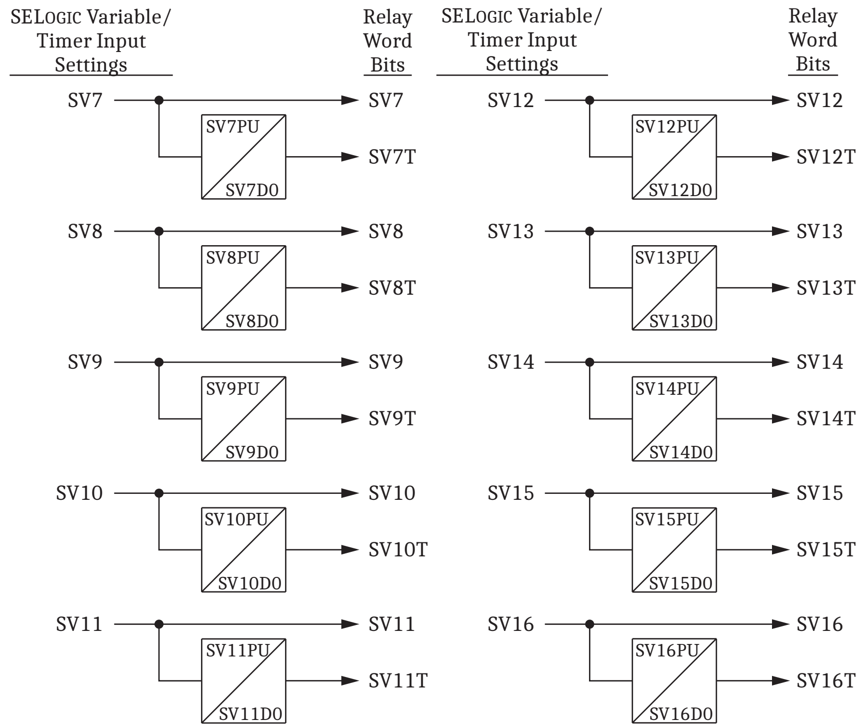


Figure 7.25 SELOGIC Control Equation Variables/Timers SV7/SV7T Through SV16/SV16T

Factory Settings Example

In the factory SELOGIC control equation settings, a SELOGIC control equation timer is used for a simple breaker failure scheme:

SV1 = **TRIP**

The TRIP Relay Word bit is run through a timer for breaker failure timing. Timer pickup setting SV1PU is set to the breaker failure time (SV1PU = 12 cycles). Timer dropout setting SV1DO is set for a 2-cycle dropout (SV1DO = 2 cycles). The output of the timer (Relay Word bit SV1T) operates output contact OUT103.

OUT103 = **SV1T**

Additional Settings Example

Another application idea is dedicated breaker failure protection with breaker failure initiate seal-in (see *Figure 7.26*):

SV6 = **IN101** (breaker failure initiate)

SV7 = **(SV7 + IN101) * (50BFT)**

OUT104 = **SV6T** (retrip)

OUT103 = **SV7T** (breaker failure trip)

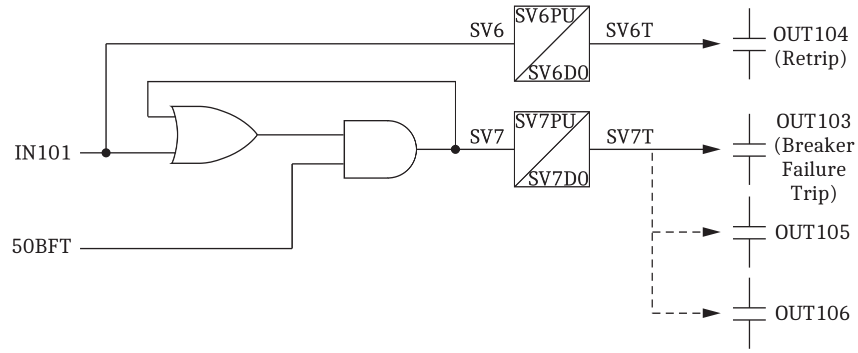


Figure 7.26 Dedicated Breaker Failure Scheme Created With SELOGIC Control Equation Variables/Timers

Relay Word bit 50BFT is the output of the three-phase breaker current detector logic (see *Breaker Failure Protection* on page 5.32).

Note that SELOGIC control equation setting SV7 creates a seal-in logic circuit (as shown in *Figure 7.26*) by virtue of SELOGIC control equation setting SV7 containing Relay Word bit SV7 (SELOGIC control equation variable SV7):

SV7 = **(SV7 + IN101) * 50BFT**

Optoisolated input **IN101** functions as a breaker failure initiate input. Relay Word bit 50BFT functions as a fault detector.

Timer pickup setting SV6PU provides retrip delay, if desired (can be set to zero). Timer dropout setting SV6DO holds the retrip output (output contact **OUT101**) closed for extra time if needed after the breaker failure initiate signal (IN101) goes away.

Timer pickup setting SV7PU provides breaker failure timing. Timer dropout setting SV7DO holds the breaker failure trip output (output contact **OUT103**) closed for extra time if needed after the breaker failure logic unlatches (fault detector 50BFT drops out).

Note that *Figure 7.26* suggests the option of having output contacts **OUT105** and **OUT106** operate as additional breaker failure trip outputs. This is done by making the following SELOGIC control equation settings:

OUT105 = **SV7T** (breaker failure trip)

OUT106 = **SV7T** (breaker failure trip)

If SV6T and SV7T are programmed to output relays to operate high-current loads such as breaker trip coils, SV6DO and SV7DO should be set equal to Group setting TDURD.

SELOGIC Variable and Timer Behavior After Power Loss, Settings Change, or Group Change

Power Loss

If power is lost to the relay, all SELOGIC Variables and Timers are in an initial state of logical 0, and the timer counts are all at zero when the relay is powered back up.

Settings Change or Active Group Change

NOTE: The logical condition immediately after an active setting group change must be considered when developing relay settings for multiple settings groups. See *Processing Order Considerations* on page F.12 for more information.

If settings are changed (for the active setting group), or the active setting group is changed, the SELOGIC control equation variables/timers logical states are retained when the relay enables, and they will exhibit this carried-through state in any SELOGIC control equation that appears earlier in the processing order, shown in *Table F.4*. The next state of the variables/timers depends on which scenario is encountered. The following examples cover the various possibilities.

Example 1: Both SV7 and SV7T Asserted Before Group Change

If SV7 and SV7T are both asserted in Group 5, they are still asserted immediately after switching to another setting group. Once the new setting group logic is processed, the SV7 variable is updated with the newly evaluated SV7 equation result.

If the SV7 equation evaluates to logical 0 in the new settings group, SV7 and SV7T immediately deassert.

If the SV7 equation evaluates to logical 1 in the new settings group, SV7 and SV7T remain asserted.

Example 2: SV7 Asserted, SV7T Not Asserted Before Group Change

If SV7 is asserted in Group 5, but SV7T has not yet asserted (because it is still timing on the group 5 SV7PU setting), SV7 is still asserted immediately after switching to another setting group, and SV7T is deasserted. Once the new setting group logic is processed, the SV7 variable is updated with the newly evaluated SV7 equation result.

If the SV7 equation evaluates to logical 0 in the new settings group, SV7 deasserts immediately, SV7T remains deasserted, and the timer fully resets.

If the SV7 equation evaluates to logical 1 in the new settings group, SV7 remains asserted, and SV7T starts timing anew on its pickup setting SV7PU from the newly enabled setting group. If the SV7 equation remains at logical 1, SV7T asserts after SV7PU cycles have elapsed (from the time the new settings group started running).

Example 3: SV7 Deasserted, SV7T Asserted Before Group Change

If SV7 is deasserted in Group 5, but SV7T has not yet deasserted (because it is still timing on the group 5 SV7DO setting), SV7 is still deasserted immediately after switching to another setting group, and SV7T stays asserted. Once the new setting group logic is processed, the SV7 variable is updated with the newly evaluated SV7 equation result.

If the SV7 equation evaluates to logical 0 in the new settings group, SV7 stays deasserted and SV7T deasserts immediately, regardless of the SV7DO setting.

If the SV7 equation evaluates to logical 1 in the new settings group, SV7 asserts and SV7T remains asserted.

Example 4: Both SV7 and SV7T Deasserted Before Group Change

If SV7 and SV7T are both deasserted in Group 5, they remain deasserted immediately after switching to another setting group. Once the new setting group logic is processed, the SV7 variable is updated with the newly evaluated SV7 equation result.

If the SV7 equation evaluates to logical 0 in the new settings group, SV7 and SV7T remain deasserted.

If the SV7 equation evaluates to logical 1 in the new settings group, SV7 asserts, and SV7T starts timing on its pickup setting SV7PU from the newly enabled setting group. If the SV7 equation remains at logical 1, SV7T asserts after SV7PU cycles have elapsed (from the time the new settings group started running).

Seal-In Behavior and Methods for Breaking Seal-In

Preceding *Figure 7.26* shows an effective seal-in logic circuit, created by use of Relay Word bit SV7 (SELOGIC control equation variable SV7) in SELOGIC control equation SV7:

SV7 = **(SV7 + IN101) * 50BFT**

This seal-in example is not cleared by a group change or settings group change. The only actions that clear this seal-in are the drop-out (deassertion to logical 0) of current detector 50BFT, or turning off the relay.

Here are a few setting examples that can be employed to change this behavior.

Assuming the seal-in logic is in active Group 6:

1. In Group 5, make setting

   SV7 = **0** (effectively)

   Switch to Group 5, and then back to Group 6 to break the seal-in condition.

2. In Group 6, make setting

   SV7 = **(SV7 + IN101) * 50BFT * !/SG6**

   In Group 5:

   SV7 = **(SV7 + IN101) * 50BFT * !/SG5**

   •
   •
   •

   In Group 1:

   SV7 = **(SV7 + IN101) * 50BFT * !/SG1**

   Switch to any settings group to break the seal-in condition, and the logic is armed and available for a new breaker failure initiate condition (assuming the other related settings are the same in each group).

3. In Group 6, make setting

   SV7 = **(SV7 + IN101) * 50BFT * !/TRGTR**

   Press the TARGET RESET button to assert Relay Word bit TRGTR and break the seal-in.

4. In Group 6, make setting

   SV7 = **(SV7 + IN101) * 50BFT * !/IN106**

   Assert control input IN106 to break the seal-in.

Logic Variables

The SEL-351 supports 32 logic variables (LV1 through LV32). These logic variables are similar to SELOGIC control equation Variables/Timers (SV1–SV16, and SV1T–SV16T), except the LVs do not have associated pickup/dropout timers. Use logic variables as intermediate SELOGIC terms to help break a long SELOGIC control equation into smaller, simpler equations.

Each logic variable has a SELOGIC control equation (LV1, LV2, … LV32), and a Relay Word bit with the same label (LV1, LV2, … LV32) as shown in *Figure 7.27*.

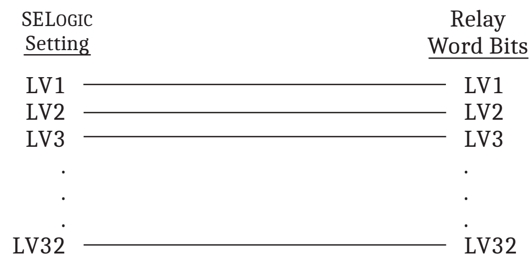


Figure 7.27 Logic Variables

There is no enable setting for the logic variables. The settings for the logic variables are accessed through 32 SELOGIC control equations in the Logic Settings class, and each setting has a factory default value of logical 0.

See *Section 9: Setting the Relay* for more information on setting classes, modifying settings, and displaying settings.

Logic Variable Application Ideas

Example 1: Simplify Logic Expressions

Use logic variables to consolidate settings into functional blocks. For example, if a protection application requires the same logic expression in several places, a logic variable can make the resulting settings easier to read.

Example settings without a logic variable:

Four torque-control settings requiring a common expression:

67N1TC = IN103 * LB2 + LT9 + 50P1

67G1TC = IN103 * LB2 + LT9 + 50P1

51NTC = IN103 * LB2 + LT9

51GTC = IN103 * LB2 + LT9

NOTE: The example settings are not from a real application.

Same example settings using a logic variable:

67N1TC = LV1 + 50P1

67G1TC = LV1 + 50P1

51NTC = LV1

51GTC = LV1

LV1 = IN103 * LB2 + LT9

See *Table F.5* for details on the processing order of SELOGIC equations. In this example, logic variable LV1 is evaluated after the torque-control equations each processing interval, and any state change of LV1 will be delayed one processing interval when used in the torque-control equations. For many situations this one-quarter-cycle delay is not significant, but should be considered when designing settings.

Example 2: Free Up SELOGIC Control Equation Variables/Timers

Use logic variables LV1–LV32 for non-timing functions to free up SELOGIC variables/timers SV1T–SV16T.

Example settings without a logic variable:

In this design, SV14 is being used as a variable only:

SV14 = (IN106 * SV13T + RB7 * LT5) * LT3 + (!59V1 + INT3P * SV13T) * !LT3

SV15 = /SV14 * LB7 + \SV14

NOTE: These example settings are not from a real application.

Same example settings using a logic variable:

Now SV14 is available for use as a timer:

LV6 = (IN106 * SV13T + RB7 * LT5) * LT3 + (!59V1 + INT3P * SV13T) * !LT3

SV14 = available

SV15 = /LV6 * LB7 + \LV6

View Logic Variables in CEV Reports or SER

Logic variables LV1–LV32 are not shown in standard event reports (**EVE** command), but are present in Compressed Event Reports (**CEV** command).

For easier analysis, any of the logic variables LV1–LV32 may be included in the Sequential Events Recorder (SER) trigger list. See *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER* for details on event reports and SER.

Logic Variable Behavior After Power Loss, Settings Change, or Group Change

Power Loss

If power is lost to the relay, when the relay is powered back up all logic variables are forced to an initial state of logical 0.

Settings Change or Active Group Change Does Not Clear Logic Variables

NOTE: If Logic Variables are used in mission-critical SELOGIC control equations, such as in the trip equation, care should be taken to consider the power loss condition and the processing order of Logic Variables (refer to *Table F.4*). See *Processing Order Considerations* on page F.12 for more information.

If settings are changed (for the active setting group), or the active setting group is changed, the relay keeps the logical states of the logic variable Relay Word bits from before the change. When the relay re-enables, the Relay Word bits LV1–LV32 are held at their previous logic states until the relay evaluates the LV1–LV32 equations and updates the Relay Word bits.

This is only important to consider when the LV1–LV32 Relay Word bit(s) are part of a SELOGIC control equation that is evaluated earlier in the processing order than the LV1–LV32 settings, and the variables are being used for different purposes in two or more settings groups.

As shown in *Table F.5*, in the SEL-351 processing order, equations 52A, SET1–SET16, RST1–RST16, BSYNCH, E32IV, 67*xx*TC, 51*xx*TC, and CLMON are processed before the logic variable equations.

Virtual Bits

The SEL-351 supports 128 virtual bits, VB001–VB128 for the IEC 61850 protocol. These Relay Word bits are active only in relays ordered with IEC 61850.

When IEC 61850 is enabled, the relay uses the externally-created CID file to define the behavior of these virtual bits (received GOOSE messages can be mapped to these bits). Once defined, the virtual bits can be used in SELOGIC control equations like any other Relay Word bit.

Virtual bits are volatile and are reset to zero when a new CID file is loaded, the device is restarted, or they are overwritten by another GOOSE message.

The CID file also defines what information gets transmitted in GOOSE messages. See *Appendix P: IEC 61850* for details on the IEC 61850 protocol.

Output Contacts

Figure 7.28 and *Figure 7.29* show the example operation of output contact Relay Word bits (e.g., Relay Word bits OUT101–OUT107 in *Figure 7.28*) as a result of one of the following:

NOTE: Do not use *Figure 7.28* or *Figure 7.29* to create relay wiring diagrams. See *Output Contacts* on page 2.8 for wiring considerations.

- SELOGIC control equation operation (e.g., SELOGIC control equation settings OUT101–OUT107 in *Figure 7.28*)
- **PULSE** command execution
- Modbus command (see *Appendix O: Modbus RTU and TCP Communications*)

The output contact Relay Word bits in turn control the output contacts (e.g., output contacts **OUT101–OUT107** in *Figure 7.28*).

Alarm logic/circuitry controls the **ALARM** output contact (see *Figure 7.28*)

Figure 7.28 is used for following discussion/examples. The output contacts in *Figure 7.29* operate similarly.

Factory Settings Example

In the factory SELOGIC control equation settings, the equations of four output contacts are used:

OUT101 = **TRIP** (overcurrent tripping/manual tripping; see *Section 5: Trip and Target Logic*)

OUT102 = **CLOSE** (automatic reclosing/manual closing; see *Section 6: Close and Reclose Logic*)

OUT103 = **SV1T** (breaker failure trip; see *SELOGIC Control Equation Variables/Timers* on page 7.26)

OUT104 = **0** (output contact **OUT104** not used—set equal to zero)

•
•
•

OUT107 = **0** (output contact **OUT107** not used—set equal to zero)

ALRMOUT = **!(SALARM + HALARM)**

Operation of Output Contacts for Different Output Contact Types

Output Contacts OUT101–OUT107

Refer to *Figure 7.28*.

The execution of the serial port command **PULSE *n*** (*n* = OUT101–OUT107) asserts the corresponding Relay Word bit (OUT101–OUT107) to logical 1. The assertion of SELOGIC control equation setting OUT*m* (*m* = 101–107) to logical 1 also asserts the corresponding Relay Word bit OUT*m* (*m* = 101–107) to logical 1.

The assertion of Relay Word bit OUT*m* (*m* = 101–107) causes the energization of the corresponding output contact OUT*m* coil. Depending on the contact type (a or b), the output contact closes or opens as demonstrated in *Figure 7.28*. An a-type output contact is open when the output contact coil is de-energized and closed when the output contact coil is energized. A b-type output contact is closed when the output contact coil is de-energized and open when the output contact coil is energized.

Notice in *Figure 7.28* that all four possible combinations of output contact coil states (energized or de-energized) and output contact types (a or b) are demonstrated. See *Output Contact Jumpers* on page 2.40 for output contact type options.

ALARM Output Contact

NOTE: Firmware versions R510 and earlier have fixed alarm logic. Refer to the documentation provided with earlier firmware for details on the operation of the ALARM output.

Refer to *Figure 7.28* and *Relay Self-Tests* on page 13.7. With factory default logic settings, when the relay is operational and there are no alarm conditions, the **ALARM** output contact coil is energized and the Relay Word bit ALARM is deasserted. When an alarm occurs, the **ALARM** output contact closes or opens, depending on the **ALARM** output contact type (a or b), as demonstrated in *Figure 7.28*, and Relay Word bit ALARM asserts.

The alarm outputs are controlled by SELOGIC control equation ALRMOUT. The default setting for this equation is:

ALRMOUT = **!(SALARM + HALARM)**

NOTE: The default setting of SELOGIC control equation ALRMOUT mimics the alarm behavior of firmware versions R510 and earlier.

With this setting, SELOGIC control equation and Relay Word bit ALRMOUT are asserted and the ALARM output relay coil is energized when the relay has power and there are no alarm conditions. OUT107, if it is configured as an alarm output using main board jumper JMP10, is also energized. As shown in *Figure 7.28*, Relay Word bit ALARM is deasserted, because it is the opposite of ALRMOUT.

When a software or hardware alarm condition occurs, SELOGIC control equation and Relay Word bit ALRMOUT are deasserted, Relay Word bit ALARM is asserted, and the ALARM output relay coil is de-energized. OUT107, if it is configured as an alarm output using main board jumper **JMP10**, is also de-energized.

The ALARM and OUT107 output relay coils are also de-energized if the relay restarts, there is a loss of power, or a failure prevents the relay from operating.

The alarm output contacts can be programmed to change state for the following reasons:

1. Software alarm conditions programmed in SELOGIC control equation SALARM
2. Hardware warning or failure conditions from relay self-test logic

Software alarm conditions are programmed in SELOGIC control equation SALARM and may be modified as necessary for the application. The following Relay Word bits are available to monitor software alarm conditions:

ACCESS—Asserts while any user is logged in at Access Level B or higher.

ACCESSP—Pulses for approximately one second when any user increases their access level to B or higher.

SETCHG—Pulses for approximately one second whenever settings are changed or saved. SETCHG does not pulse when settings are reset to defaults or when the active settings group switches.

CHGPASS—Pulses for approximately one second whenever a password changes.

PASNVAL—Pulses for approximately one second when an incorrect password is entered when attempting to Access Level B or higher, or when an incorrect password is entered when attempting to change passwords.

BADPASS—Pulses for approximately one second whenever a user enters three successive incorrect passwords in an SEL ASCII terminal session or web session.

GRPSW—Pulses for approximately one second when the relay switches active settings group.

These Relay Word bits are intended for indication only and should not be used in protection logic.

NOTE: The SALARM setting makes the software alarm behavior similar to that of firmware version R510 and earlier. SETCHG now pulses when Port, DNP, and Modbus settings are saved and when settings are copied into a setting group which is not the active setting group. The alarm output does not pulse for these setting save operations in R510 and earlier.

In default settings, SELOGIC control equation SALARM is set as follows:

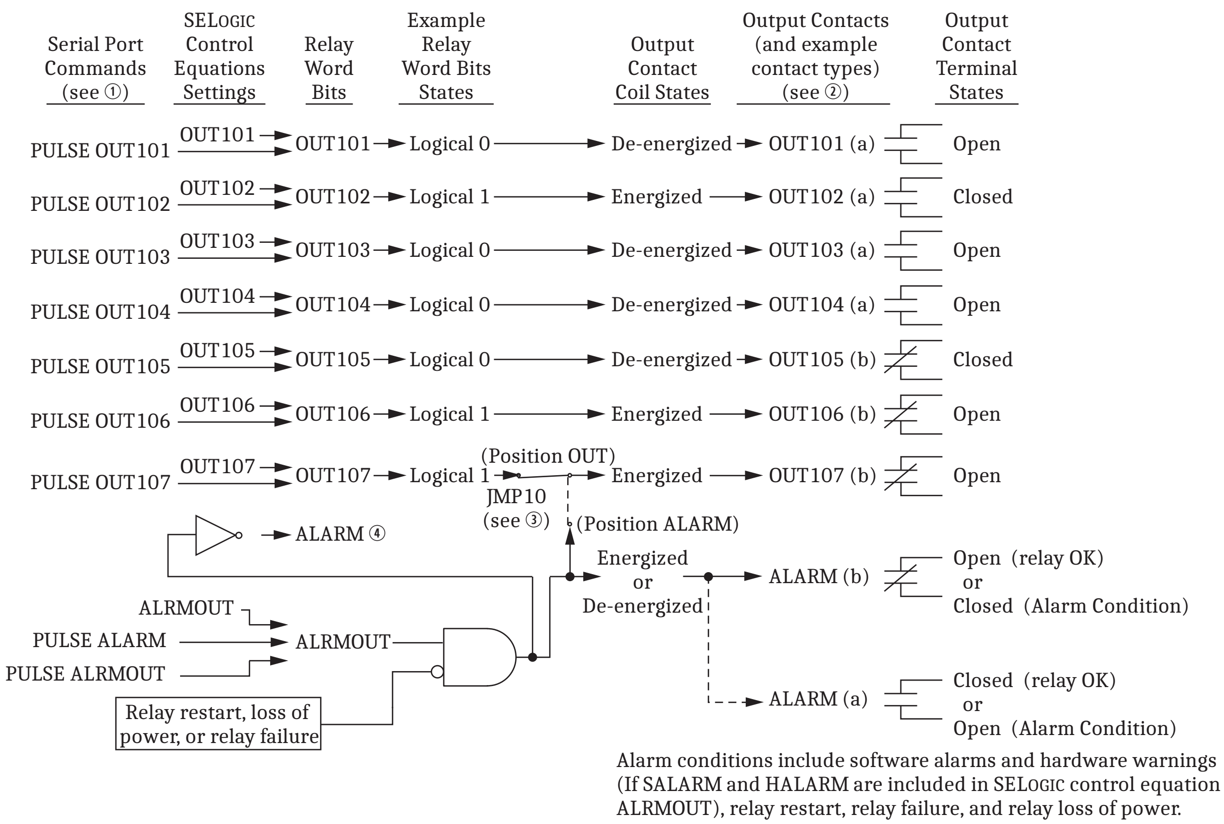
SALARM = **BADPASS + CHGPASS + SETCHG + GRPSW + ACCESSP + PASNVAL**

Hardware alarm conditions are generated by the relay self-test logic (see *Table 13.3*) and are classified as warnings or failures, depending upon severity. Relay Word bit HALARM pulses for approximately five seconds to indicate that a hardware warning has occurred and asserts continuously when there is a hardware failure. Additional hardware alarm Relay Word Bits HALARMP, HALARML, and HALARMA are available to support custom alarm schemes. See *Relay Self-Tests* on page 13.7.

In a standard shipment, the ALARM output is a Form B contact. This contact closes to alarm with the factory default logic. If a Form A contact is necessary (open to alarm), do not change the ALRMOUT SELOGIC control equation so that the ALARM output must energize to alarm, as this will cause incorrect alarm operation during hardware and power failures. Instead, use OUT107 as an extra alarm output or change the ALARM output to a Form A contact. See *Output Contact Jumpers* on page 2.40 and *"Extra Alarm" Output Contact Control Jumper* on page 2.40.

To verify **ALARM** output contact mechanical integrity, execute the serial port commands **PULSE ALARM** or **PULSE ALRMOUT**. This momentarily de-energizes the **ALARM** output contact coil and causes Relay Word bit ALARM to assert.

Notice that *Figure 7.28* shows all possible combinations of **ALARM** output contact coil states (energized or de-energized) and output contact types (a or b). See *Output Contact Jumpers* on page 2.40 for output contact type options.



① **PULSE** command is also available via the front panel (**CNTRL** pushbutton, `Output Contact Testing` option). Execution of the **PULSE** command results in a logical 1 input into the above logic (one-second default pulse width).

② Output contacts **OUT101–ALARM** are configurable as Form A or Form B output contacts. See *Output Contact Jumpers* on page 2.40 for more information on selecting output contact type. **OUT101–OUT107** are shipped as Form A contacts and **ALARM** is shipped as a Form B contact in the standard relay configuration.

③ Main I/O board jumper **JMP10** allows output contact **OUT107** to operate as: a regular output contact **OUT107** or an extra Alarm output contact. See *"Extra Alarm" Output Contact Control Jumper* on page 2.40 for more information on jumper **JMP10**.

④ Although the **ALARM** output changes state, Relay Word bit ALARM does not assert during a loss of power, relay restart, or a relay failure. Relay Word bit ALARM asserts briefly after a restart and upon recovery from loss of power.

Figure 7.28 Logic Flow for Example Output Contact Operation (All Models)

Output Contacts OUT201–OUT2xx (On Relays With Optional Extra Input/Output Board)

Refer to *Figure 7.29*. The various input/output board choices have four or 12 outputs that act in a similar fashion to those described in *Output Contacts OUT101–OUT107* on page 7.34.

① **PULSE** command is also available via the front panel (**CNTRL** pushbutton, `Output Contact Testing` option). Execution of the **PULSE** command results in a logical 1 input into the above logic (one-second default pulse width).

② All output contacts are configurable as Form A or Form B output contacts. See *Output Contact Jumpers* on page 2.40 for more information on selecting output contact type. **OUT201–OUT212** are shipped as Form A contacts in the standard relay configuration for extra I/O board options 2 or 6. **OUT201–OUT204** are shipped as Form A contacts in the standard relay configuration for extra I/O board option 4.

③ I/O board option 4 has output contacts **OUT201–OUT204** only.

Figure 7.29 Logic Flow for Example Output Contact Operation (Models With Extra I/O Board Option 2, 4, or 6)

Rotating Display

The rotating display on the relay front-panel replaces indicating panel lights. Traditional indicating panel lights are turned on and off by circuit breaker auxiliary contacts, front-panel switches, SCADA contacts, etc. They indicate such conditions as:

- circuit breaker open/closed
- reclosing relay enabled/disabled

Traditional Indicating Panel Lights

Figure 7.30 shows traditional indicating panel lights wired in parallel with SEL-351 optoisolated inputs. Input IN101 provides circuit breaker status to the relay, and input IN102 enables/disables reclosing in the relay via the following SELOGIC control equation settings:

52A = **IN101**

79DTL = **!IN102** [= NOT(IN102); drive-to-lockout setting]

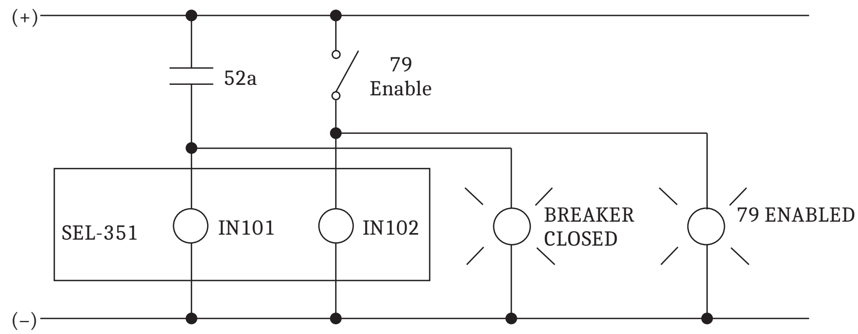


Figure 7.30 Traditional Panel Light Installations

Note that *Figure 7.30* corresponds to *Figure 7.3* (factory input settings example).

Reclosing Relay Status Indication

In *Figure 7.30*, the 79 ENABLED panel light illuminates when the “79 Enable” switch is closed. When the “79 Enable” switch is open, the 79 ENABLED panel light extinguishes, and it is understood that the reclosing relay is disabled.

Circuit Breaker Status Indication

In *Figure 7.30*, the BREAKER CLOSED panel light illuminates when the 52a circuit breaker auxiliary contact is closed. When the 52a circuit breaker auxiliary contact is open, the BREAKER CLOSED panel light extinguishes, and it is understood that the breaker is open.

Traditional Indicating Panel Lights Replaced With Rotating Display

The indicating panel lights are not needed if the rotating display feature in the SEL-351 Relay is used. *Figure 7.31* shows the elimination of the indicating panel lights by using the rotating display.

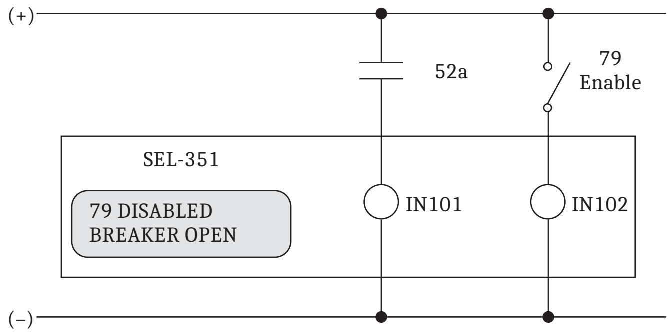


Figure 7.31 Rotating Default Display Replaces Traditional Panel Light Installations

There are 16 of these displays available in the SEL-351. Each display has two complementary screens (e.g., BREAKER CLOSED and BREAKER OPEN) available.

General Operation of Rotating Display Settings

SELOGIC control equation display point setting DP*n* (*n* = 1 through 16) controls the display of corresponding, complementary text settings:

DP*n*_1 (displayed when DP*n* = logical 1)

DP*n*_0 (displayed when DP*n* = logical 0)

Make each text setting through the serial port using the command **SET T** or the Text settings in QuickSet. View these text settings using the serial port command **SHO T** (see *Section 9: Setting the Relay* and *Section 10: Communications*) or the Text settings in QuickSet. These text settings are displayed on the SEL-351 front-panel display on a time-variable rotation using Global setting SCROLD (see *Rotating Display* on page 11.10 for more specific operation information).

The following factory settings examples use Relay Word bits 52A and IN102 in the display points settings. Local bits (LB1–LB16), latch bits (LT1–LT16), remote bits (RB1–RB32), setting group indicators (SG1–SG6), and any other combination of Relay Word bits in a SELOGIC control equation setting can also be used in display point setting DP*n*.

Settings Examples

The factory settings provide the replacement solution shown in *Figure 7.31* for the traditional indicating panel lights in *Figure 7.30*.

Reclosing Relay Status Indication

Make SELOGIC control equation display point setting DP1: (**SET L**)

DP1 = **IN102**

Make corresponding, complementary text settings: (**SET T**)

DP1_1 = **79 ENABLED**

DP1_0 = **79 DISABLED**

Display point setting DP1 controls the display of the text settings.

Reclosing Relay Enabled

In *Figure 7.31*, optoisolated input **IN102** is energized to enable the reclosing relay, resulting in:

DP1 = **IN102** = logical 1

This results in the display of corresponding text setting DP1_1 on the front-panel display:

```
79 ENABLED
```

Reclosing Relay Disabled

In *Figure 7.31*, optoisolated input **IN102** is de-energized to disable the reclosing relay, resulting in:

DP1 =**IN102** = logical 0

This results in the display of corresponding text setting DP1_0 on the front-panel display:

```
79 DISABLED
```

Circuit Breaker Status Indication

Make SELOGIC control equation display point setting DP2 (and 52A):

52A = **IN101** (see *Figure 7.3*)

DP2 = **52A**

Make corresponding, complementary text settings:

DP2_1 = **BREAKER CLOSED**

DP2_0 = **BREAKER OPEN**

Display point setting DP2 controls the display of the text settings.

Circuit Breaker Closed

In *Figure 7.31*, optoisolated input **IN101** is energized when the 52a circuit breaker auxiliary contact is closed, resulting in:

52A = **IN101** = logical 1

DP2 = **52A** = logical 1

This results in the display of corresponding text setting DP2_1 on the front-panel display:

```

BREAKER CLOSED
```

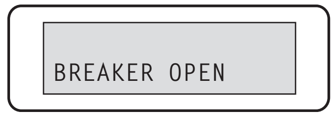
Circuit Breaker Open

In *Figure 7.31*, optoisolated input **IN101** is de-energized when the 52a circuit breaker auxiliary contact is open, resulting in:

52A = **IN101** = logical 0

DP2 = **52A** = logical 0

This results in the display of corresponding text setting DP2_0 on the front-panel display:



Additional Settings Examples

Display Only One Message

To display just one screen, but not its complement, set only one of the text settings. For example, to display just the "breaker closed" condition, but not the "breaker open" condition, make the following settings:

52A = **IN101** (52a circuit breaker auxiliary contact connected to input **IN101**—see *Figure 7.31*)

DP2 = **52A**

DP2_1 = **BREAKER CLOSED** (displays when DP2 = logical 1)

DP2_0 = (blank)

Circuit Breaker Closed

In *Figure 7.31*, optoisolated input **IN101** is energized when the 52a circuit breaker auxiliary contact is open, resulting in:

52A = **IN101** = logical 1

DP2 = **52A** = logical 1

This results in the display of corresponding text setting DP2_1 on the front-panel display.

Circuit Breaker Open

In *Figure 7.31*, optoisolated input **IN101** is de-energized when the 52a circuit breaker auxiliary contact is open, resulting in:

52A = **IN101** = logical 0

DP2 = **52A** = logical 0

Corresponding text setting DP2_0 is not set (it is "blank"), so no message is displayed on the front-panel display.

Continually Display a Message

To permanently include a message in the rotation, set the SELOGIC control equation display point setting directly to 0 (logical 0) or 1 (logical 1) and the corresponding text setting. For example, if an SEL-351 is protecting a 12 kV distribution feeder, labeled "Feeder 1204," the feeder name can be permanently included in the display with the following settings:

DP5 = **1** (set directly to logical 1)

DP5_1 = **FEEDER 1204** (displays when DP5 = logical 1)

DP5_0 = ("blank")

This results in the display of text setting DP5_1 on the front-panel display:

```
FEEDER 1204
```

This can also be realized with the following settings:

DP5 = **0** (set directly to logical 0)

DP5_1 = ("blank")

DP5_0 = **FEEDER 1204** (displays when DP5 = logical 0)

This results in the display of text setting DP5_0 on the front-panel display:

```
FEEDER 1204
```

Active Setting Group Switching Considerations

The SELOGIC control equation display point settings DP*n* (*n* = 1 through 16) are available separately in each setting group. The corresponding text settings DP*n*_1 and DP*n*_0 are made only once and used in all setting groups.

Refer to *Figure 7.31* and the following example setting group switching discussion.

Setting Group 1 Is the Active Setting Group

When setting Group 1 is the active setting group, optoisolated input **IN102** operates as a reclose enable/disable switch with the following settings:

SELOGIC control equation settings:

79DTL = **... + !IN102 + ...** [= ... + NOT(IN102) + ...; drive-to-lockout setting]

DP1 = **IN102**

Text settings:

DP1_1 = **79 ENABLED** (displayed when DP1 = logical 1)

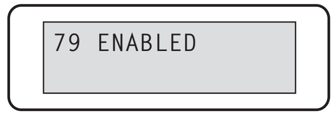
DP1_0 = **79 DISABLED** (displayed when DP1 = logical 0)

Reclosing Relay Enabled

In *Figure 7.31*, optoisolated input IN102 is energized to enable the reclosing relay, resulting in:

DP1 = **IN102** = logical 1

This results in the display of corresponding text setting DP1_1 on the front-panel display:



Reclosing Relay Disabled

In *Figure 7.31*, optoisolated input IN102 is de-energized to disable the reclosing relay, resulting in:

DP1 =**IN102** = logical 0

This results in the display of corresponding text setting DP1_0 on the front-panel display:

Now the active setting group is switched from setting Group 1 to 4.

Switch to Setting Group 4 as the Active Setting Group

When setting Group 4 is the active setting group, the reclosing relay is always disabled and optoisolated input IN102 has no control over the reclosing relay. The text settings cannot be changed (they are used in all setting groups), but the SELOGIC control equation settings can be changed:

SELOGIC control equation settings:

79DTL = **1** (set directly to logical 1—reclosing relay permanently “driven-to-lockout”)

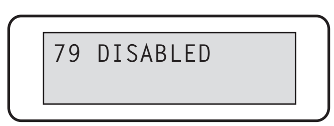
DP1 = **0** (set directly to logical 0)

Text settings (remain the same for all setting groups):

DP1_1 = **79 ENABLED** (displayed when DP1 = logical 1)

DP1_0 = **79 DISABLED** (displayed when DP1 = logical 0)

Because SELOGIC control equation display point setting DP1 is always at logical 0, the corresponding text setting DP1_0 is permanently included in the rotating displays:



Additional Rotating Display Example

See *Figure 5.20* and accompanying text in *Section 5: Trip and Target Logic* for an example of resetting a rotating display with the **TARGET RESET** pushbutton.

Displaying Analog Values on the Rotating Display

Several analog quantities are available for display using display points. These quantities are indicated with an "x" mark in the Display Points column in *Table E.1*.

The available analog values cover metering, breaker wear monitor, and time-overcurrent element pickup values.

In general, any of these values can be selected for the rotating display with a leading two-character sequence:

"::" (double colon)

followed by the analog quantity name (mnemonic) in the display point text setting DP*n*_1 or DP*n*_0. For example, to display peak demand currents for currents IA, IB, IC, and IN, make the following text (**SET T** command) and logic (**SET L** command) settings:

SET T	SET L
DP1_0 = ::IAPK	DP1 = 0
DP2_0 = ::IBPK	DP2 = 0
DP3_0 = ::ICPK	DP3 = 0
DP4_0 = ::INPK	DP4 = 0

Logic settings DP1–DP4 are permanently set to logical 0 in this example. This causes the corresponding DP*n*_0 value to permanently rotate in the display (the mnemonics in the DP*n*_0 settings indicate the value displayed, per *Table E.1*):

```
IA  PEAK = 603.5
IB  PEAK = 598.7
```

then,

```
IC  PEAK = 605.1
IN  PEAK = 88.2
```

Values Displayed for Incorrect Settings

If the display point setting does not match the correct format (using the leading two-character sequence "::" followed by the correct mnemonic), the relay will display the setting text string as it was actually entered, without substituting the display value. For example:

SET T	SET L
DP1_0 = :IAPK (missing ":")	DP1 = 0
DP2_0 = ::IBPJ (misspelled mnemonic)	DP2 = 0

Again, logic settings DP1 and DP2 are permanently set to logical 0. This causes the corresponding DP*n*_0 value to permanently rotate in the display. With the DP*n*_0 setting problems just discussed, the relay displays the setting text string as it was actually entered, without substituting the intended display value from *Table E.1*:

```
:IAPK
::IBPJ
```

Extra Details for Displaying Metering Values on the Rotating Display

Table E.1 lists all the available metering values that can be configured to rotate on the default display, subject to the number of available display points. These values correspond to the primary metering values available via the **METER** command [**MET** (Instantaneous), **MET X** (Extended Instantaneous), **MET D** (Demand), **MET E** (Energy), and **MET H** (Harmonics); see *Section 10: Communications* for serial port commands].

Automatic Decimal Point

Many of the magnitude values are displayed with as many as three digits behind the decimal point. For example, to display the ::IA value in *Table E.1* the relay uses a magnitude field and a phase-angle field. The relay automatically selects the number of decimal digits to fit in the magnitude display as shown in these sample screens.

Magnitudes less than 10 display with three digits behind the decimal point:

```
IA= 8.372A    0°
```

Magnitudes greater than or equal to 10 display with two or fewer digits behind the decimal point:

```
IA= 52.37A    0°
IB= 635.8A -120°
```

```
IC= 1173A   120°
```

Quantities Not Always Available for Display

Some of the analog quantities marked as Display Points in *Table E.1* are marked with table footnotes, for example, ::VA is not valid when Global setting PTCONN = DELTA. If ::VA is used in a display point setting when PTCONN = DELTA, the relay displays the setting as entered.

Example settings (when PTCONN = DELTA):

DP1_0 = **::VA**

DP2_0 = **::VAB**

DP1 = **0**

DP2 = **0**

Then the front-panel displays:

```
::VA
VAB= 34.76kV  0°
```

in sequence with any other defined display points and the default screens.

Other *Table E.1* footnotes indicate when a Display Point analog quantity is reported as 0.00 (zero). For example, ::V2 is displayed as 0.000 when Global setting PTCONN = SINGLE. If ::V2 is used in a display point setting when PTCONN = SINGLE, the relay displays the value as:

```
 V2=0.000kV   0°
```

Extra Details for Displaying Breaker Wear Monitor Quantities on the Rotating Default Display

Table E.1 lists all the available breaker wear monitor values that can be configured to rotate on the display, subject to the number of available display points. These values correspond to the breaker monitor values available via the **BRE** (Breaker) command (see *Section 10: Communications* for serial port commands).

See *Breaker Monitor* on page 8.1 details on configuring the breaker monitor function.

This example demonstrates use of the rotating display to show breaker wear monitor quantities automatically on the rotating display. This example will set the EXTTR, INTTR, INTIA, EXTIA, and WEARA quantities to display in the rotating display.

Set the following:

SET T	SET L
DP1_0 = ::EXTTR	DP1 = 0
DP2_0 = ::INTTR	DP2 = 0
DP3_0 = ::INTIA	DP3 = 0
DP4_0 = ::EXTIA	DP4 = 0
DP5_0 = ::WEARA	DP5 = 0

Setting DP*n* = 0 and using the DP*n*_0 in the text settings allows the setting to permanently rotate in the display. The DP*n* logic equation can be set to control the text display—turning it on and off under certain conditions. With the relay set as shown previously, the LCD will show the following:

```
EXT TRIPS=    4
INT TRIPS=   67
```

then,

```
INT IA=     2 kA
EXT IA=   122 kA
```

and then,

```
WEAR A=    16 %
```

Extra Details for Displaying Time-Overcurrent Elements on the Rotating Display

Table E.1 lists all the available Time-Overcurrent Element pickup values that can be configured to rotate on the display, subject to the number of available display points. As with the previously described display points, the operator does not need to press any buttons to see this information.

To program a display point to show the pickup setting of a time-overcurrent element, first enter the two-character sequence "::" (double colon) followed by the name of the desired time-overcurrent element pickup setting (e.g., 51PP, 51AP, 51BP, 51CP, 51NP, 51GP, 51G2P, or 51QP).

For example, with the factory default settings for 51PP and CTR, setting DP1_0 =::51PP will display `720.00 A pri`.

The relay calculates the value to display by multiplying the 51PP setting (6.00 A secondary) by the CTR setting (120), arriving at 720.00 A primary. The relay displays the display point DP1_0 because the factory default SELOGIC control equation DP1 = 0 (logical 0).

The calculations for the remaining time-overcurrent elements are similar, except for 51NP which is multiplied by the CTRN setting.

If the display point setting does not match the correct format, the relay will display the setting text string as it was actually entered, without substituting the time-overcurrent element setting value.

Displaying Time-Overcurrent Elements Example

This example demonstrates use of the rotating display to show time-overcurrent elements in primary units. This example will set the 51PP and 51NP to display in the rotating display.

Set the following:

SET	SET T	SET L
CTR = 100	DP1_0 = PHASE TRIPS AT	DP1 = 0
CTRN = 100	DP2_0 = ::51PP	DP2 = 0
E51P = 1	DP3_0 = NEUTRAL TRIPS AT	DP3 = 0
E51N = Y	DP4_0 = ::51NP	DP4 = 0
51PP = 5		
51NP = 1		

Setting DP*n* = 0 and using the DP*n*_0 in the text settings allows the setting to permanently rotate in the display. The DP*n* logic equation can be set to control the text display—turning it on and off under certain conditions. With the relay set as shown above, the LCD will show the following:

```
PHASE TRIPS AT
   500.00 A pri
```

then,

```
NEUTRAL TRIPS AT
   100.00 A pri
```

With the control string set on the even display points "DP2, DP4, DP6, …" and the description set on the odd display points "DP1, DP3, …," each screen the relay scrolls through will have a description with the value below it.

Additional Format for Displaying Time-Overcurrent Elements on the Rotating Display

The previous method for displaying Time-Overcurrent Element pickup values required two display points per overcurrent element: one display points acts as the title, and the other contains the data. Because this reduces the number of display points available for other reporting functions, a special one-line format is available for the Time-Overcurrent Element pickup values.

Instead of the double colon operator (e.g., ::51PP), the special formatting options use a double or triple semicolon operator (e.g. ;;51PP or ;;;51PP), and descriptive text may be entered.

To set the description and the control string of time-overcurrent element on one display point, use the following **SET T** format:

DPi_j = **XXX;;[;]ABCDE;YYY**

where:

i is a display point number from 1 to 16

j is either 1 or 0 (logic high or low)

XXX is an optional prelabel consisting of any characters that you want to add for labeling the setting value

[;] signifies an optional ";" for the ";;;" control string to make more characters available for labeling purposes

The label character count is the sum of the characters used in the pre- and postlabels. (For example, three characters at the beginning and three characters at the end of the string equal six total characters used for labeling.)

ABCDE is a relay setting variable from *Table 7.8*

YYY is an optional post-label, preceded by a single semicolon (;) character. If no trailing semicolon and label text is added, the relay does not display a post-setting label. Refer to *Table 7.8* to determine the maximum characters allowed for use in pre/postlabel text.

Table 7.8 Mnemonic Settings for Time-Overcurrent (TOC) Element Pickups Using the Same-Line-Label Format on the Rotating Display

SET T Setting Variable	Displays Relay Setting Value	Display Format/ Resolution	Maximum Label Characters
;;51AP	51AP	xxxxxxx.xx	6
;;51BP	51BP	xxxxxxx.xx	6
;;51CP	51CP	xxxxxxx.xx	6
;;51PP	51PP	xxxxxxx.xx	6
;;51GP	51GP	xxxxxxx.xx	6
;;51G2P	51G2P	xxxxxxx.xx	6
;;51QP	51QP	xxxxxxx.xx	6
;;51NP	51NP	xxxxxxx.xx	6
;;;000	51AP	xxxxxxx	9
;;;001	51BP	xxxxxxx	9
;;;002	51CP	xxxxxxx	9
;;;003	51PP	xxxxxxx	9
;;;004	51GP	xxxxxxx	9
;;;005	51QP	xxxxxxx	9
;;;006	51NP	xxxxxxx	9
;;;007	51G2P	xxxxxxx	9

Examples With ";;   ;" Control Strings

SET L

DP1 = **IN101**

DP2 = **IN101**

SET T

DP1_1 = **PTO=;;51PP;Ap**

The pre- and postlabel characters for DP1_1, are "P," "T," "O," "=," "A," "p," a total of six characters. The relay setting to be displayed is 51PP, as indicated after the control string ";;". The relay converts lowercase "p" to upper case when the setting is saved.

DP1_0 = **NEUTRP;;51NP;**

The prelabel characters for DP1_0, are "N," "E," "U," "T," "R," "P," a total of six characters. The relay setting to be displayed is 51NP, as indicated after the control string ";;".

DP2_1 = **GND PU;;51GP;B1**

The characters for DP2_1, consist of six pre characters “G,” “N,” “D,” “ “, “P,” “U,” and two post characters “B,” “1.” The maximum number of label characters is six, so the “B1” will be ignored. The relay setting to be displayed is 51GP, as indicated after the control string “;;”.

DP2_0 = **N SEQ=;;51QP;A**

The characters for DP2_0, consist of six pre characters “N,” “ “, “S,” “E,” “Q,” “=” and one post character “A.” The “A” will be ignored. The relay setting to be displayed is 51QP, as indicated after the control string “;;”.

When IN101 = 1, the following will display on the front-panel display (assuming 51PP= 720 A primary, and 51GP = 121.2 A primary):

```
PTO=   720.00AP
GND PU    121.20
```

When IN101 = 0, the following will display on the front-panel display (assuming 51NP= 180 A primary, and 51QP = OFF):

```
NEUTRP    180.00
N SEQ=  OFF
```

If the prelabel is longer than six characters, the string is processed as if there were only six precharacters.

To illustrate this, continuing from the above example:

DP1_0 = **NEUTRP=;;51NP;A**

with **IN101** deasserted, will display:

```
NEUTRP    180.00
N SEQ=  OFF
```

The addition of the “=” sign caused the number of precharacters to exceed six, so the processing logic stops there, and will display the first six characters followed by the setting values. The post character(s), “A” in this case, are ignored.

Examples With “;;; ;” Control Strings

Use the “;;;” control string to decrease the display resolution, and make more characters available for labeling purposes. Use the table above to determine the appropriate numerical setting variable. The following setting example allows nine characters of label text.

SET L

DP1 = **IN101**

DP2 = **IN101**

SET T

DP1_0 = **51THXYZ=;;;000;A**

(The prelabel characters are: “5, 1, T, H, X, Y, Z, =”. The post-label character is “A.” The total number of label characters is 9.)

DP2_0 = **51ABCD=;;;001;AP**

When IN101 = 0, the following will display on the front-panel display (assuming 51AP = 720 A primary, and 51BP = 600 A primary):

```
51THXYZ=   720A
51ABCD=    600AP
```

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SECTION 8

Breaker Monitor, Metering, and Load Profile Functions

Overview

This section covers the reporting and metering functions of the SEL-351, in the following subsections:

Breaker Monitor

The breaker monitor in the SEL-351 helps in scheduling circuit breaker maintenance. The breaker monitor is enabled with the enable setting:

EBMON = **Y**

The breaker monitor settings in *Table 8.2* are available via the **SET G** and **SET L** commands (see *Table 9.2* and also *Breaker Monitor Settings (see Breaker Monitor on page 8.1)* on page SET.3). Also, refer to **BRE *(Breaker Monitor Data)*** on page 10.37.

Breaker Wear Monitor

The breaker wear monitor is set with breaker maintenance information provided by circuit breaker manufacturers. This breaker maintenance information lists the number of close/open operations that are permitted for a given current interruption level. The following is an example of breaker maintenance information for a 25 kV circuit breaker.

Table 8.1 Breaker Maintenance Information for a 25 kV Circuit Breaker

Current Interruption Level (kA)	Permissible Number of Close/Open Operations[a]
0.00–1.20	10,000
2.00	3,700
3.00	1,500
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 counted as **one** close/open operation.

The breaker maintenance information in *Table 8.1* is plotted in *Figure 8.1*.

Connect the plotted points in *Figure 8.1* for a breaker maintenance curve. To estimate this breaker maintenance curve in the SEL-351 breaker wear monitor, three set points are entered:

- Set Point 1—maximum number of close/open operations with corresponding current interruption level.
- Set Point 2—number of close/open operations that correspond to some midpoint current interruption level.
- Set Point 3—number of close/open operations that correspond to the maximum current interruption level.

These three points are entered with the settings in *Table 8.2*.

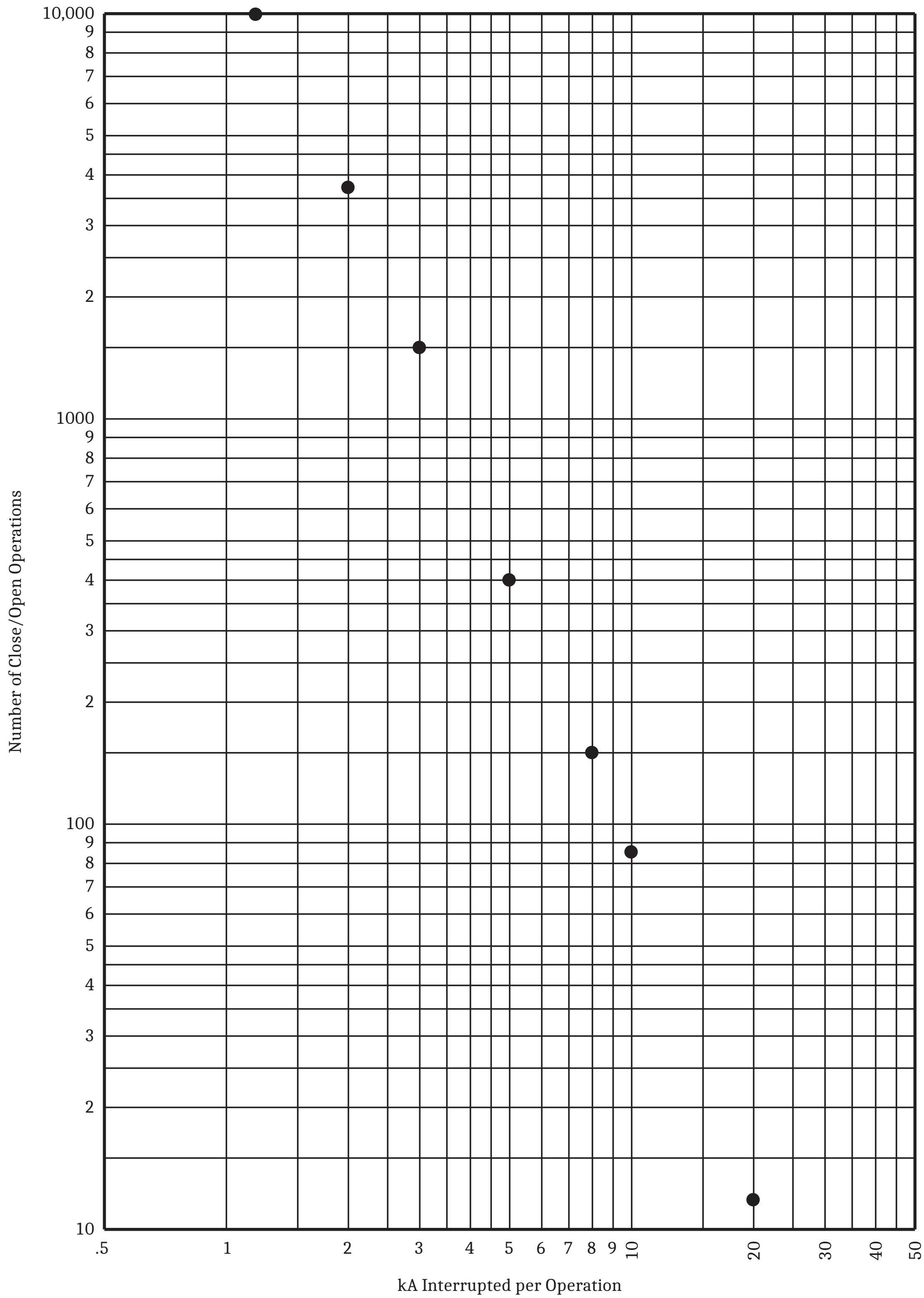

Figure 8.1 Plotted Breaker Maintenance Points for a 25 kV Circuit Breaker

Breaker Wear Monitor Setting Example

Table 8.2 Breaker Wear Monitor Settings and Settings Ranges

Setting	Definition	Range
COSP1	Close/Open set point 1—maximum	0–65000 close/open operations
COSP2	Close/Open set point 2—middle	0–65000 close/open operations
COSP3	Close/Open set point 3—minimum	0–65000 close/open operations
KASP1	kA Interrupted set point 1—minimum	0.00–999.00 kA in 0.01 kA steps
KASP2	kA Interrupted set point 1—middle	0.00–999.00 kA in 0.01 kA steps
KASP3	kA Interrupted set point 1—maximum	0.00–999.00 kA in 0.01 kA steps
BKMON	SELOGIC control equation breaker monitor initiation setting	Relay Word bits referenced in *Table D.1*

Setting notes:

- COSP1 must be set greater than COSP2.
- COSP2 must be set greater than or equal to COSP3.
- KASP1 must be set less than KASP2.
- If COSP2 is set the same as COSP3, then KASP2 must be set the same as KASP3.
- KASP3 must be set at least 5 times (but no more than 100 times) the KASP1 setting value.

The following settings are made from the breaker maintenance information in *Table 8.1* and *Figure 8.1*:

COSP1 = **10000**

COSP2 = **150**

COSP3 = **12**

KASP1 = **1.20**

KASP2 = **8.00**

KASP3 = **20.00**

Figure 8.2 shows the resultant breaker maintenance curve.

Breaker Maintenance Curve Details

In *Figure 8.2*, note that set points KASP1, COSP1 and KASP3, COSP3 are set with breaker maintenance information from the two extremes in *Table 8.1* and *Figure 8.1*.

In this example, set point KASP2, COSP2 happens to be from an in-between breaker maintenance point in the breaker maintenance information in *Table 8.1* and *Figure 8.1*, but it does not have to be. Set point KASP2, COSP2 should be set to provide the best “curve-fit” with the plotted breaker maintenance points in *Figure 8.1*.

Each phase (A, B, and C) has its own breaker maintenance curve (like that in *Figure 8.2*), because the separate circuit breaker interrupting contacts for phases A, B, and C do not necessarily interrupt the same magnitude current (depending on fault type and loading).

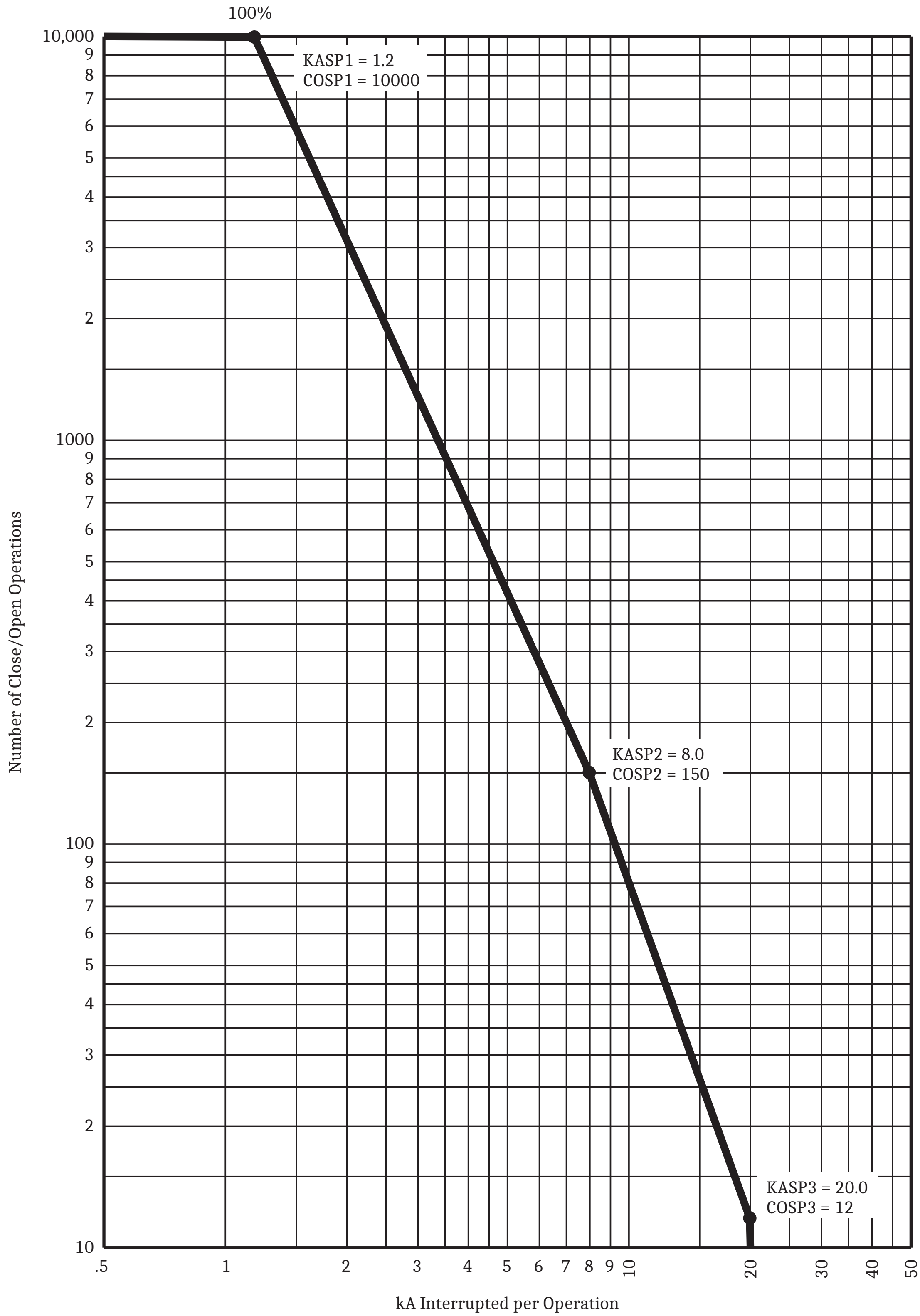

Figure 8.2 Breaker Maintenance Curve for a 25 kV Circuit Breaker

In *Figure 8.2*, note that the breaker maintenance curve levels off horizontally below set point KASP1, COSP1. This is the close/open operation limit of the circuit breaker (COSP1 = 10000), regardless of interrupted current value.

Also, note that the breaker maintenance curve falls vertically above set point KASP3, COSP3. This is the maximum interrupted current limit of the circuit breaker (KASP3 = 20.0 kA). If the interrupted current is greater than setting KASP3, the relay sets contact wear at 100 percent.

Operation of SELOGIC Control Equation Breaker Monitor Initiation Setting BKMON

The SELOGIC control equation breaker monitor initiation setting BKMON in *Table 8.2* determines when the breaker wear monitor reads in current values (Phases A, B, and C) for the breaker maintenance curve (see *Figure 8.2*) and the breaker monitor accumulated currents/trips (see **BRE *(Breaker Monitor Data)*** on page 10.37).

The BKMON setting looks for a rising edge (logical 0 to logical 1 transition) as the indication to read in current values. The acquired current values are then applied to the breaker maintenance curve and the breaker monitor accumulated currents/trips (see references in previous paragraph).

In the factory default settings, the SELOGIC control equation breaker monitor initiation setting is set:

BKMON = **TRIP** (TRIP is the logic output of *Figure 5.1*)

Refer to *Figure 8.3*. When BKMON asserts (Relay Word bit TRIP goes from logical 0 to logical 1), the breaker monitor reads in the current values and applies them to the breaker monitor maintenance curve and the breaker monitor accumulated currents/trips.

As detailed in *Figure 8.3*, the breaker monitor actually reads in the current values 1.5 cycles after the assertion of BKMON. This helps especially if an instantaneous trip occurs. The instantaneous element trips when the fault current reaches its pickup setting level. The fault current may still be “climbing” to its full value and then levels off. The 1.5-cycle delay on reading in the current values allows time for the fault current to level off.

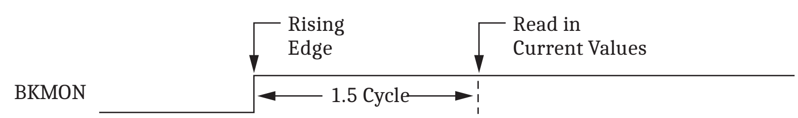

Figure 8.3 Operation of SELOGIC Control Equation Breaker Monitor Initiation Setting

See *Figure 8.10* and accompanying text for more information on setting BKMON. The operation of the breaker monitor maintenance curve, when new current values are read in, is explained in the following example.

Breaker Wear Monitor Operation Example

As stated earlier, each phase (A, B, and C) has its own breaker maintenance curve. For this example, presume that the interrupted current values occur on a single phase in *Figure 8.4–Figure 8.7*. Also, presume that the circuit breaker interrupting contacts have no wear at first (brand new or recent maintenance performed).

Note in the following four figures (*Figure 8.4–Figure 8.7*) that the interrupted current in a given figure is the same magnitude for all the interruptions (e.g., in *Figure 8.5*, 2.5 kA is interrupted 290 times). This is not realistic, but helps in demonstrating the operation of the breaker maintenance curve and how it integrates for varying current levels.

0 Percent to 10 Percent Breaker Wear

Refer to *Figure 8.4*. 7.0 kA is interrupted 20 times (20 close/open operations = 20 – 0), pushing the breaker maintenance curve from the 0 percent wear level to the 10 percent wear level.

Compare the 100 percent and 10 percent curves and note that for a given current value, the 10 percent curve has only 1/10 of the close/open operations of the 100 percent curve.

10 Percent to 25 Percent Breaker Wear

Refer to *Figure 8.5*. The current value changes from 7.0 kA to 2.5 kA. 2.5 kA is interrupted 290 times (290 close/open operations = 480 – 190), pushing the breaker maintenance curve from the 10 percent wear level to the 25 percent wear level.

Compare the 100 percent and 25 percent curves and note that for a given current value, the 25 percent curve has only 1/4 of the close/open operations of the 100 percent curve.

25 Percent to 50 Percent Breaker Wear

Refer to *Figure 8.6*. The current value changes from 2.5 kA to 12.0 kA. 12.0 kA is interrupted 11 times (11 close/open operations = 24 – 13), pushing the breaker maintenance curve from the 25 percent wear level to the 50 percent wear level.

Compare the 100 percent and 50 percent curves and note that for a given current value, the 50 percent curve has only 1/2 of the close/open operations of the 100 percent curve.

50 Percent to 100 Percent Breaker Wear

Refer to *Figure 8.7*. The current value changes from 12.0 kA to 1.5 kA. 1.5 kA is interrupted 3000 times (3000 close/open operations = 6000 – 3000), pushing the breaker maintenance curve from the 50 percent wear level to the 100 percent wear level.

When the breaker maintenance curve reaches 100 percent for a particular phase, the percentage wear remains at 100 percent (even if additional current is interrupted), until reset by the **BRE R** command (see *View or Reset Breaker Monitor Information* on page 8.14). But the current and trip counts continue to be accumulated, until reset by the **BRE R** command.

Additionally, logic outputs assert for alarm or other control applications—see the following discussion.

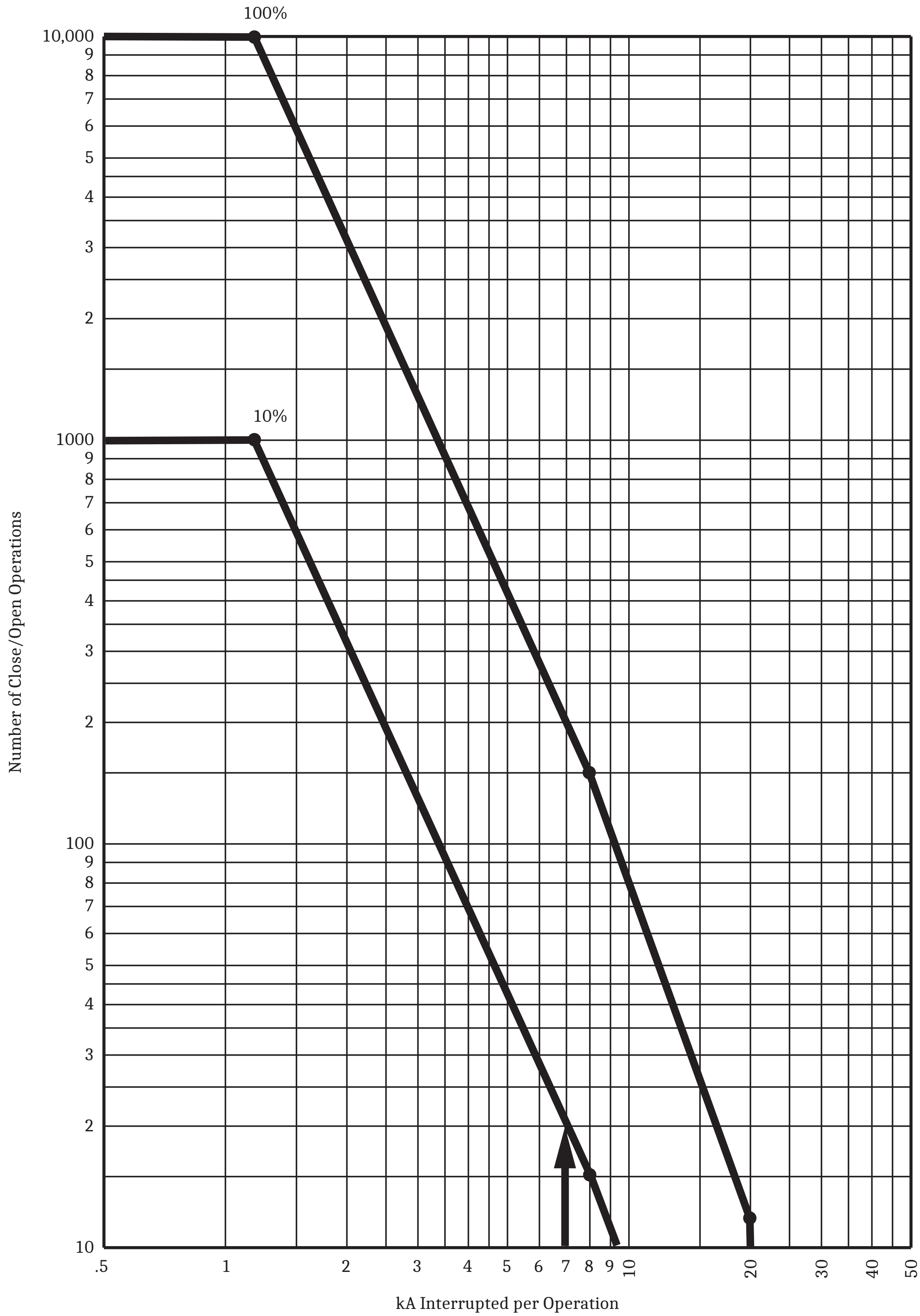

Figure 8.4 Breaker Monitor Accumulates 10 Percent Wear

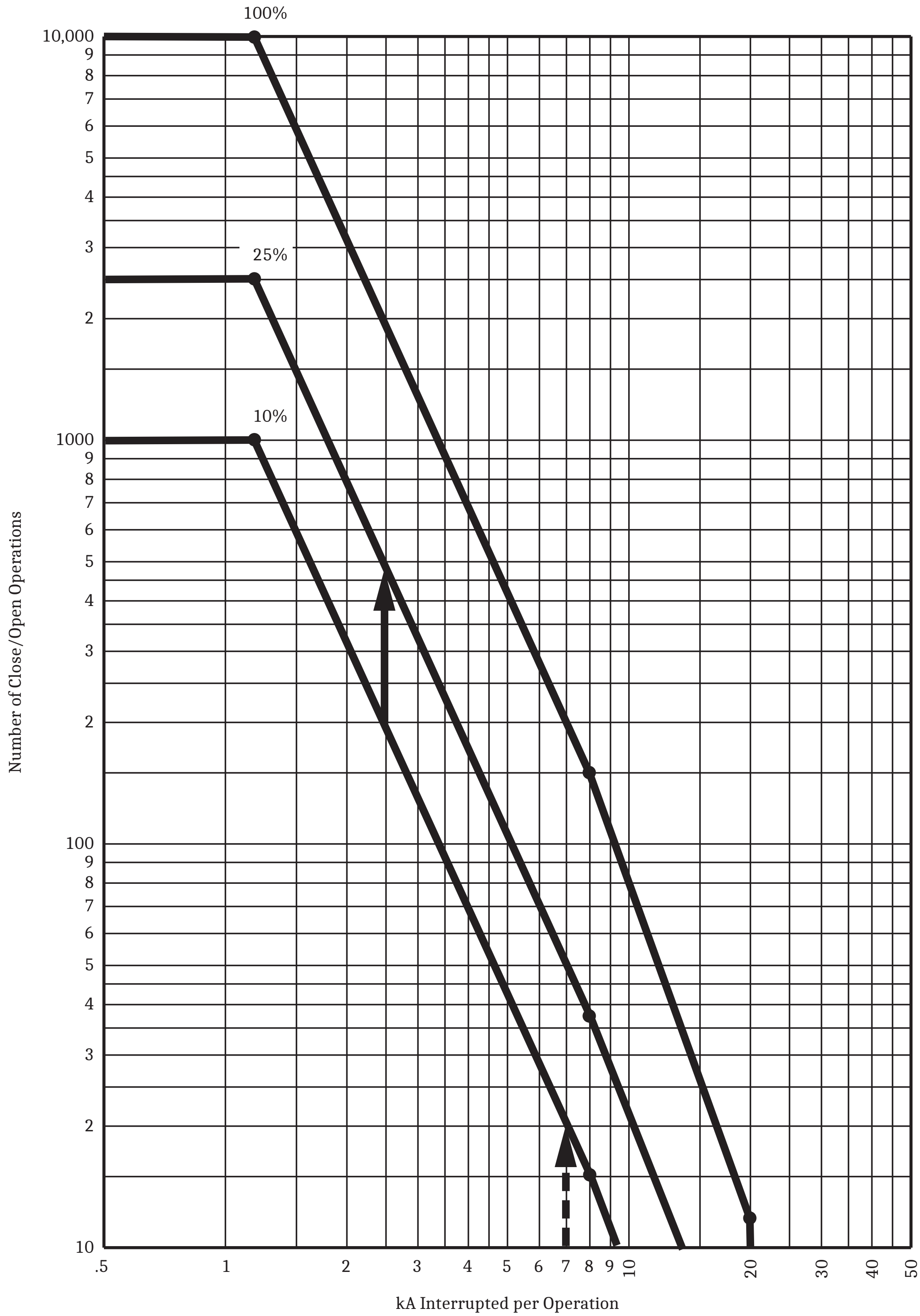

Figure 8.5 Breaker Monitor Accumulates 25 Percent Wear

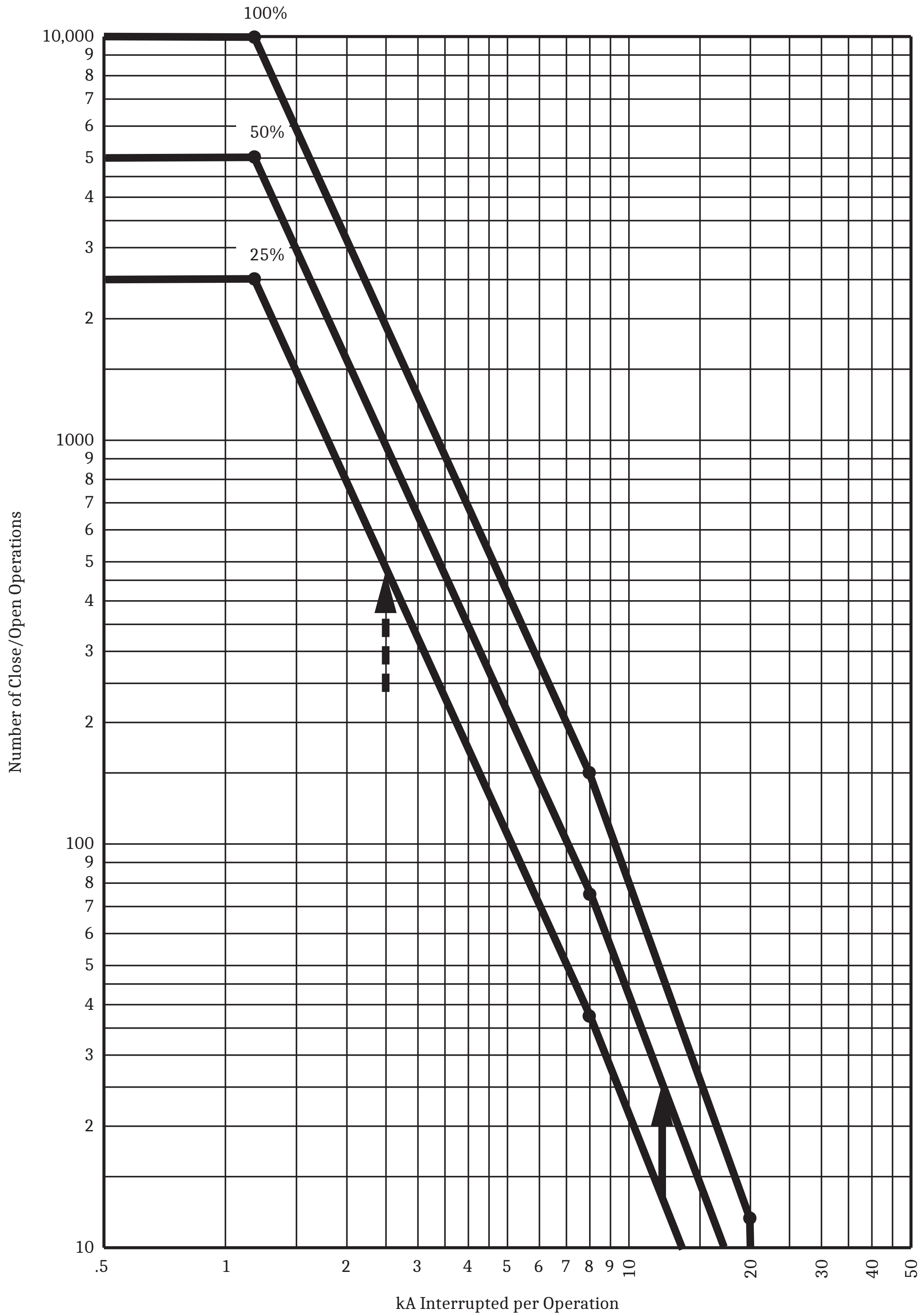

Figure 8.6 Breaker Monitor Accumulates 50 Percent Wear

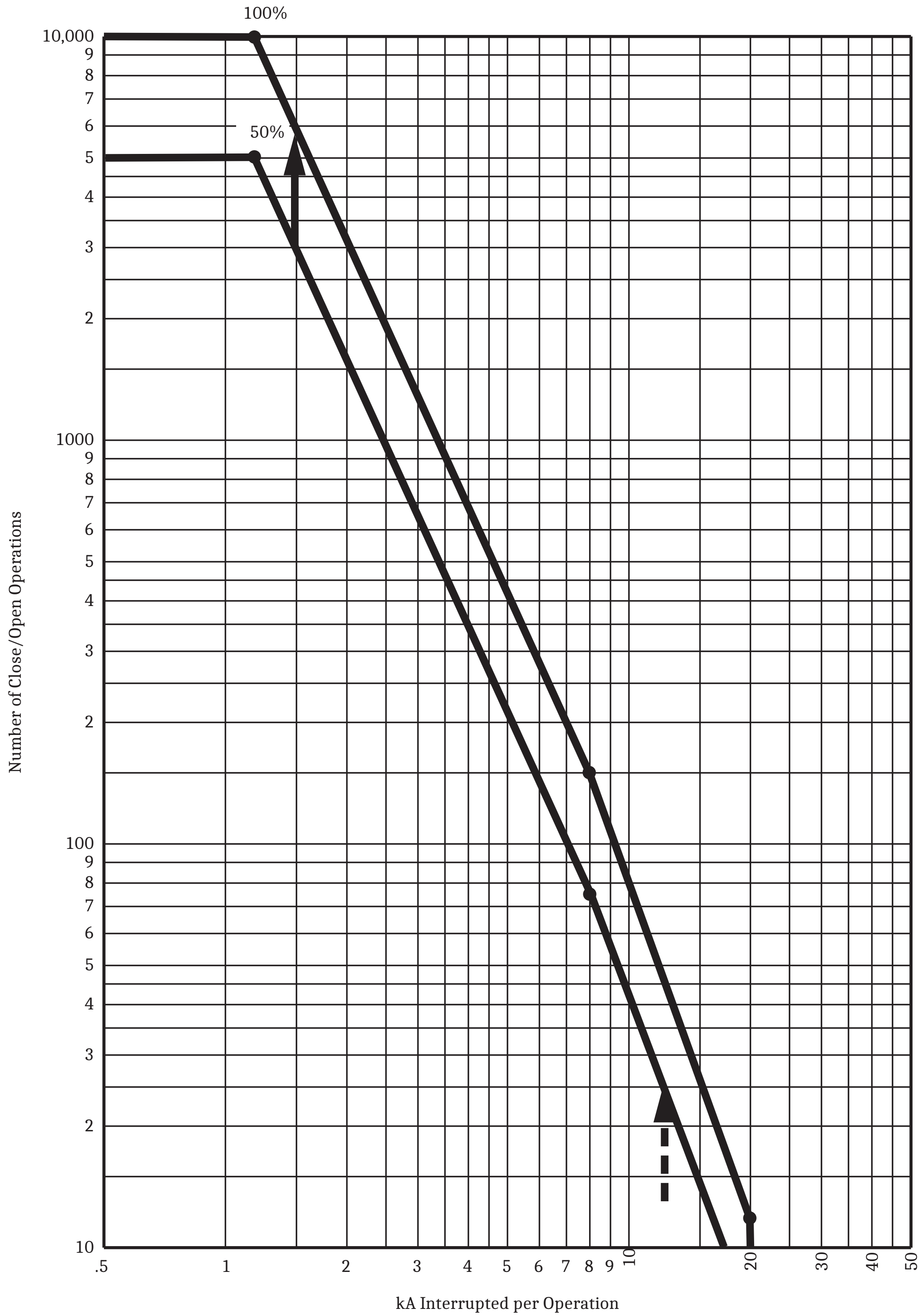

Figure 8.7 Breaker Monitor Accumulates 100 Percent Wear

Breaker Wear Monitor Output

When the breaker maintenance curve for a particular phase (A, B, or C) reaches the 100 percent wear level (see *Figure 8.7*), a corresponding Relay Word bit (BCWA, BCWB, or BCWC) asserts.

Relay Word Bits	Definition
BCWA	Phase A breaker contact wear has reached the 100 percent wear level
BCWB	Phase B breaker contact wear has reached the 100 percent wear level
BCWC	Phase C breaker contact wear has reached the 100 percent wear level
BCW	BCWA + BCWB + BCWC

Example Applications

These logic outputs can be used to alarm:

OUT105 = **BCW**

or drive the relay to lockout the next time the relay trips:

79DTL = **TRIP * BCW**

Mechanical and Electrical Operate Timers and Alarms

Mechanical Operate Time

The mechanical operating time is the time between trip or close initiation and the change of status of the circuit breaker status contact. The relay determines the mechanical trip time for the breaker by measuring the time elapsed between the assertion of SELOGIC control equation BKMON and the deassertion of Relay Word bit 52A. The relay determines the mechanical close time for the breaker by measuring the time elapsed from the assertion of SELOGIC control equation BKCLS to the assertion of Relay Word bit 52A. The relay compares the trip and close time to the mechanical slow operation time thresholds for tripping and closing, Global settings MSTRT and MSCLT, respectively. If the trip or close time exceeds its threshold, Relay Word bit MSCL (close) or MSTR (trip) pulses for 1/4 cycle, which asserts the mechanical slow operation alarm Relay Word bit, MSOAL, for five seconds. The mechanical operation time alarm counter also increments.

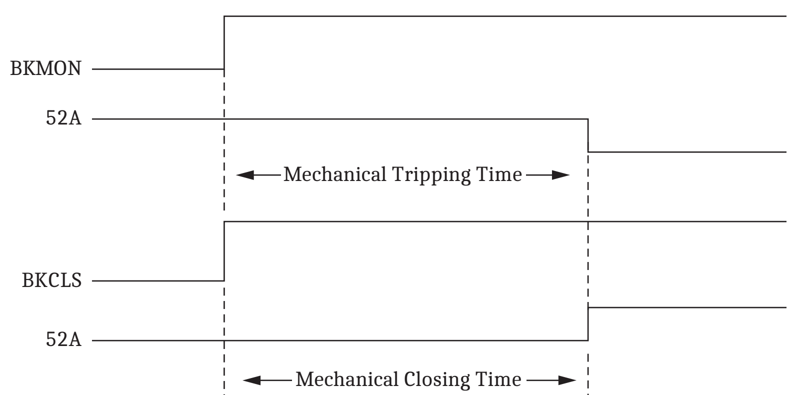

Figure 8.8 Mechanical Operating Time

Electrical Operate Time

NOTE: Open pole detection logic in the SEL-351 differs from that used in other products, such as the SEL-451. As a result, electrical operating times calculated by these relays may differ slightly.

The electrical operating time is the time between trip or close initiation and the change of status of the open pole detection logic. The relay determines the electrical trip time for each breaker pole by measuring the time elapsed between the assertion of SELOGIC control equation BKMON and the assertion of the open pole detection logic. The relay determines the electrical close time for each breaker pole by measuring the time elapsed from the assertion of SELOGIC control equation BKCLS to the de-assertion of the open pole detection logic. The relay compares the trip and close time to the electrical slow operation time thresholds for tripping and closing, Global settings ESTRT and ESCLT, respectively. If the trip or close time exceeds the threshold for a particular phase, the corresponding Relay Word bit ESTRA, ESTRB, or ESTRC for trip or ESCLA, ESCLB, or ESCLC for close pulses for 1/4 cycle, which asserts the electrical slow operation alarm Relay Word bit, ESOAL, for five seconds. The electrical operation time alarm counter also increments.

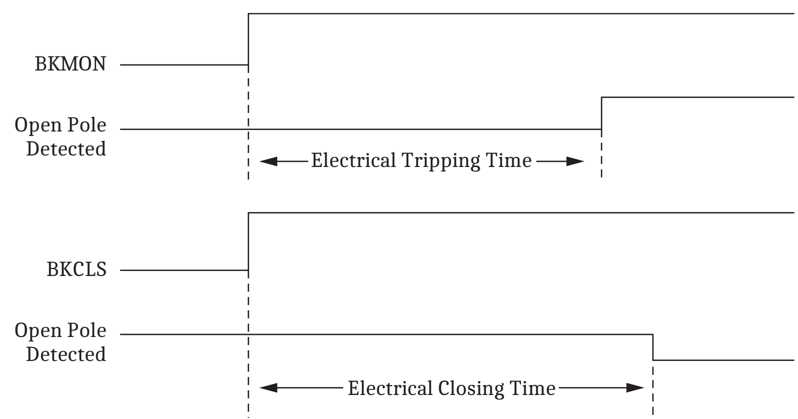

Figure 8.9 Electrical Operating Time

Breaker Operation Reporting

After each trip or close operation, the relay stores the mechanical and electrical operate time. If this time does not exceed the slow operating time threshold, the new operate time is combined with previous data to calculate the average operating time. If the time exceeds the threshold, a plus sign (+) is appended to indicate the slow operation. If the time exceeds the threshold by more than 100 milliseconds, timing is stopped. This information can be viewed with the **BRE** command. See **BRE** ***(Breaker Monitor Data)*** on page 10.37.

NOTE: Trip and close initiations are independent of one another, so back-to-back events only occur when the relay receives two trip or two close initiations.

If the relay detects back-to-back breaker operations and the first event has not finished before the second event starts, the relay displays all incomplete information as 0.00. The relay excludes operate times displayed as 0.00 from the average.

When Global setting DCLOP is set to a numerical value, the relay stores the minimum voltage measured by the DC Voltage monitor function (see *Station DC Battery Monitor* on page 8.17 for details) during a 20-cycle period after BKMON asserts or during a 30-cycle period after BKCLS asserts.

View or Reset Breaker Monitor Information

Accumulated breaker wear/operations and operating time data are retained if the relay loses power or the breaker monitor is disabled (setting EBMON = N). The accumulated data can only be reset if the **BRE R** command is executed (see the following discussion on the **BRE R** command).

Via Serial Port

See **BRE *(Breaker Monitor Data)*** on page 10.37. The **BRE** command displays the following information:

- ➤ Accumulated number of relay initiated trips
- ➤ Accumulated interrupted current from relay initiated trips
- ➤ Accumulated number of externally initiated trips
- ➤ Accumulated interrupted current from externally initiated trips
- ➤ Percent circuit breaker contact wear for each phase
- ➤ Mechanical operate time data
- ➤ Electrical operate time data
- ➤ Date when the preceding items were last reset (via the **BRE R** command)

See **BRE *n (Preload/Reset Breaker Wear)*** on page 10.38. The **BRE W** command allows the trip counters, accumulated values, and percent breaker wear to be preloaded for each individual phase.

The **BRE H** command displays the following information for as many as 128 operations:

- ➤ Date and time of relay operation
- ➤ Type of operation (trip/close)
- ➤ Mechanical operate time
- ➤ Electrical operate time
- ➤ Interrupted current for trip operations (measured 1.5 cycles after BKMON asserts)
- ➤ Minimum dc voltage

The **BRE R** command resets the accumulated values, operating time data, and the percent wear for all three phases, and clears the events in the **BRE H** command. For example, if breaker contact wear has reached the 100 percent wear level for A-phase, the corresponding Relay Word bit BCWA asserts (BCWA = logical 1). Execution of the **BRE R** command resets the wear levels for all three phases back to 0 percent and consequently causes Relay Word bit BCWA to deassert (BCWA = logical 0).

Via Front Panel

The information available via the **BRE** command is also available via the front-panel **OTHER** pushbutton, with the exception of the electrical and mechanical operate times and the minimum dc voltage. All breaker monitor data can be reset via the front-panel **OTHER** pushbutton. See *Figure 11.3*.

Via DNP or Modbus

The internal and external trip counters, breaker wear data, electrical and mechanical alarm counters, and the average electrical and mechanical trip and close times are available via DNP and Modbus. See the Breaker Monitor section of *Table E.1*.

The DNP binary output DRST_BK can be used to reset the breaker monitor data, and is similar in function to the **BRE R** command. See *Appendix L: DNP3 Communications* for more details.

The Modbus protocol can be used to reset the breaker monitor data, and is similar in function to the **BRE R** command. There are two methods available:

- ➤ Writing to the Reset Breaker Monitor output coil.
- ➤ Writing a specific analog value to the RSTDAT register.

See *Appendix O: Modbus RTU and TCP Communications* for details.

Via IEC 61850

Selected breaker monitor data are available via IEC 61850. See the Breaker Monitor section of *Table E.1*.

Via File Transfer

The BRE and BRE H reports are also available via file transfer protocols. See *Virtual File Interface* on page 10.26.

Reset Via SELOGIC Control Equation

The RST_BK SELOGIC control equation setting can be used to reset the breaker monitor data, similar in function to the **BRE R** command. The relay resets the function when the setting first asserts (rising edge, e.g., a logical 0 to a logical 1 transition). For an example of how to use the RST_BK setting, see the similar function *View or Reset Energy Metering Information* on page 8.37.

Determination of Relay Initiated Trips and Externally Initiated Trips

See **BRE *(Breaker Monitor Data)*** on page 10.37. Note in the **BRE** command response that the accumulated number of trips and accumulated interrupted current are separated into two groups of data: that generated by *relay initiated trips* (Rly Trips) and that generated by *externally initiated trips* (Ext Trips). The categorization of these data is determined by the status of the TRIP Relay Word bit when the SELOGIC control equation breaker monitor initiation setting BKMON operates.

Refer to *Figure 8.3* and accompanying explanation. If BKMON newly asserts (logical 0 to logical 1 transition), the relay reads in the current values (A-, B-, and C-Phases). Now the decision has to be made: where is this current and trip count information accumulated? Under *relay initiated trips* or *externally initiated trips*?

To make this determination, the status of the TRIP Relay Word bit is checked at the instant BKMON newly asserts (TRIP is the logic output of *Figure 5.1*). If TRIP is asserted (TRIP = logical 1), the current and trip count information is accumulated under *relay initiated trips* (Rly Trips). If TRIP is deasserted (TRIP = logical 0), the current and trip count information is accumulated under *externally initiated trips* (Ext Trips).

Regardless of whether the current and trip count information is accumulated under relay initiated trips or externally initiated trips, this same information is routed to the breaker maintenance curve for continued breaker wear integration (see *Figure 8.4–Figure 8.7*).

Relay initiated trips (Rly Trips) are also referred to as *internally initiated trips* (Int Trips) in the course of this manual; the terms are interchangeable.

Factory Default Setting Example

As discussed previously, the SELOGIC control equation breaker monitor initiation factory default setting is:

BKMON = **TRIP**

Thus, any new assertion of BKMON will be deemed a relay trip, and the current and trip count information is accumulated under *relay initiated trips* (Rly Trips).

Additional Example

Refer to *Figure 8.10*. Output contact OUT101 is set to provide tripping:

OUT101 = **TRIP**

Note that optoisolated input IN106 monitors the trip bus. If the trip bus is energized by output contact OUT101, an external control switch, or some other external trip, then IN106 is asserted.

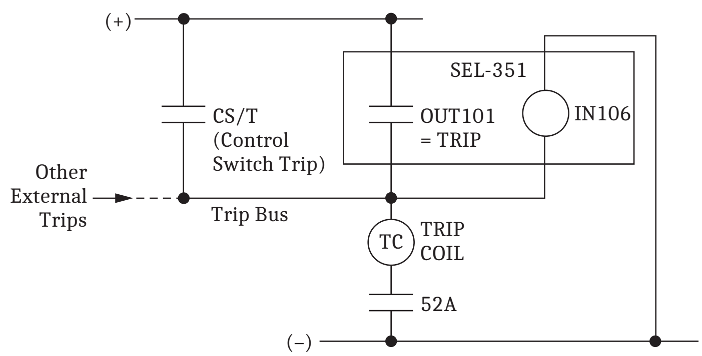

Figure 8.10 Input IN106 Connected to Trip Bus for Breaker Monitor Initiation

If the SELOGIC control equation breaker monitor initiation setting is set:

BKMON = **IN106**

then the SEL-351 breaker monitor sees all trips.

If output contact OUT101 asserts, energizing the trip bus, the breaker monitor will deem it a *relay initiated trip*. This is because when BKMON is newly asserted (input IN106 energized), the TRIP Relay Word bit is asserted. Thus, the current and trip count information is accumulated under *relay initiated trips* (Rly Trips).

If the control switch trip (or some other external trip) asserts, energizing the trip bus, the breaker monitor will deem it an *externally initiated trip*. This is because when BKMON is newly asserted (input IN106 energized), the TRIP Relay Word bit is deasserted. Thus, the current and trip count information is accumulated under *externally initiated trips* (Ext Trips).

Station DC Battery Monitor

The station dc battery monitor in the SEL-351 can alarm for under- or overvoltage dc battery conditions and give a view of how much the station dc battery voltage dips when tripping, closing, and other dc control functions take place. The monitor measures the station dc battery voltage applied to the rear-panel terminals labeled **POWER** (see *Figure 2.2* through *Figure 2.6*). The station dc battery monitor settings (DCLOP and DCHIP) are available via the **SET G** command (see *Table 9.2* and also *Station DC Battery Monitor (see Figure 8.11 and Figure 8.12)* on page SET.2).

DC Under- and Overvoltage Elements

Refer to *Figure 8.11*. The station dc battery monitor compares the measured station battery voltage (Vdc) to the undervoltage (low) and overvoltage (high) pickups DCLOP and DCHIP. The setting range for pickup settings DCLOP and DCHIP is:

20 to 300 Vdc, 0.02 Vdc increments

This range allows the SEL-351 to monitor nominal battery voltages of 24, 48, 110, 125, 220, and 250 V. When testing the pickup settings DCLOP and DCHIP, *do not* operate the SEL-351 outside of its power supply limits. See the Specifications subsection *General* on page 1.4 for the various power supply specifications. The power supply rating is located on the serial number sticker on the relay rear panel.

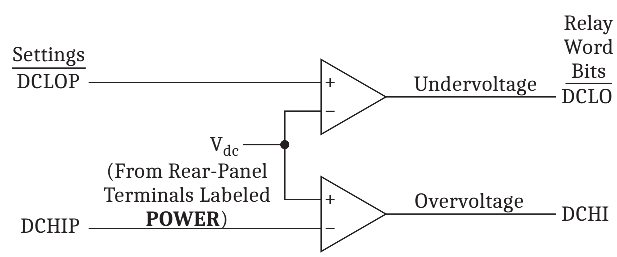

Figure 8.11 DC Under- and Overvoltage Elements

Logic outputs DCLO and DCHI in *Figure 8.11* operate as follows:

DCLO = 1 (logical 1), if $V_{dc} \le$ pickup setting DCLOP
= 0 (logical 0), if $V_{dc} >$ pickup setting DCLOP
DCHI = 1 (logical 1), if $V_{dc} \ge$ pickup setting DCHIP
= 0 (logical 0), if $V_{dc} <$ pickup setting DCHIP

Create Desired Logic for DC Under- and Overvoltage Alarming

Pickup settings DCLOP and DCHIP are set independently. Thus, they can be set:

DCLOP < DCHIP or DCLOP > DCHIP

Figure 8.12 shows the resultant dc voltage elements that can be created with SELOGIC control equations for these two setting cases. In these two examples, the resultant dc voltage elements are time-qualified by timer SV4T and then routed to output contact **OUT106** for alarm purposes.

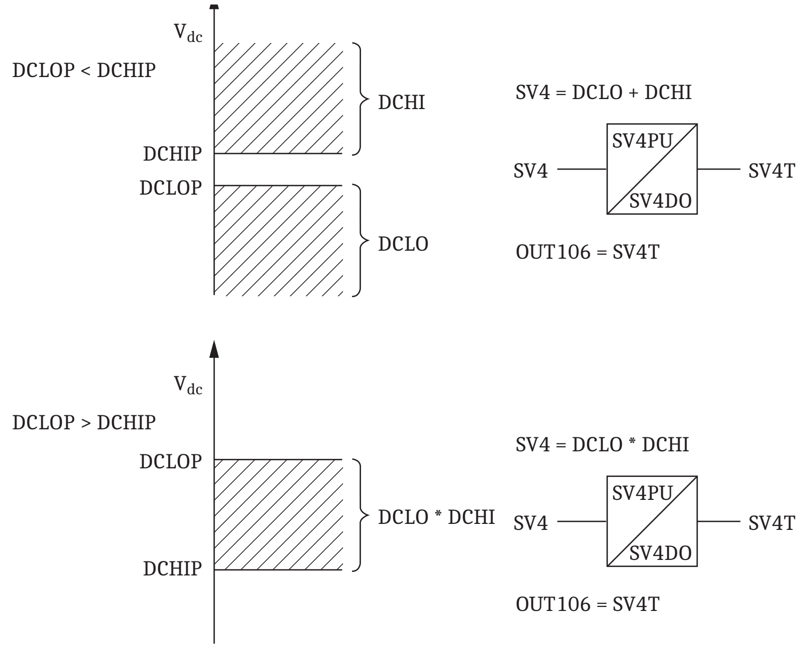

Figure 8.12 Create DC Voltage Elements With SELOGIC Control Equations

DCLO < DCHI (Top of *Figure 8.12*)

Output contact **OUT106** asserts when:

$V_{dc} \leq$ DCLOP or $V_{dc} \geq$ DCHIP

Pickup settings DCLOP and DCHIP are set such that output contact **OUT106** asserts when dc battery voltage goes below or above allowable limits.

If the relay loses power entirely (V_{dc} = 0 Vdc)

V_{dc} = < DCLOP

then output contact **OUT106** should logically assert (according to top of *Figure 8.12*), but cannot because of the total loss of power (all output contacts deassert on total loss of power). Thus, the resultant dc voltage element at the bottom of *Figure 8.12* would probably be a better choice—see following discussion.

DCLO > DCHI (Bottom of *Figure 8.12*)

Output contact **OUT106** asserts when:

DCHIP $\leq V_{dc} \leq$ DCLOP

Pickup settings DCLOP and DCHIP are set such that output contact **OUT106** asserts when dc battery voltage stays between allowable limits.

If the relay loses power entirely (V_{dc} = 0 Vdc)

V_{dc} = < DCHIP

then output contact **OUT106** should logically deassert (according to bottom of *Figure 8.12*), and this is surely what happens for a total loss of power (all output contacts deassert on total loss of power).

Output Contact Type Considerations (a or b)

Refer to *Output Contacts* on page 7.33 (especially *Note 2* in *Figure 7.29*). Consider the output contact type (a or b) needed for output contact **OUT106** in the bottom of *Figure 8.12* (dc voltage alarm example).

If SELOGIC control equation setting OUT106 is asserted (OUT106 = SV4T = logical 1; dc voltage OK), the state of output contact **OUT106** (according to contact type) is:

- closed (a-type output contact)
- open (b-type output contact)

If SELOGIC control equation setting OUT106 is deasserted (OUT106 = SV4T = logical 0; dc voltage *not* OK), the state of output contact **OUT106** (according to contact type) is:

- open (a-type output contact)
- closed (b-type output contact)

If the relay loses power entirely, all output contacts deassert, and the state of output contact **OUT106** (according to contact type) is:

- open (a-type output contact)
- closed (b-type output contact)

Additional Application

Other than alarming, the dc voltage elements can be used to disable reclosing.

For example, if the station dc batteries have a problem and the station dc battery voltage is declining, drive the reclosing relay to lockout:

79DTL = **!SV4T + ...** [= NOT(SV4T) + ...]

Timer output SV4T is from the bottom of *Figure 8.12*. When dc voltage falls below pickup DCHIP, timer output SV4T drops out (= logical 0), driving the relay to lockout:

79DTL = **!SV4T + ...** = NOT(SV4T) + ... = NOT(logical 0) + ... = logical 1

Circuit breaker tripping and closing requires station dc battery energy. If the station dc batteries are having a problem and the station dc battery voltage is declining, the relay should not reclose after a trip because there might not be enough dc battery energy to trip a second time after a reclose.

View Station DC Battery Voltage

Via Serial Port

See **MET *(Metering Data)*** on page 10.55. The **MET** command displays the station dc battery voltage (labeled VDC).

Via Front Panel

The information available via the previously discussed **MET** serial port command is also available via the front-panel **METER** pushbutton. See *Figure 11.3*.

Via Fast Meter, DNP, Modbus, or IEC 61850

The station dc battery voltage reading VDC is available via Fast Meter, DNP, Modbus, and IEC 61850. See the Instantaneous Metering section of *Table E.1*.

Via File Transfer

The station dc battery voltage reading VDC is available via file transfer protocols within various metering reports. See *Virtual File Interface* on page 10.26.

Analyze Station DC Battery Voltage

See *Standard 15/30/60-Cycle Event Reports* on page 12.3. The station dc battery voltage is displayed in column `Vdc` in the example event report in *Figure 12.7*. Changes in station dc battery voltage for an event (e.g., circuit breaker tripping) can be observed. Use the **EVE** command to retrieve event reports as discussed in *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*.

Station DC Battery Voltage Dips During Circuit Breaker Tripping

Event reports are automatically generated when the TRIP Relay Word bit asserts (TRIP is the logic output of *Figure 5.1*). For example, output contact **OUT101** is set to trip:

OUT101 = **TRIP**

Anytime output contact **OUT101** closes and energizes the circuit breaker trip coil. Any dip in station dc battery voltage can be observed in column `Vdc` in the event report.

To generate an event report for external trips, make connections similar to *Figure 8.10* and program optoisolated input **IN106** (monitoring the trip bus) in the SELOGIC control equation event report generation setting, e.g.,

ER = **/IN106 + ...**

Any time the trip bus is energized, any dip in station dc battery voltage can be observed in column `Vdc` in the event report.

Station DC Battery Voltage Dips During Circuit Breaker Closing

To generate an event report when the SEL-351 closes the circuit breaker, make the SELOGIC control equation event report generation setting:

ER = **/OUT102 + ...**

NOTE: The **BRE** and **BRE H** commands display the minimum dc voltage recorded by the breaker monitor when the breaker trips or closes.

In this example, output contact **OUT102** is set to close:

OUT102 = **CLOSE** (CLOSE is the logic output of *Figure 6.2*)

Anytime output contact **OUT102** closes and energizes the circuit breaker close coil, any dip in station dc battery voltage can be observed in column `Vdc` in the event report.

This event report generation setting (ER = /OUT102 + ...) might be made just as a testing setting. Generate several event reports when doing circuit breaker close testing and observe the “signature” of the station dc battery voltage in column `Vdc` in the event reports.

Station DC Battery Voltage Dips Anytime

To generate an event report anytime there is a station dc battery voltage dip, set the dc voltage element directly in the SELOGIC control equation event report generation setting:

ER = **\SV4T + ...**

Timer output SV4T is an example dc voltage element from the bottom of *Figure 8.12*. Anytime dc voltage falls below pickup DCHIP, timer output SV4T drops out (logical 1 to logical 0 transition), creating a falling-edge condition that generates an event report.

Also, the Sequential Event Recorder (SER) report can be used to time-tag station dc battery voltage dips (see *Sequential Events Recorder (SER) Report* on page 12.31).

Operation of Station DC Battery Monitor When AC Voltage Is Powering the Relay

If the SEL-351 has a power supply that can be powered by ac voltage, when powering the relay with ac voltage, the dc voltage elements in *Figure 8.11* see the *average* of the sampled ac voltage powering the relay, which is very near zero volts (as displayed in column `Vdc` in event reports). Thus, pickup settings DCLOP and DCHIP should be set off (DCLOP = OFF, DCHIP = OFF). They are of no real use.

If a "raw" event report is displayed (with the **EVE R** command), column `Vdc` will display the sampled ac voltage waveform, rather than the average.

Fundamental (Instantaneous) Metering

The SEL-351 performs current, voltage, symmetrical component, and power metering using the fundamental (filtered) signals obtained from the same cosine filter that is used in the protective relay algorithms. These values respond to the fundamental signal at the measured system frequency, which is usually near 50 Hz or 60 Hz. Frequency tracking ensures that frequency variations do not adversely affect metering accuracy.

The fundamental metering function updates the metering values approximately twice per second.

The relay converts the metered values to primary units using the current transformer ratio Group settings CTR and CTRN, and potential transformer ratio Group settings PTR and PTRS.

The metered values are available through several interfaces:

- Serial port ASCII communications; see **MET *(Metering Data)*** on page 10.55
- Serial port Fast Meter communications; see *Appendix J: Configuration, Fast Meter, and Fast Operate Commands*
- DNP (Serial Port or Ethernet); see *Appendix L: DNP3 Communications*
- Modbus (Serial Port or Ethernet); see *Appendix O: Modbus RTU and TCP Communications*

- Front-panel LCD; see *Front-Panel Pushbutton Operation* on page 11.1
- Display points; see *Displaying Analog Values on the Rotating Display* on page 7.44
- Load Profile Recorder; see *Load Profile Report (Available in Firmware Versions 6 and 7)* on page 8.45

See *Specifications* on page 1.4 for a listing of the fundamental metering accuracy in the SEL-351.

The relay applies a small-signal cutoff threshold to the voltage and current signals, and this can affect subsequent uses of the measurement. See *Small Signal Cutoff for Metering* on page 8.41 for more details.

These fundamental quantities are used in the Instantaneous Metering quantities, as well as the Demand/Peak Demand, Energy, and Maximum/Minimum Metering functions, described later in this section.

Because the fundamental quantities are filtered to the power system frequency, they are immune to signal energy at dc and harmonic frequencies.

Wye-, Delta-, and Single-Phase Voltage Connections for Metering

Description

The SEL-351 supports metering from the following PT connections:

- Three-phase voltage connection from wye-connected Potential Transformers (PTs)
- Three-phase voltage connection from open-delta connected PTs
- Single-phase voltage connection from a line-neutral connected PT
- Single-phase voltage connection from a line-to-line connected PT
- No voltage connection to **VA**, **VB**, **VC** terminals
- Synchronism check or broken-delta 3V0 PT voltage connection to **VS-NS** terminals.

See *Potential Transformer Inputs* on page 2.11 for terminal designations and wiring details.

The PT selection (except for the VS terminal) is made via Global setting PTCONN = WYE, DELTA, or SINGLE, and is fully described in *Settings for Voltage Input Configuration* on page 9.18.

NOTE: Harmonic metering functions are discussed separately—see *Global Setting PTCONN Effect on Harmonic Metering* on page 8.44.

When either of the three-phase connections (wye or delta) is selected, the relay automatically configures the metering functions to calculate and display the quantities as listed in *Table 8.3*.

When a single-phase voltage connection is selected, the relay can be configured to create “phantom” voltage values for the missing phases. An additional Global setting PHAN TV designates which phase is connected to the relay. *Table 8.3* lists the metering functions available for the single-phase connection option. See *Phantom Metering for Single-Phase Voltage Connections* on page 8.24 for a full discussion.

When no voltage signals are connected to the relay, the metering system only provides current measurement capabilities, with all voltage, power, and energy values reported as 0.00, and the frequency reported as 50.00 or 60.00 Hz, matching the Global nominal frequency setting NFREQ.

The synchronism check or broken-delta PT connection is selected by Global setting VSCONN = VS or 3V0, respectively, and is fully discussed in *Settings for Voltage Input Configuration* on page 9.18. The only instance that this setting affects metering is when PTCONN = DELTA and VSCONN = 3V0, and in this situation the broken-delta signal is used in the three-phase power calculations, as shown in *Table 9.8*.

Metering Quantities Available for Various Voltage Connections

The SEL-351 metering output values are available as Analog Quantities, and a full listing appears in *Table E.1*.

Use *Table 8.3* to identify which metering outputs are available for each voltage input configuration. To make *Table 8.3* easier to read, the Analog Quantity names are not fully listed for the Demand, Peak Demand, Energy and Maximum/Minimum Metering functions. The full names appear in *Table E.1* under the appropriate table section.

Table 8.3 Fundamental Metering Quantities Available for Various PTCONN Settings (Sheet 1 of 2)

Global Settings	Currents[a]	Voltages[a]	Power	Demand and Peak Demand IN and OUT[b]	Energy IN and OUT[b]	Maximum/ Minimum
Command:	**MET**	**MET**	**MET**	**MET D**	**MET E**	**MET M**
PTCONN = WYE	IA, IB, IC, IN, IG, I1, 3I2, 3I0	VA, VB, VC, VS, V1, V2, 3V0, VAB[c], VBC[c], VCA[c]	MWA, MWB, MWC, MW3, MVARA, MVARB, MVARC, MVAR3, PFA, PFB, PFC, PF3	IA, IB, IC, IN, IG, 3I2, MWA, MWB, MWC, MW3, MVARA, MVARB, MVARC, MVAR3	MWHA, MWHB, MWHC, MWH3, MVRHA, MVRHB, MVRHC, MVRH3	IA, IB, IC, IN, IG, VA, VB, VC, VS, MW3, MVAR3
PTCONN = DELTA	IA, IB, IC, IN, IG, I1, 3I2, 3I0	VAB, VBC, VCA, VS, V1, V2	MW3, MVAR3, PF3	IA, IB, IC, IN, IG, 3I2, MW3, MVAR3	MWH3, MVRH3	IA, IB, IC, IN, IG, VAB, VBC, VCA, VS, MW3, MVAR3

Table 8.3 Fundamental Metering Quantities Available for Various PTCONN Settings (Sheet 2 of 2)

Global Settings Command:	Currents[a] MET	Voltages[a] MET	Power MET	Demand and Peak Demand IN and OUT[b] MET D	Energy IN and OUT[b] MET E	Maximum/ Minimum MET M
PTCONN = SINGLE and PHANTV = VA, VB, VC, VAB, VBC, or VCA	IA, IB, IC, IN, IG, I1, 3I2, 3I0	VA[d], VB[d], VC[d], VS, VAB[c, d], VBC[c, d], VCA[c, d] (V1, V2, 3V0 forced to 0.00)	MWA, MWB, MWC, MW3, MVARA, MVARB, MVARC, MVAR3, PFA, PFB, PFC, PF3	IA, IB, IC, IN, IG, 3I2, MWA, MWB, MWC, MW3, MVARA, MVARB, MVARC, MVAR3	MWHA, MWHB, MWHC, MWH3, MVRHA, MVRHB, MVRHC, MVRH3	IA, IB, IC, IN, IG, VA, VB, VC, VS, MW3, MVAR3
PTCONN = SINGLE and PHANTV = OFF	IA, IB, IC, IN, IG, I1, 3I2, 3I0	VA[e], VB[e], VC[e], VS, VAB[c, e], VBC[c, e], VCA[c, e] (V1, V2, 3V0 forced to 0.00)	None (MWA, MWB, MWC, MW3, MVARA, MVARB, MVARC, MVAR3, PFA, PFB, PFC, PF3 forced to 0.00)	IA, IB, IC, IN, IG, 3I2 (MWA, MWB, MWC, MW3, MVARA, MVARB, MVARC, MVAR3 forced to 0.00)	None (MWHA, MWHB, MWHC, MWH3, MVRHA, MVRHB, MVRHC, MVRH3 forced to 0.00)	IA, IB, IC, IN, IG, VA[e], VB[e], VC[e], VS (MW3, MVAR3 forced to 0.00)

[a] For clarity, the corresponding angle quantities are not shown in table (e.g., IAFA, VBFA, etc.)
[b] For clarity, not all values are shown. See *Table E.1* for a complete listing and proper Analog Quantity labels.
[c] Available via **MET X** command.
[d] Balanced three-phase voltage quantities are created from the single-phase voltage connected to the VA-N terminal. Magnitudes VA = VB = VC, angles = 0, –120, 120 or 0, 120, –120, depending on phase rotation setting PHROT = ABC or ACB.
[e] Values reported are based on terminal readings. The phase designations are correct only if VA is connected to VA-N, VB is connected VB-N, VC is connected VC-N.

Phantom Metering for Single-Phase Voltage Connections

For power systems that operate in a nearly balanced state, the system voltage magnitudes are closely matched, and the voltage phase angles are nearly symmetric, displaced 120 degrees from each other. If only one potential signal is available, it is possible to establish a set of three voltage signals from the supplied signal. These so called “phantom phases” are representative of the expected power system voltages when the power system is in a balanced state.

Phantom Voltage Function

When Global setting PTCONN = SINGLE, a phantom setting allows three-phase voltages to be generated from a single metered quantity, and the power and energy quantities to be calculated from the generated voltages. The single-phase voltage must be connected to terminal **VA-N**.

Global setting PHANTV is set as shown in *Table 8.4*, depending on the connected voltage signals. The magnitude adjustment factor is 1 for phase-to-neutral signals, and $1/\sqrt{3}$ to convert phase-to-phase signals to phase-to-neutral signals.

Table 8.4 Phantom Voltage Adjustments

Voltage Connected VA-N (Becomes "Reference" Voltage)	Setting PHANTV	Magnitude and Phase Displacement Adjustment, Multiplied By Reference Voltage to Create V_{phnt}	
		Systems With ABC Rotation (PHROT = ABC)	Systems With ACB Rotation (PHROT = ACB)
V_A	A	$1\angle 0°$	$1\angle 0°$
V_B	B	$1\angle 120°$	$1\angle -120°$
V_C	C	$1\angle -120°$	$1\angle 120°$
V_{AB}	AB	$\frac{1}{\sqrt{3}}\angle -30°$	$\frac{1}{\sqrt{3}}\angle 30°$
V_{BC}	BC	$\frac{1}{\sqrt{3}}\angle 90°$	$\frac{1}{\sqrt{3}}\angle -90°$
V_{CA}	CA	$\frac{1}{\sqrt{3}}\angle -150°$	$\frac{1}{\sqrt{3}}\angle 150°$
See [a]	OFF	N/A	N/A

[a] When PHANTV = OFF, no voltage adjustments are made, and all power, energy, and symmetric component voltage values are forced to 0.00.

The phantom voltage V_{phnt} signal created using *Table 8.4* is labeled as V_A. The relay derives B- and C-phase signals by rotating V_{phnt} by either 120 or –120, depending on the phase rotation Global setting PHROT.

Figure 8.13 shows an example of the phantom voltage function with ABC phase rotation.

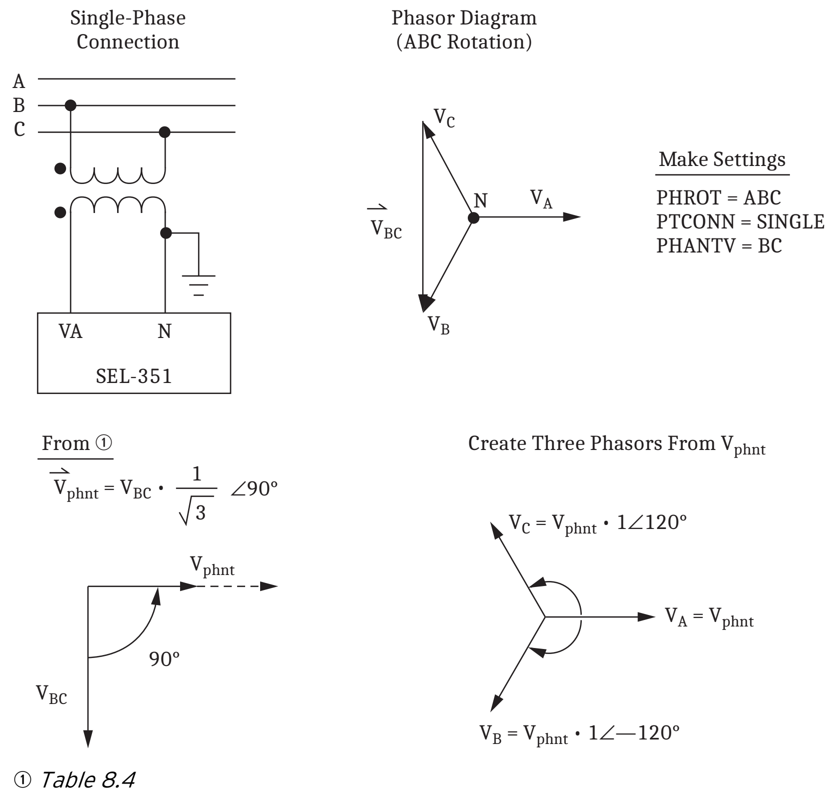

Figure 8.13 Example Phasor Diagram of Phantom Voltage Adjustment

NOTE: The phantom voltage settings have no effect on the protection elements in the SEL-351.

When the phantom voltage option is being used (i.e., PHANTV is not set to OFF), the fundamental power and energy quantities are based on the derived phantom voltages, and the symmetrical components (positive-, negative-, and zero-sequence voltages) are not calculated. In the example shown in *Figure 8.13*, PHANTV = BC, thus V1, V2, and 3V0 are set to zero internally.

Phantom Voltage Option Not in Service

If Global setting PTCONN = SINGLE and PHANTV = OFF, power and energy metering is disabled.

Phantom Voltages Used Only in Metering Functions

NOTE: The SEL-351 harmonic metering functions are not affected by the PHANTV setting.

In the SEL-351, phantom voltages are only used in the metering functions shown in *Table 8.3*, and are available to the various interfaces that access these Analog Quantities, as shown in *Table E.1*. The phantom voltages are not used in any protection elements, such as the 27/59 under-/overvoltage elements, power elements, and event report oscillography.

Accuracy of Phantom Voltage Metering Functions

The SEL-351 uses the phantom voltages in power calculations with the measured power system currents. The relay calculates the single-phase and three-phase power and energy values using a wye-connected calculation method. Single-phase voltages are generated even when there is a line-to-line voltage selection for Global setting PHANTV.

If the connected power system has a three-wire configuration, the per-phase phantom metering values do not have a system equivalency. However, the three-phase power, power factor, and energy values are representative of the power system.

The power calculation accuracy is inversely related to the voltage imbalance of the power system. If there is no system voltage imbalance, the phantom metering accuracy is the same as if the relay was connected to three-phase voltages. As system voltage imbalance increases, the phantom metering error increases.

Even though the phantom voltages represent a “perfect” positive-sequence voltage, the per-phase power results differ when the phase currents are not balanced. This per-phase difference is expected because system currents are seldom perfectly balanced, especially in distribution systems with line-neutral connected single-phase loads. The current imbalance, alone, does not reduce the accuracy of phantom metering.

Because the full system voltage information is not available to the relay, the phantom voltage feature should not be used for revenue metering.

If the power system experiences an emergency situation such as a fault condition or an open-phase load condition, the phantom voltages may not be realistic models of the power system voltages, and the power and energy metering accuracy could suffer during the disturbance.

Relay Commissioning With Phantom Metering

The Global phase rotation setting PHROT = ABC or ACB determines how the phantom voltage phase angles are assigned, and how the current symmetric components I1, 3I2, and 3I0 are calculated. It is important to test the metering functions during commissioning to ensure the currents and phantom voltage signals are in the expected power quadrants.

The configuration can be easily checked using the serial port **MET X** command, and comparing the single-phase power and power factor quantities. If the system is known to be in a balanced state, the per-phase powers should all have the same sign and similar magnitudes, and the per-phase power factor values should be closely matched. For example, on a radial line with standard residential load (without shunt capacitors), the power factor is expected to be between 0.80 and 0.99 lagging on all three phases.

If this test shows unexpected results, it is likely that one of the settings needs to be modified, or the voltage polarity switched (see *Demand Metering* on page 8.28). If another metering device is connected to the same power system, that device can be used to qualify the measured values.

See ***MET X k—Extended Instantaneous Metering*** on page 10.57 for an example **MET X** command response.

Polarity Reversal With Phantom Metering

The PHANTV setting choices only include one polarity for each connection: VA, VB, VC, VAB, VBC, and VCA. Opposite polarity signals must be corrected through wiring.

NOTE: If the Synchronism Check function is being used (e.g., Group setting E25 = Y), changing the polarity of the **VA-N** terminal wiring may require a SYNCP setting change—see *Setting SYNCP* on page 3.37.

For example, the PHANVT = VBC setting is available for a VBC connection to the **VA-N** terminal. If VCB = –VBC is connected to the **VA-N** terminal instead, there is no way to configure the PHANTV setting to accommodate this reverse polarity situation (e.g., PHANTV = VCB is not an available setting option). The solution is to swap the polarity of the applied signal on the **VA-N** terminals and use PHANTV = VBC, provided this change does not jeopardize any grounding practices.

Demand Metering

The SEL-351 offers the choice between two types of demand metering, settable with the enable setting:

- ➤ EDEM = THM (Thermal Demand Meter)
- ➤ EDEM = ROL (Rolling Demand Meter)

The demand metering settings (in *Table 8.5*) are available via the **SET** command (see *Table 9.2* and also *Demand Metering Settings (see Figure 8.14 and Figure 8.16)* on page SET.20). Also refer to ***MET (Metering Data)*** on page 10.55).

The SEL-351 provides demand and peak demand metering for the following values:

Currents:

$I_{A,B,C,N}$	Input currents (A primary)
I_G	Residual ground current (A primary; $I_G = 3I_0 = I_A + I_B + I_C$)
$3I_2$	Negative-sequence current (A primary)

Power (with separate IN and OUT values):

$MW_{A,B,C}$	Single-phase megawatts (not available with delta-connected voltages)
$MVAR_{A,B,C}$	Single-phase megavars (not available with delta-connected voltages)
MW_{3P}	Three-phase megawatts
$MVAR_{3P}$	Three-phase megavars

Depending on enable setting EDEM, these demand and peak demand values are thermal demand or rolling demand values. The thermal demand method is well-suited to monitoring equipment loading, and the demand results are updated regularly. The rolling demand method is available to match legacy metering systems used by some electrical utilities, and the demand results are updated every five minutes.

The differences between thermal and rolling demand metering are explained in the following discussion.

Comparison of Thermal and Rolling Demand Meters

The example in *Figure 8.14* shows the response of thermal and rolling demand meters to a step current input. The current input is at a magnitude of zero and then suddenly goes to an instantaneous level of 1.0 per unit (a “step”).

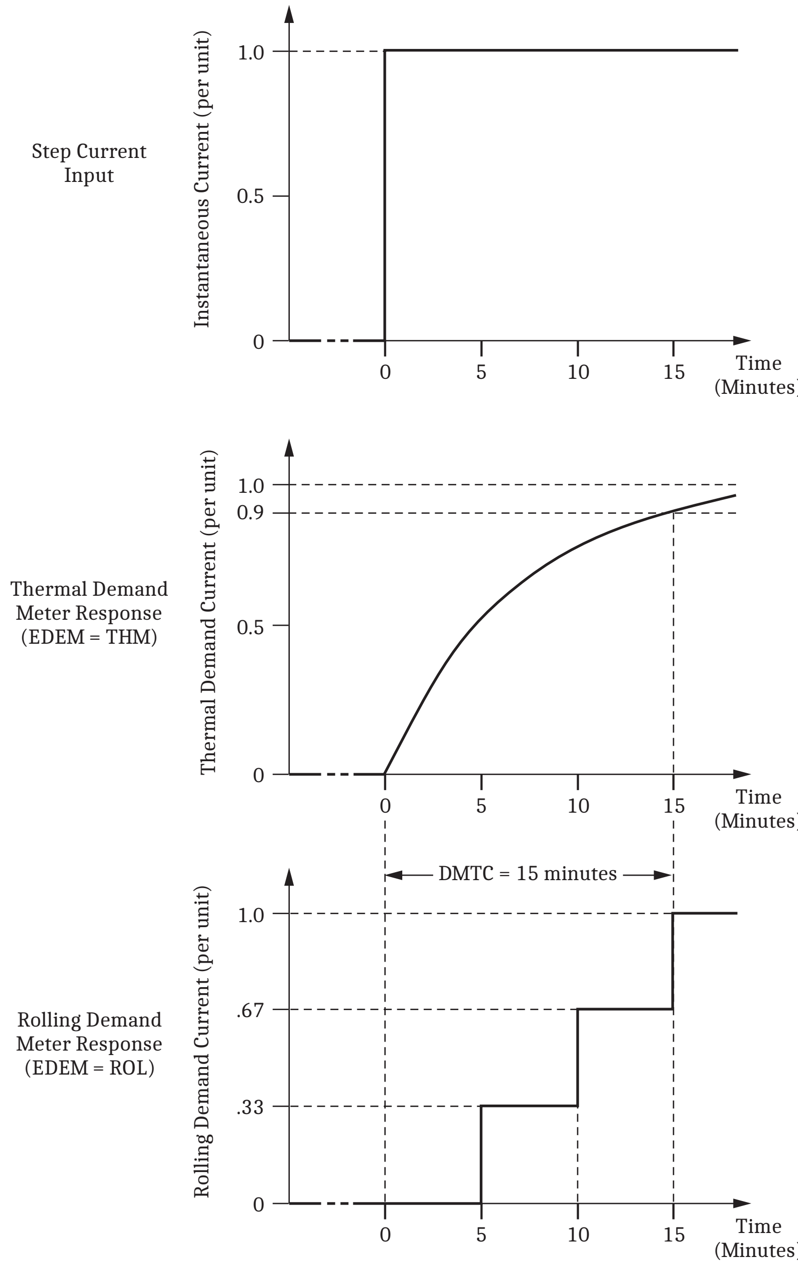

Figure 8.14 Response of Thermal and Rolling Demand Meters to a Step Input (Setting DMTC = 15 Minutes)

Thermal Demand Meter Response (EDEM = THM)

The response of the thermal demand meter in *Figure 8.14* (middle) to the step current input (top) is analogous to the series RC circuit in *Figure 8.15*.

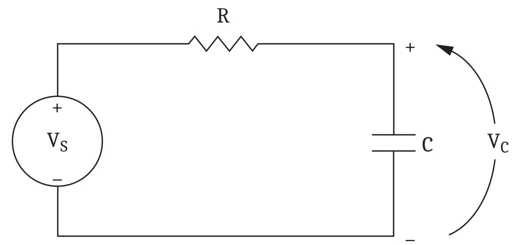

Figure 8.15 Voltage V_S Applied to Series RC Circuit

In the analogy:

Voltage V_S in *Figure 8.15* corresponds to the step current input in *Figure 8.14* (top).

Voltage V_C across the capacitor in *Figure 8.15* corresponds to the response of the thermal demand meter in *Figure 8.14* (middle).

If voltage V_S in *Figure 8.15* has been at zero (V_S = 0.0 per unit) for some time, voltage V_C across the capacitor in *Figure 8.15* is also at zero (V_C = 0.0 per unit). If voltage V_S is suddenly stepped up to some constant value (V_S = 1.0 per unit), voltage V_C across the capacitor starts to rise toward the 1.0 per unit value. This voltage rise across the capacitor is analogous to the response of the thermal demand meter in *Figure 8.14* (middle) to the step current input (top).

In general, as voltage V_C across the capacitor in *Figure 8.15* cannot change instantaneously, the thermal demand meter response is not immediate either for the increasing or decreasing applied instantaneous current. The thermal demand meter response time is based on the demand meter time constant setting DMTC (see *Table 8.5*). Note in *Figure 8.14*, the thermal demand meter response (middle) is at 90 percent (0.9 per unit) of full applied value (1.0 per unit) after a time period equal to setting DMTC = 15 minutes, referenced to when the step current input is first applied.

The SEL-351 updates thermal demand values approximately every two seconds.

Rolling Demand Meter Response (EDEM = ROL)

The response of the rolling demand meter in *Figure 8.14* (bottom) to the step current input (top) is calculated with a sliding time-window arithmetic average calculation. The width of the sliding time-window is equal to the demand meter time constant setting DMTC (see *Table 8.5*). Note in *Figure 8.14*, the rolling demand meter response (bottom) is at 100 percent (1.0 per unit) of full applied value (1.0 per unit) after a time period equal to setting DMTC = 15 minutes, referenced to when the step current input is first applied.

The rolling demand meter integrates the applied signal (e.g., step current) input in five-minute intervals. The integration is performed approximately every two seconds. The average value for an integrated five-minute interval is derived and stored as a five-minute total. The rolling demand meter then averages a number of the five-minute totals to produce the rolling demand meter response. In the *Figure 8.14* example, the rolling demand meter averages the three latest five-minute totals because setting DMTC = 15 (15/5 = 3). The rolling demand meter response is updated every five minutes, after a new five-minute total is calculated.

The following is a step-by-step calculation of the rolling demand response example in *Figure 8.14* (bottom).

Time = 0 Minutes

Presume that the instantaneous current has been at zero for quite some time before "Time = 0 minutes" (or the demand meters were reset). The three five-minute intervals in the sliding time-window at "Time = 0 minutes" each integrate into the following five-minute totals:

Five-Minute Totals	Corresponding Five-Minute Interval
0.0 per unit	–15 to –10 minutes
0.0 per unit	–10 to –5 minutes
0.0 per unit	–5 to 0 minutes
0.0 per unit	

Rolling demand meter response at "Time = 0 minutes" = 0.0/3 = 0.0 per unit

Time = 5 Minutes

The three five-minute intervals in the sliding time-window at "Time = 5 minutes" each integrate into the following five-minute totals:

Five-Minute Totals	Corresponding Five-Minute Interval
0.0 per unit	–10 to –5 minutes
0.0 per unit	–5 to 0 minutes
1.0 per unit	0 to 5 minutes
1.0 per unit	

Rolling demand meter response at "Time = 5 minutes" = 1.0/3 = 0.33 per unit

Time = 10 Minutes

The three five-minute intervals in the sliding time-window at "Time = 10 minutes" each integrate into the following five-minute totals:

Five-Minute Totals	Corresponding Five-Minute Interval
0.0 per unit	–5 to 0 minutes
1.0 per unit	0 to 5 minutes
1.0 per unit	5 to 10 minutes
2.0 per unit	

Rolling demand meter response at "Time = 10 minutes" = 2.0/3 = 0.67 per unit

Time = 15 Minutes

The three five-minute intervals in the sliding time-window at "Time = 15 minutes" each integrate into the following 5-minute totals:

Five-Minute Totals	Corresponding Five-Minute Interval
1.0 per unit	0 to 5 minutes
1.0 per unit	5 to 10 minutes
1.0 per unit	10 to 15 minutes
3.0 per unit	

Rolling demand meter response at “Time = 15 minutes” = 3.0/3 = 1.0 per unit

Demand Meter Settings

Table 8.5 Demand Meter Settings and Settings Range

Setting	Definition	Range
EDEM	Demand meter type	THM = thermal ROL = rolling
DMTC	Demand meter time constant	5, 10, 15, 30, or 60 minutes
PDEMP	Phase demand current pickup	OFF, 0.50–16.00 A sec (5 A nominal) OFF, 0.10–3.20 A sec (1 A nominal)
NDEMP	Neutral ground demand current pickup	OFF, 0.50–16.00 A sec (5 A nominal IN channel) OFF, 0.10–3.20 A sec (1 A nominal IN channel) OFF, 0.005–0.640 A sec (0.2 A nominal IN channel) OFF, 0.005–0.160 A sec (0.05 A nominal IN channel)
GDEMP	Residual ground demand current pickup	OFF, 0.10–16.00 A sec (5 A nominal) OFF, 0.02–3.20 A sec (1 A nominal)
QDEMP	Negative-sequence demand current pickup	OFF, 0.50–16.00 A sec (5 A nominal) OFF, 0.10–3.20 A sec (1 A nominal)

NOTE: Changing setting EDEM or DMTC resets the demand meter values to zero. This also applies to changing the active setting group, and setting EDEM or DMTC is different in the new active setting group. Demand current pickup settings PDEMP, NDEMP, GDEMP, and QDEMP can be changed without affecting the demand meters.

The examples in this section discuss demand current, but MW and MVAR demand values are also available, as stated at the beginning of this subsection.

The demand current pickup settings in *Table 8.5* are applied to demand current meter outputs as shown in *Figure 8.16*. For example, when residual ground demand current $I_{G(DEM)}$ goes above corresponding demand pickup GDEMP, Relay Word bit GDEM asserts to logical 1. Use these demand current logic outputs (PDEM, NDEM, GDEM, and QDEM) to alarm for high loading or unbalance conditions. Use in other schemes such as the following example.

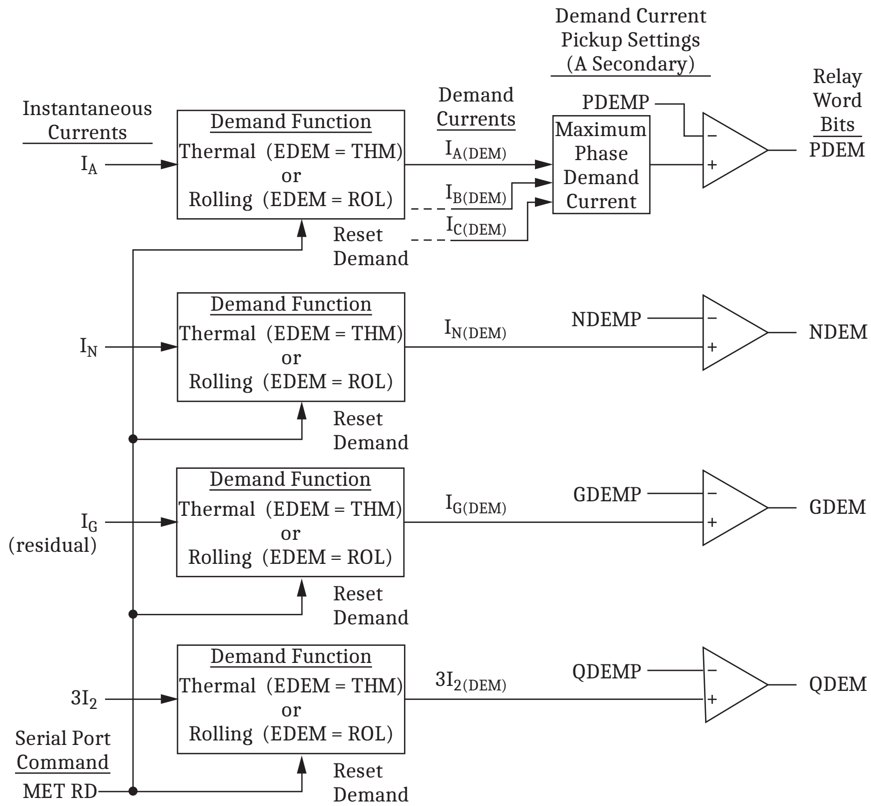

Figure 8.16 Demand Current Logic Outputs

Demand Current Logic Output Application—Raise Pickup for Unbalance Current

During times of high loading, the residual ground overcurrent elements can see relatively high unbalance current I_G ($I_G = 3I_0$). To avoid tripping on unbalance current I_G, use Relay Word bit GDEM to detect the residual ground (unbalance) demand current $I_{G(DEM)}$ and effectively raise the pickup of the residual ground time-overcurrent element 51GT. This is accomplished with the following settings from *Table 8.5*, pertinent residual ground overcurrent element settings, and SELOGIC control equation torque-control setting 51GTC:

EDEM = **THM**

DMTC = **5**

GDEMP = **1.0**

51GP = **1.50**

50G5P = **2.30**

51GTC = **GDEM + GDEM * 50G5**

Refer to *Figure 8.16*, *Figure 8.17*, and *Figure 3.19*.

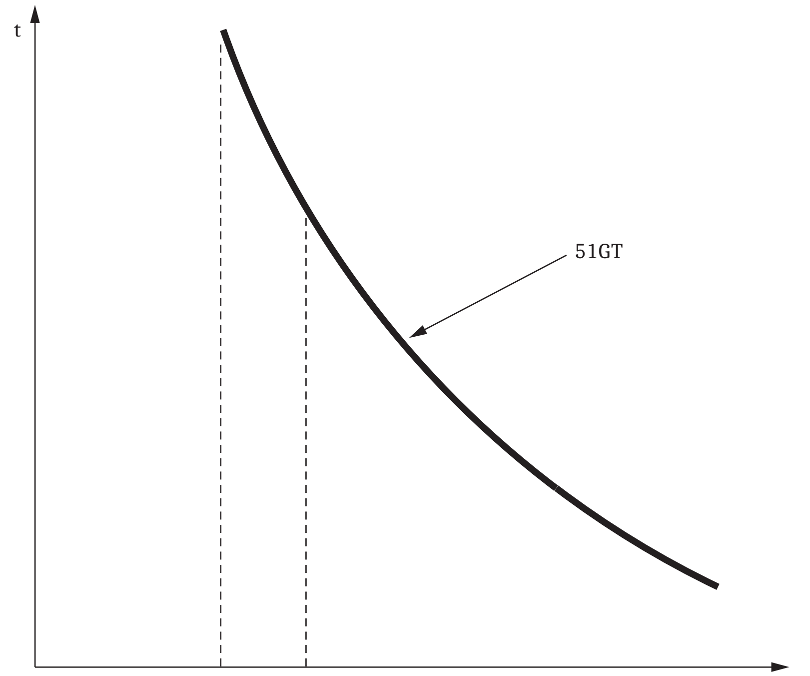

Figure 8.17 Raise Pickup of Residual Ground Time-Overcurrent Element for Unbalance Current

Residual Ground Demand Current Below Pickup GDEMP

When unbalance current I_G is low, unbalance demand current $I_{G(DEM)}$ is below corresponding demand pickup GDEMP = 1.00 A secondary, and Relay Word bit GDEM is deasserted to logical 0. This results in SELOGIC control equation torque-control setting 51GTC being in the state:

51GTC = **!GDEM + GDEM * 50G5** = NOT(GDEM) + GDEM * 50G5
= NOT(logical 0) + (logical 0) * 50G5 = logical 1

Thus, the residual ground time-overcurrent element 51GT operates on its standard pickup:

51GP = **1.50 A secondary**

If a ground fault occurs, the residual ground time-overcurrent element 51GT operates with the sensitivity provided by pickup 51GP = 1.50 A secondary. The thermal demand meter, even with setting DMTC = 5 minutes, does not respond fast enough to the ground fault to make a change to the effective residual ground time-overcurrent element pickup—it remains at 1.50 A secondary. Demand meters respond to more "slow moving" general trends.

Residual Ground Demand Current Goes Above Pickup GDEMP

When unbalance current I_G increases, unbalance demand current $I_{G(DEM)}$ follows, going above corresponding demand pickup GDEMP = 1.00 A secondary, and Relay Word bit GDEM asserts to logical 1. This results in SELOGIC control equation torque-control setting 51GTC being in the state:

51GTC = **!GDEM + GDEM * 50G5** = NOT(GDEM) + GDEM * 50G5
= NOT(logical 1) + (logical 1) * 50G5 = logical 0 + 50G5 = 50G5

Thus, the residual ground time-overcurrent element 51GT operates with an effective, less-sensitive pickup:

50G5P = **2.30 A secondary**

The reduced sensitivity keeps the residual ground time-overcurrent element 51GT from tripping on higher unbalance current I_G.

Residual Ground Demand Current Goes Below Pickup GDEMP Again

When unbalance current I_G decreases again, unbalance demand current $I_{G(DEM)}$ follows, going below corresponding demand pickup GDEMP = 1.00 A secondary, and Relay Word bit GDEM deasserts to logical 0. This results in SELOGIC control equation torque-control setting 51GTC being in the state:

51GTC = **!GDEM + GDEM * 50G5** = NOT(GDEM) + GDEM * 50G5 = NOT(logical 0) + (logical 0) * 50G5 = logical 1

Thus, the residual ground time-overcurrent element 51GT operates on its standard pickup again:

51GP = **1.50 A secondary**

View or Reset Demand Metering Information

Via Serial Port

See **MET *(Metering Data)*** on page 10.55. The **MET D** command displays demand and peak demand metering for the following values:

Currents:

$I_{A,B,C,N}$	Input currents (A primary)
I_G	Residual ground current (A primary; $I_G = 3I_0 = I_A + I_B + I_C$)
3I2	Negative-sequence current (A primary)

Power:

$MW_{A,B,C}$	Single-phase megawatts (not available with delta-connected voltage)
$MVAR_{A,B,C}$	Single-phase megavars (not available with delta-connected voltage)
MW_{3P}	Three-phase megawatts
$MVAR_{3P}$	Three-phase megavars

The **MET RD** command resets the demand metering values. The **MET RP** command resets the peak demand metering values.

If setting EDEM = ROL, after resetting the demand values, there may be a delay of as long as two times the DMTC setting before the demand values are updated.

Via Front Panel

The information and reset functions available via the previously discussed serial port commands **MET D**, **MET RD**, and **MET RP** are also available via the front-panel METER pushbutton. See *Figure 11.2*.

Via DNP or Modbus

The demand and peak demand metering values are available via DNP and Modbus. See the Demand Metering and Peak (Demand) Metering section of *Table E.1*.

The DNP binary outputs DRST_DEM and DRST_PDM can be used to reset the demand metering and peak demand metering, respectively. These controls are similar in function to the **MET RD** and **MET RP** commands. See *Appendix L: DNP3 Communications* for more details.

The Modbus protocol can be used to reset the demand metering and peak demand metering, with functions similar to the **MET RD** and **MET RP** commands. Two methods are available:

- ➤ Writing to the Reset Demands or Reset Demand Peaks output coil.
- ➤ Writing a specific analog value to the RSTDAT register.

See *Appendix O: Modbus RTU and TCP Communications* for details.

Via Fast Meter or IEC 61850

Selected demand and peak demand metering values are available via Fast Metering and IEC 61850. See the Demand Metering and Peak (Demand) Metering section of *Table E.1*.

Via File Transfer

The MET D report is available via file transfer protocols. See *Virtual File Interface* on page 10.26.

Reset Via SELogic Control Equation

The RST_DEM and RST_PDM SELogic control equation settings can be used to reset the demand metering and peak demand metering respectively. The relay resets the function when the setting first asserts (rising edge, e.g., a logical 0 to a logical 1 transition).

Example Application of RST_DEM and RST_PDM:

A control scheme requires:

- ➤ Demand metering to be reset the when control input IN106 asserts, or when SV12T asserts
- ➤ Peak demand metering to be reset when control input IN106 asserts, or when remote bit RB14 asserts.

Make the logic settings in each settings group that will be used (e.g., use **SET L 1**, for setting group 1):

RST_DEM = **/IN106 + /SV12T**

RST_PDM = **/IN106 + /RB14**

NOTE: To avoid unexpected clearing of metering data, the proposed SELogic control equations should be tested to ensure they do not assert after a group change or after relay power-up.

The "/" rising edge operators ensure that a maintained logical 1 on IN106 does not prevent SV12T from resetting the demand metering, and does not prevent RB14 from resetting the peak demand metering.

Demand Metering Updating and Storage

The SEL-351 updates demand values approximately every two seconds.

The relay stores peak demand values 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 values saved by the relay at 23:50 hours on the previous day.

Demand metering peak recording is momentarily suspended when SELOGIC control equation setting FAULT is asserted (= logical 1). See the explanation for the FAULT setting in *Maximum/Minimum Metering* on page 8.39.

Energy Metering

The SEL-351 provides energy metering for the following values:

$MWH_{A,B,C,3P}$ IN Single-phase and three-phase megawatt-hours, primary

$MWH_{A,B,C,3P}$ OUT Single-phase and three-phase megawatt-hours, primary

$MVARH_{A,B,C,3P}$ IN Single-phase and three-phase megaVAr-hours, primary

$MVARH_{A,B,C,3P}$ OUT Single-phase and three-phase megaVAr-hours, primary

where IN and OUT correspond to the standard relay convention of OUT for positive power, and IN for negative power.

See *Table E.1* for a listing of the Analog Quantities for energy metering.

The single-phase energy values are not available with a delta voltage connection (Global setting PTCONN = DELTA).

Energy metering is available only when three-phase voltages are connected to the relay, or when a single-phase voltage is connected and phantom metering is selected (Global settings PTCONN = SINGLE and PHANTV ≠ OFF). See *Wye-, Delta-, and Single-Phase Voltage Connections for Metering* on page 8.22 for more information.

Energy metering accuracy degrades when the phantom voltage feature is used. The error is proportional to the amount of system imbalance. See *Accuracy of Phantom Voltage Metering Functions* on page 8.26.

View or Reset Energy Metering Information

Via Serial Port

NOTE: Single-phase quantities are only available when Global setting PTCONN = WYE.

See **MET** ***(Metering Data)*** on page 10.55. The **MET E** command displays accumulated single- and three-phase megawatt and megavar hours. The **MET RE** command resets the accumulated single- and three-phase megawatt and megavar hours.

Via Front Panel

The information and reset functions available via the previously discussed serial port commands **MET E** and **MET RE** are also available via the front-panel **METER** pushbutton. See *Figure 11.2*.

Via DNP or Modbus

The energy metering values are available via DNP and Modbus. See the Energy Metering section of *Table E.1*.

The DNP binary output DRST_ENE can be used to reset the energy metering, and is similar in function to the **MET RE** command. See *Appendix L: DNP3 Communications* for more details.

The Modbus protocol can be used to reset the energy metering, with functions similar to the **MET RE** command. Two methods are available:

- Writing to the Reset Energy Data output coil.
- Writing a specific analog value to the RSTDAT register.

See *Appendix O: Modbus RTU and TCP Communications* for details.

Via IEC 61850

Three-phase energy metering values are available via IEC 61850. See the Energy Metering section of *Table E.1*.

Via File Transfer

The MET E report is available via file transfer protocols. See *Virtual File Interface* on page 10.26.

Reset Via SELOGIC Control Equation

The RST_ENE SELOGIC control equation setting can be used to reset the energy metering. The relay resets the function when the setting first asserts (rising edge, e.g., a logical 0 to a logical 1 transition).

Example Application of RST_ENE

A control scheme requires energy metering to be reset when control input IN105 asserts, or when SV11T asserts.

NOTE: To avoid unexpected clearing of metering data, the proposed SELOGIC control equation should be tested to ensure it does not assert after a group change or after relay power-up.

Make the logic settings in each settings group that will be used (e.g., use **SET L 1**, for setting group 1):

RST_ENE = **/IN105 + /SV11T**

The "/" rising edge operators ensure that a maintained logical 1 on IN105 does not prevent SV11T from resetting the energy metering.

Energy Metering Updating and Storage

The SEL-351 updates energy values approximately every two seconds.

The relay stores energy values to nonvolatile storage once per day (it overwrites the previous stored value). Should the relay lose control power, it will restore the energy values saved by the relay at 23:50 hours on the previous day.

Accumulated energy metering values function like those in an electromechanical energy meter. When the energy meter reaches 99999 MWh or 99999 MVARh, it starts over at zero.

Maximum/Minimum Metering

The SEL-351 provides maximum/minimum metering for the following values:

Currents:

$I_{A,B,C,N}$	Input currents (A primary)
I_G	Residual ground current (A primary; $I_G = 3I_0$)

Voltages:

$V_{A,B,C}$	Input voltages (kV primary, not available with delta-connected voltages)
$V_{AB,BC,CA}$	Input voltages (kV primary, delta-connected voltage only)
V_S	Input voltages (kV primary)

Power:

MW_{3P}	Three-phase megawatts
$MVAR_{3P}$	Three-phase megavars

The power maximum and minimum values can be negative or positive, indicating the range of power flow that has occurred since the last reset command. These functions simulate analog meter drag-hands, with the maximum value representing the upper drag-hand and the minimum value representing the lower drag-hand.

Table 8.6 shows the values that the relay would record for various power flow directions (either MW3P or MVAR3P).

Table 8.6 Operation of Maximum/Minimum Metering With Directional Power Quantities[a]

If Power Varies		Recorded MAX	Recorded MIN
From:	To:		
9.7	16.2	16.2	9.7
–4.2	1.4	1.4	–4.2
–25.3	–17.4	–17.4	–25.3
–6.2	27.4	27.4	–6.2

[a] For simplicity, the date and time stamps are not shown here.

View or Reset Maximum/Minimum Metering Information

Via Serial Port

See **MET M—*Maximum/Minimum Metering*** on page 10.61. The **MET M** command displays maximum/minimum metering values. The **MET RM** command resets the maximum/minimum metering values.

Via Front Panel

The metering and reset functions available via serial port commands **MET M** and **MET RM** are also available via the front-panel METER pushbutton. See *Figure 11.2*.

Via File Transfer

The MET M report is available via file transfer protocols. See *Virtual File Interface* on page 10.26.

Reset Via DNP or Modbus Control

The DNP binary output DRST_MML can be used to reset the Max/Min metering, and is similar in function to the **MET RM** command. See *Appendix L: DNP3 Communications* for more details.

The Modbus protocol can be used to reset the Max/Min metering, with methods that are similar in function to the **MET RM** command. Two methods are available:

- ➤ Writing to the Reset Max/Min output coil.
- ➤ Writing a specific analog value to the RSTDAT register.

See *Appendix O: Modbus RTU and TCP Communications* for details.

Reset Via SELogic Control Equation

The RST_MML SELogic control equation setting can be used to reset the Maximum/Minimum metering. The relay resets the function when the setting first asserts (rising edge, e.g., a logical 0 to a logical 1 transition).

Example Application of RST_MML

A control scheme requires Maximum/Minimum metering to be reset when control input IN104 asserts, or when SV10T asserts.

NOTE: To avoid unexpected clearing of metering data, the proposed SELogic control equation should be tested to ensure it does not assert after a group change or after relay power-up.

Make the logic settings in each settings group that will be used (e.g., use **SET L 1**, for setting group 1):

RST_MML = **/IN104 + /SV10T**

The “/” rising edge operators ensure that a maintained logical 1 on IN104 does not prevent SV10T from resetting the energy metering.

Maximum/Minimum Metering Update and Storage

The maximum/minimum metering function is intended to reflect normal load variations rather than fault conditions or outages. Therefore, the SEL-351 updates maximum/minimum values only if SELogic control equation setting FAULT is deasserted (= logical 0) and has been deasserted for at least 3600 cycles.

NOTE: SELogic control equation setting FAULT also controls other relay functions; see *SELogic Control Equation Setting FAULT* on page 5.39.

The factory default setting is set with time-overcurrent element pickups:

FAULT = **51P + 51G**

If there is a fault, 51P or 51G asserts and blocks updating of maximum/minimum metering values.

In addition to FAULT being deasserted for at least 3600 cycles, the following conditions must also be met:

- For wye-connected voltage values (V_A, V_B, V_C, V_S), or delta-connected voltage values (V_{AB}, V_{BC}, V_{CA}, V_S), the voltage is above the corresponding threshold:

  25.0 V secondary (300 V voltage inputs)

- For current values $I_{A,B,C,N}$ the current is above the corresponding threshold:

  25.0 mA secondary (5 A nominal current inputs)

  5.0 mA secondary (1 A nominal current inputs)

  1.0 mA secondary (0.2 A nominal channel IN current input)

  1.0 mA secondary (0.05 A nominal channel IN current input)

- For the residual current value I_G:

  All three phase currents I_A, I_B, I_C are above threshold.

- For power values MW_{3P} and $MVAR_{3P}$:

  All three phase currents I_A, I_B, I_C are above threshold and all three voltages V_A, V_B, V_C (or V_{AB}, V_{BC}, V_{CA}) are above threshold.

- The metering value is above the previous maximum or below the previous minimum for approximately four seconds.

NOTE: The values used by the maximum/minimum metering are the same values used by the regular **MET** command (serial port or instantaneous, front panel), which are eight-cycle averaged values. The maximum/minimum metering function updates every two seconds (approximately). These values are relatively immune to transient conditions.

The SEL-351 stores maximum/minimum values to nonvolatile storage once per day and overwrites the previous stored value if that is exceeded. If the relay loses control power, it will restore the maximum/minimum values saved at 23:50 hours on the previous day.

Small Signal Cutoff for Metering

Global setting METHRES controls how various metering functions respond when the metered value is small. Set METHRES to Y, N or E as explained below.

METHRES = Y

Make Global setting METHRES = Y to force instantaneous current and voltage metered values to zero when the applied signal is less than the values shown in *Table 8.7*.

Table 8.7 Metering Thresholds (Secondary Units)

Current Channels:	Nominal Current Input Rating			
	5 A	1 A	0.2 A	0.05 A
IA, IB, IC	0.025 A	0.005 A	N/A	N/A
IN	0.025 A	0.005 A	0.001 A	0.001 A
Voltage Channels:	**All Models**			
VA, VB, VC, VS	0.1 V			

The metered values are forced to zero on a phase-by-phase basis. For example, if IA is below the applicable threshold shown in *Table 8.7* but IB, IC, and IN are all above their respective thresholds, then the fundamental magnitude and angle for IA are forced to zero, but the metered values for IB, IC, and IN are unchanged.

When a fundamental value is forced to zero, other metering displays are also impacted. In the above example, the A-phase current inputs to metered sequence values, demand calculations, and energy calculations are also forced to zero. The changes impact all non-harmonic meter reports available from any interface on the relay including ASCII reports, the webpages, Fast Meter reports, etc. The changes do not impact harmonics metering, protection, synchrophasors, or event reporting.

METHRES = N

Make Global setting METHRES = N to disable all meter threshold checks. When METHRES = N, some energy may be accumulated and some small value is input to the demand models even if the breaker is open.

METHRES = E

Make Global setting METHRES = E to force the inputs to the energy and power demand calculations to zero when currents drop below the thresholds shown in *Table 8.7 and* when Relay Word bit 52A = 0. If 52A = 1 or current is above the levels shown in *Table 8.7*, then energy and power demand metering continue unaffected by any threshold check. METHRES = E only impacts power demand and energy metering. Fundamental metering and current demand metering are not affected. Metered voltages are never forced to zero when METHRES = E. However, setting PTCONN does change the conditions for which the current inputs to the energy and power demand calculations are forced to zero.

When PTCONN = WYE or SINGLE, the current inputs to the energy and power demand calculations are forced to zero on a phase-by-phase basis. For example, if IA is below the applicable threshold shown in *Table 8.7* and 52A = 0, then only the A-phase input to the energy and power demand calculations is forced to zero. The B- and C-phase inputs to the energy and power demand calculations are not forced to zero.

When PTCONN = DELTA, the input to the three-phase energy and power demand calculations are forced to zero only if 52A = 0 and all three currents are below their respective thresholds.

Harmonic Metering

Introduction

The SEL-351 measures signal distortions to the 16th harmonic on the eight analog input channels.

The signals connected to the SEL-351 terminals IA, IB, IC, IN, VA, VB, VC, and VS are first conditioned by analog low-pass filters, and then sampled at 128 times per power system cycle. Every two seconds, an 8-cycle (1024-sample) data set from each channel is processed to calculate the following:

- Fundamental magnitude (1st harmonic) in primary units.
- True root mean squared (rms) magnitude in primary units.
- Total Harmonic Distortion (THD) in percent of fundamental.
- Harmonic *n* content, where *n* = 2 through 16, expressed in percent of fundamental.

See the Harmonic Metering section of *Table E.1* for a list of the Analog Quantity names for these values.

Two Types of Fundamental

The fundamental (1st harmonic) values calculated by the harmonic metering subsystem are different than the output from the fundamental metering subsystem of the SEL-351, and care should be taken to make sure you are referencing the correct value when selecting Analog Quantities for reporting via Load Profile, Display Points, DNP, or Modbus.

To minimize the chance of using the wrong values, the analog quantity names for these two different fundamental values are unique. For example, the fundamental metering subsystem A-phase current is called IA, while the harmonic metering fundamental (1st harmonic) is called IAH01.

The fundamental (1st harmonic) values are scalar quantities, therefore no phase angle or polarity sign is included.

The fundamental (1st harmonic) values are only used in the harmonics subsystem as follows:

- To determine whether there is a sufficient signal for the harmonic, RMS, and THD calculations of each channel
- As part of the THD calculation
- As a reference for harmonics 2 through 16, which are expressed as a percentage of the fundamental value for a given channel.

True RMS Magnitudes and Total Harmonic Distortion (THD)

The true RMS calculations are based on the same 8-cycle data set that is used in the harmonics calculations. Signal energy from the fundamental (1st harmonic) and harmonics 2 through 16 are included in the RMS magnitude.

The true RMS current and voltage readings for a given channel are greater than the fundamental (1st harmonic) magnitude if the relay measures any harmonic energy in the signal.

The true RMS values are scalar quantities, therefore no phase angle or polarity sign is included.

The THD value for a channel is calculated from the fundamental (1st harmonic) and true RMS magnitudes for that channel, according to IEEE Std. 1459-2000 (3.1.2.1). If the relay detects a waveform with no harmonics, the THD for that channel is 0, and the fundamental (1st harmonic) and RMS magnitudes are numerically close in value.

When viewing harmonic metering data on the SEL-351, the THD value can be inspected to determine whether there is any other harmonic data of interest on that channel.

Harmonic Metering Small Signal Cutoff Thresholds

The SEL-351 calculates the harmonic metering quantities for a given analog channel when that channel’s fundamental magnitude, calculated from the harmonics sample data set, is greater than the value shown in *Table 8.8*.

These harmonic metering thresholds are greater than the thresholds used by the fundamental metering system.

Table 8.8 Harmonic Metering Thresholds (Secondary Units)

Current Channels:	Nominal Current Input Rating			
	5 A	1 A	0.2 A	0.05 A
IA, IB, IC	0.25 A	0.05 A	N/A	N/A
IN	0.25 A	0.05 A	0.01 A	0.01 A
Voltage Channels:	**All Models**			
VA, VB, VC, VS	6 V[a]			

[a] If the system frequency deviates from nominal (50 Hz or 60 Hz), harmonic metering accuracy may be compromised when all of the voltages applied to terminals VA-N, VB-N, and VC-N are below 20 V secondary.

These thresholds affect the harmonic metering functions on a per-channel basis. For example, during a lightly loaded condition on C-phase, if the IC fundamental (1st harmonic) calculation is 0.20 A secondary on a 5 A nominal relay, the SEL-351 will force all of the IC harmonics metering values to 0.00, including the fundamental (1st harmonic), RMS, THD, and individual harmonics 2 through 16. In this same situation, if voltage channel VC is still receiving an adequate signal (greater than 6 V sec), the relay calculates the VC harmonic metering values.

The small signal cutoff will cause any de-energized or unused channels to be displayed as numeric zero values.

Global Setting PTCONN Effect on Harmonic Metering

When Global setting PTCONN = WYE:

The SEL-351 processes and reports all eight analog inputs in the harmonic metering subsystem.

When Global setting PTCONN = DELTA:

The SEL-351 harmonic metering subsystem ignores the VB channel input, and processes the remaining seven analog inputs. The analog quantity values for the VB channel are forced to numeric zero.

In the open-delta configuration, the VA channel quantities represent VAB, and the VC channel quantities represent VCB (= –VBC). In the MET H report and front-panel harmonic metering screens, the SEL-351 displays voltage labels VAB and VBC to reflect the phase-to-phase connection. No VCA column is present in the harmonic metering reports.

When Global setting PTCONN = SINGLE:

The SEL-351 processes and reports all eight analog inputs in the harmonic metering subsystem. Global setting PHANTV has no effect on the harmonic metering subsystem.

Harmonic Metering Reports

The relay converts the fundamental (1st harmonic) and RMS magnitude values to primary units using the current transformer ratio Group settings CTR and CTRN, and potential transformer ratio Group settings PTR and PTRS.

Harmonic metering values are available through several interfaces, as detailed in the Harmonic Metering section of *Table E.1*:

- ➤ Serial port ASCII communications; see **MET** ***(Metering Data)*** on page 10.55
- ➤ Front-panel LCD; see *Front-Panel Pushbutton Operation* on page 11.1
- ➤ DNP (Serial Port or Ethernet); see *Appendix L: DNP3 Communications*
- ➤ Modbus (Serial Port or Ethernet); see *Appendix O: Modbus RTU and TCP Communications*
- ➤ Display points; see *Displaying Analog Values on the Rotating Display* on page 7.44
- ➤ Load profile recorder; see *Load Profile Report (Available in Firmware Versions 6 and 7)* on page 8.45
- ➤ File transfer; see *Virtual File Interface* on page 10.26.

See *Specifications* on page 1.4 for a listing of the harmonic metering accuracy in the SEL-351.

Synchrophasor Metering

View Synchrophasor Metering Information

Via Serial Port

See **MET** ***(Metering Data)*** on page 10.55. The **MET PM** command displays the synchrophasor measurements. For more information, see *View Synchrophasors by Using the MET PM Command* on page N.18.

Via File Transfer

The MET PM report is available via file transfer protocols. See *Virtual File Interface* on page 10.26.

Load Profile Report (Available in Firmware Versions 6 and 7)

Introduction and Configuration

The SEL-351 Load Profile Recorder is capable of recording as many as 15 selectable analog quantities at a periodic rate and storing the data in a report in nonvolatile memory.

The load profile report is available via serial port communications by using the **LDP** command.

At the interval given by load profile acquisition rate setting LDAR, the relay adds a record to the load profile buffer. This record contains the date and time stamp and the present value of each of the analog quantities listed in the load profile list setting LDLIST.

These settings are made and reviewed with the **SET R** and **SHO R** serial port commands, respectively. Setting LDAR can be set to any of the following values: 5, 10, 15, 30, and 60 minutes. Setting LDLIST may contain any of the quantities that are marked with an “x” in the Load Profile column of *Table E.1*.

The load profile settings are shown in *Report Settings (Serial Port Command SET R)* on page SET.30. Labels are entered into the setting as either comma or space delimited, but are displayed as comma delimited. Load profiling is disabled if the LDLIST setting is empty (i.e., set to NA or 0), which is displayed as LDLIST = 0.

Load Profile Report Storage

The load profile records are stored in nonvolatile memory and the acquisition is synchronized to the time of day, with a resolution of ±5 seconds. The load profile report capacity depends on the settings LDLIST and LDAR.

With an LDLIST setting containing 15 values, and LDAR = 5 minutes, the relay retains a minimum of 18 days and a maximum of 25 days of the most recent load profile entries in nonvolatile memory. When the load profile recorder memory reaches 25 days and further entries occur, the oldest 7 days of data are cleared in a block to make room for newer entries. Therefore, the apparent LDP memory size can vary between 18 and 25 days. The **LDP D** command displays the number of days before the next data clearing occurs.

If fewer than 15 values are specified in LDLIST, the SEL-351 will be able to store more days of data before data overwrite occurs. Likewise, if the interval LDAR is set longer, the SEL-351 will be able to store more days of data before data overwrite occurs.

Retrieving the Load Profile Report

Via Serial Port

The load profile report is retrieved via the **LDP** command, which has the following format:

LDP [a] [b]

The following table shows example **LDP** commands.

Example LDP Serial Port Commands	Format
LDP	If **LDP** is entered with no numbers following it, all available rows are displayed. They display with the oldest row at the beginning (top) of the report and the latest row (row 1) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
LDP 17	If **LDP** is entered with a single number following it (**17** in this example), the first 17 rows are displayed, if they exist. They display with the oldest row (row 17) at the beginning (top) of the report and the latest row (row 1) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.

Example LDP Serial Port Commands	Format
LDP 10 33	If **LDP** is entered with two numbers following it (**10** and **33** in this example; 10 < 33), all the rows between (and including) rows 10 and 33 are displayed, if they exist. They display with the oldest row (row 33) at the beginning (top) of the report and the latest row (row 10) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
LDP 47 22	If **LDP** is entered with two numbers following it (**47** and **22** in this example; 47 > 22), all the rows between (and including) rows 47 and 22 are displayed, if they exist. They display with the newest row (row 22) at the beginning (top) of the report and the oldest row (row 47) at the end (bottom) of the report. *Reverse* chronological progression through the report is down the page and in ascending row number.
LDP 3/30/2009	If **LDP** is entered with one date following it (date **3/30/2009** in this example), all the rows on that date are displayed, if they exist. They display with the oldest row at the beginning (top) of the report and the latest row at the end (bottom) of the report, for the given date. Chronological progression through the report is down the page and in descending row number.
LDP 2/17/2009 3/23/2009	If **LDP** is entered with two dates following it (date **2/17/2009** chronologically *precedes* date **3/23/2009** in this example), all the rows between (and including) dates 2/17/2009 and 3/23/2009 are displayed, if they exist. They display with the oldest row (date 2/17/2009) at the beginning (top) of the report and the latest row (date 3/23/2009) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
LDP 3/16/2009 1/5/2009	If **LDP** is entered with two dates following it (date **3/16/2009** chronologically *follows* date **1/5/2009** in this example), all the rows between (and including) dates 1/5/2009 and 3/16/2009 are displayed, if they exist. They display with the latest row (date 3/16/2009) at the beginning (top) of the report and the oldest row (date 1/5/2009) at the end (bottom) of the report. *Reverse* chronological progression through the report is down the page and in ascending row number.

NOTE: The SEL-351 accepts two or four digit years in the **LDP** command. For example, **LDP 3/30/09** is treated the same as **LDP 3/30/2009**. In either case, the LDP report only displays two digit years in the Date column.

The date entries in the above example **LDP** commands are dependent on the Global Date Format setting DATE_F. If setting DATE_F = MDY, then the dates are entered as in the above examples (Month/Day/Year). If setting DATE_F = YMD, then the dates are entered Year/Month/Day.

The load profile output has the following format:

```
=>LDP 7 <Enter>

FEEDER 1                          Date: 05/23/09    Time: 13:28:32.404
STATION A

FID=SEL-351-6-Rxxx-V0-Zxxxxxx-D2009xxxx       CID=xxxx

#     DATE     TIME        IADEM     IBDEM     ICDEM     MW3DO     FREQ
7     05/23/09 12:55:00   264.103   229.293   229.249     8.774    60.057
6     05/23/09 13:00:00   273.375   237.263   237.513     9.087    60.057
5     05/23/09 13:05:00   273.822   237.633   237.146     9.082    60.007
4     05/23/09 13:10:00   234.312   219.827   206.418     8.076    60.007
3     05/23/09 13:15:00   300.249   308.065   316.010    11.362    60.004
2     05/23/09 13:20:00   311.153   322.194   333.605    11.891    60.006
1     05/23/09 13:25:00   312.267   323.589   335.291    11.943    60.004

=>
```

If the requested load profile report rows do not exist, the relay responds:

```
No Load Profile Data
```

If the LDP memory clears while an LDP report is being displayed, the LDP report will stop and display this message:

```
Command Aborted, Data overwrite occurred
```

Via File Transfer

The LDP report is available via file transfer protocols. See *Virtual File Interface* on page 10.26.

Determining the Size of the Load Profile Buffer

The **LDP D** command displays maximum number of days of data the relay may acquire with the present settings, before data overwrite will occur.

```
=>LDP D <Enter>
There is room for a total of 45 days of data in the load profile buffer,
with room for 21 days of data remaining.
```

Clearing the Load Profile Buffer

Clear the load profile report from nonvolatile memory with the **LDP C** command as shown in the following example:

```
=>LDP C <Enter>
Clear the load profile buffer
Are you sure (Y/N) ? Y <Enter>
Clearing Complete
```

Changing the LDLIST setting will also result in the buffer being cleared.

SECTION 9

Setting the Relay

Overview

This section explains the SEL-351 settings, how to view settings, and how to modify the settings in the following subsections:

Settings specific to MIRRORED BITS communications are fully described in *Appendix H: MIRRORED BITS Communications (in Firmware Versions 6 and 7)*.

Settings specific to the Phasor Measurement Unit (Synchrophasor) operation are fully described in *Appendix N: Synchrophasors*.

Settings specific to the DNP3 Communications protocol are fully described in *Appendix L: DNP3 Communications*.

Settings specific to the Modbus Communications protocol are fully described in *Appendix O: Modbus RTU and TCP Communications*.

Other than a pair of enable settings, there are no relay settings associated with the optional IEC 61850 protocol. To configure IEC 61850, use the ACSELERATOR Architect SEL-5032 Software to create and download a CID file to the relay. For more information, see *Appendix P: IEC 61850*.

Introduction

The SEL-351 stores customer-entered settings in nonvolatile memory. Settings are divided into the following eight setting classes:

1. Global
2. Group *n* (where *n* = 1–6)
3. Logic *n* (where *n* = 1–6)
4. Report (settings for Sequential Events Recorder and Load Profile Report)
5. Text (settings for the front panel)
6. Port *n* (where *n* = 1, 2, 3, 5, or F)
7. DNP Map *n* (where *n* = 1–3)
8. Modbus Map

Some settings classes have multiple instances. For example, in the above list, there are six "setting groups" for Group and Logic settings and five Port setting instances, one for each communications port (except the optional USB port).

Settings may be viewed or modified in several ways, as shown in *Table 9.1*.

Table 9.1 Methods of Accessing Settings

	Serial Port Commands	Front-Panel Interface Set/Show Menu	QuickSet
Display Settings	All settings (**SHO** command)	Some settings[a]	All settings
Modify Settings	All settings (**SET** command)	Some settings[a]	All settings

[a] Only Global, Group, and Port n = 1, 2, 3, and F setting classes can be accessed using the front-panel.

View settings with the respective serial port **SHOW** commands (**SHO**, **SHO L**, **SHO G** , **SHO R**, **SHO T**, **SHO P**). Because the SEL-351 only uses the first three letters of a command, **SHOW** can be shortened to **SHO** as above.

See **SHO** ***(Show/View Settings)*** on page 10.68 for examples of the **SHO** command, including the SEL-351 factory default settings.

The **SET** command is described in a later subsection. *Table 9.2* lists the settings classes with a brief description, and the page numbers for the Settings Sheets included at the end of this section. The order of the setting sheets matches the numbered list, above.

See *Front-Panel Pushbutton Operation* on page 11.1 for details on accessing settings via the front-panel HMI.

See *Appendix C: PC Software* for ACSELERATOR QuickSet SEL-5030 Software information.

NOTE: Although there is no dedicated settings class for the optional USB port, the Port F settings class contains two settings that affect the USB port. See *Port Enable Settings* on page 9.27.

Table 9.2 Serial Port SET Commands (Sheet 1 of 2)

Command	Settings Type	Description	Settings Sheets[a]
SET G	Global	Battery and breaker monitors, optoisolated input debounce timers, synchrophasors, etc.	SET.1–SET.6
SET *n*	Group	Overcurrent and voltage elements, reclosing relay, timers, etc., for settings Group *n* (*n* = 1, 2, 3, 4, 5, 6).	SET.7–SET.26
SET L *n*	Logic	SELOGIC control equations for settings Group *n* (*n* = 1, 2, 3, 4, 5, 6).	SET.27–SET.34
SET R	Report	Sequential Events Recorder (SER) trigger conditions and Load Profile Recorder (LDP) settings. (LDP available only in firmware versions 6 and 7).	SET.35
SET T	Text	Front-panel default display and local control text.	SET.36–SET.39
SET P *n*	Port	Port *n* settings *n* = 1: optional EIA-485 or fiber-optic serial port *n* = 2, 3, or F: EIA-232 serial ports *n* = 5: single or optional dual Ethernet	SET.40–SET.52

Table 9.2 Serial Port SET Commands (Sheet 2 of 2)

Command	Settings Type	Description	Settings Sheets[a]
SET D *n*	DNP	DNP map *n* settings (*n* = 1, 2, or 3).	See *Appendix L*
SET M	Modbus	Modbus map settings.	See *Appendix O*

[a] Located at the end of this section.

Make Global Settings (SET G) First

Make Global settings (*Global Settings (Serial Port Command SET G and Front Panel)* on page SET.1) before making other relay settings, especially for applications that involve delta-connected or single-phase PTs, or applications requiring an external zero-sequence voltage source to be connected to the relay. Changing Global settings PTCONN or VSCONN automatically resets many of the remaining relay settings to default values and these settings will need to be re-entered.

The relay will provide two confirmation prompts prior to accepting a change to either PTCONN or VSCONN. See *Settings for Voltage Input Configuration* on page 9.18.

Settings Changes Via PC Software

QuickSet provides easy-to-use settings management tools, including the ability to develop settings off-line. This software application is a great way to transfer settings between devices, or develop new settings based on an existing settings database.

Refer to *Appendix C: PC Software* for more information on using QuickSet.

Settings Changes Via the Front Panel

The relay front-panel **SET** pushbutton provides view and modify access to the Global, Group, and Port settings only. Thus, the corresponding Global, Relay, and Port settings sheets that follow in this section can also be used when making these settings via the front panel. Refer to *Front-Panel Pushbutton Operation* on page 11.1 for information on the front-panel functions.

Settings Changes Via the Serial Port

See *Section 10: Communications* for information on serial port communications and relay access levels. The **SET** commands in *Table 9.2* operate at Access Level 2 (screen prompt: =>>). To change a specific setting, enter the command:

SET *c n* **s TERSE**

where:

c = *class*:

(G, 1–6, L, R, T, P, D, or M) Choices 1–6 select the Group (relay) settings 1 through 6. If *class* is not specified, the relay selects the Group settings for the active settings group.

n = *instance number* (only valid for class L, P, and D):

- (1–6) for *c* = L (logic) class. If *n* is not specified, the relay selects the logic settings from the active settings group.
- (1, 2, 3, 5, or F) for *c* = P (port) class. If *n* is not specified, the relay selects the present port. If this session is via the USB port, *n* must be specified.
- (1–3) for *c* = D (DNP) class. If *n* is not specified, the relay selects DNP map 1.

s = setting name to jump to at start of session.

Enter the name of the setting you want to jump to and begin session. If *s* is not specified, the relay starts from the first setting.

TERSE = instructs the relay to skip the **SHO** display after the last setting. Use this parameter to speed up the **SET** command. If you want to review the settings before saving, do not use the TERSE option.

When you issue the **SET** command, the relay presents a list of settings, one at a time. Enter a new setting, or press **<Enter>** to accept the existing setting. Editing keystrokes are shown in *Table 9.3*.

Table 9.3 Set Command Editing Keystrokes

Press Key(s)	Results
<Enter>	Retains setting and moves to the next setting.
^ <Enter>	Returns to previous setting.
< <Enter>	Returns to previous setting section.
> <Enter>	Moves to next setting section.
End <Enter>	Exits editing session, then prompts you to save the settings.
<Ctrl+X>	Aborts editing session without saving changes.
\ <Enter>	Allows text entry to be continued on next line. The \ symbol must appear at the end of a line, just before pressing **<Enter>**.

The relay checks each entry to ensure that it is within the setting range. If it is not, an `Out of Range` message is generated, and the relay prompts for the setting again.

At the end of the setting session, the relay displays the new settings and prompts for approval to save them. Answer **Y <Enter>** to save the new settings. The relay performs a final check of all settings, and if no problems are detected, the settings are saved to nonvolatile memory. If a problem is detected, the settings are not saved and the relay indicates a setting that needs attention. This final check ensures that settings from every class are compatible with the recent settings edit.

Settings Change Confirmation

If changes are made to Global, Report, or Text settings, or to the Group or Logic settings for the active settings group (see *Table 9.2*), the relay is disabled for less than two seconds while it saves the new settings. The **EN** LED extinguishes (see *Table 5.3*) while the relay is disabled. Relay Word bit SETCHG pulses for approximately one second to indicate that the settings have changed.

If changes are made to the Group or Logic Settings for a setting group other than the active setting group, or to Port, DNP maps, or Modbus map settings (see *Table 9.2*), the relay is not disabled while it saves the new settings. Relay Word bit SETCHG pulses for approximately one second, but the **EN** LED remains on (see *Table 5.3*) while the new settings are saved.

Time-Overcurrent Curves

The following information describes the curve timing for the curve and time-dial settings made for the time-overcurrent elements (see *Figure 3.14–Figure 3.21*). The U.S. and IEC time-overcurrent relay curves are shown in *Figure 9.1 – Figure 9.10*

where:

T_p = Operating time in seconds

T_R = Electromechanical induction-disk emulation reset time in seconds (if you select electromechanical reset setting)

TD = Time-dial setting

M = Applied multiples of pickup current [for operating time (T_p), $M > 1$; for reset time (T_R), $M \le 1$]

Table 9.4 Equations Associated With U.S. Curves

Curve Type	Operating Time	Reset Time	Figure
U1 (Moderately Inverse)	$T_p = TD \bullet \left(0.0226 + \frac{0.0104}{M^{0.02} - 1}\right)$	$T_R = TD \bullet \left(\frac{1.08}{1 - M^2}\right)$	*Figure 9.1*
U2 (Inverse)	$T_p = TD \bullet \left(0.180 + \frac{5.95}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{5.95}{1 - M^2}\right)$	*Figure 9.2*
U3 (Very Inverse)	$T_p = TD \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{3.88}{1 - M^2}\right)$	*Figure 9.3*
U4 (Extremely Inverse)	$T_p = TD \bullet \left(0.0352 + \frac{5.67}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{5.67}{1 - M^2}\right)$	*Figure 9.4*
U5 (Short-Time Inverse)	$T_p = TD \bullet \left(0.00262 + \frac{0.00342}{M^{0.02} - 1}\right)$	$T_R = TD \bullet \left(\frac{0.323}{1 - M^2}\right)$	*Figure 9.5*

Table 9.5 Equations Associated With IEC Curves

Curve Type	Operating Time	Reset Time	Figure
C1 (Standard Inverse)	$T_p = TD \bullet \left(\frac{0.14}{M^{0.02} - 1}\right)$	$T_R = TD \bullet \left(\frac{13.5}{1 - M^2}\right)$	*Figure 9.6*
C2 (Very Inverse)	$T_p = TD \bullet \left(\frac{13.5}{M - 1}\right)$	$T_R = TD \bullet \left(\frac{47.3}{1 - M^2}\right)$	*Figure 9.7*
C3 (Extremely Inverse)	$T_p = TD \bullet \left(\frac{80}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{80}{1 - M^2}\right)$	*Figure 9.8*
C4 (Long-Time Inverse)	$T_p = TD \bullet \left(\frac{120}{M - 1}\right)$	$T_R = TD \bullet \left(\frac{120}{1 - M}\right)$	*Figure 9.9*
C5 (Short-Time Inverse)	$T_p = TD \bullet \left(\frac{0.05}{M^{0.04} - 1}\right)$	$T_R = TD \bullet \left(\frac{4.85}{1 - M^2}\right)$	*Figure 9.10*

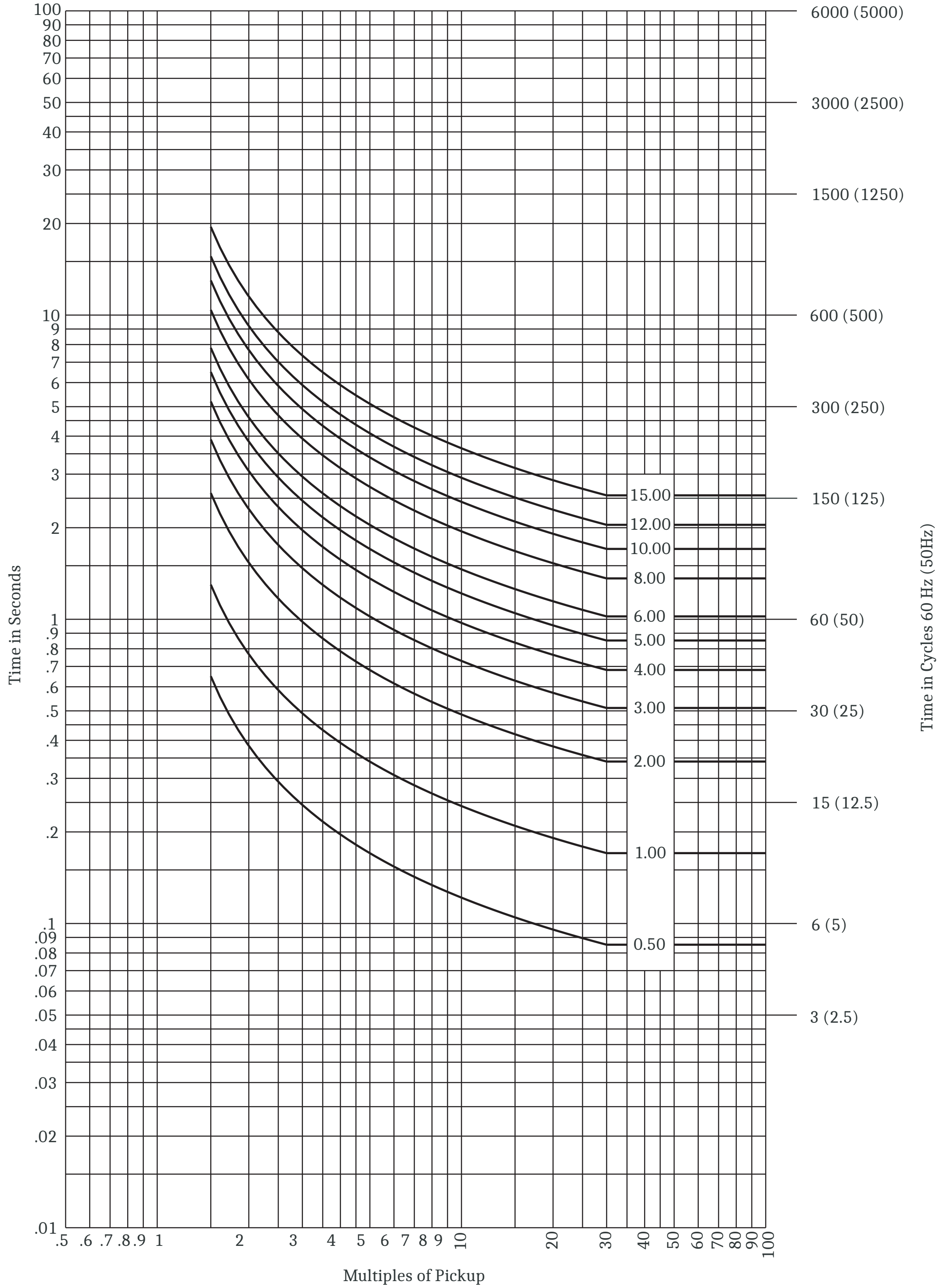

Figure 9.1 U.S. Moderately Inverse Curve: U1

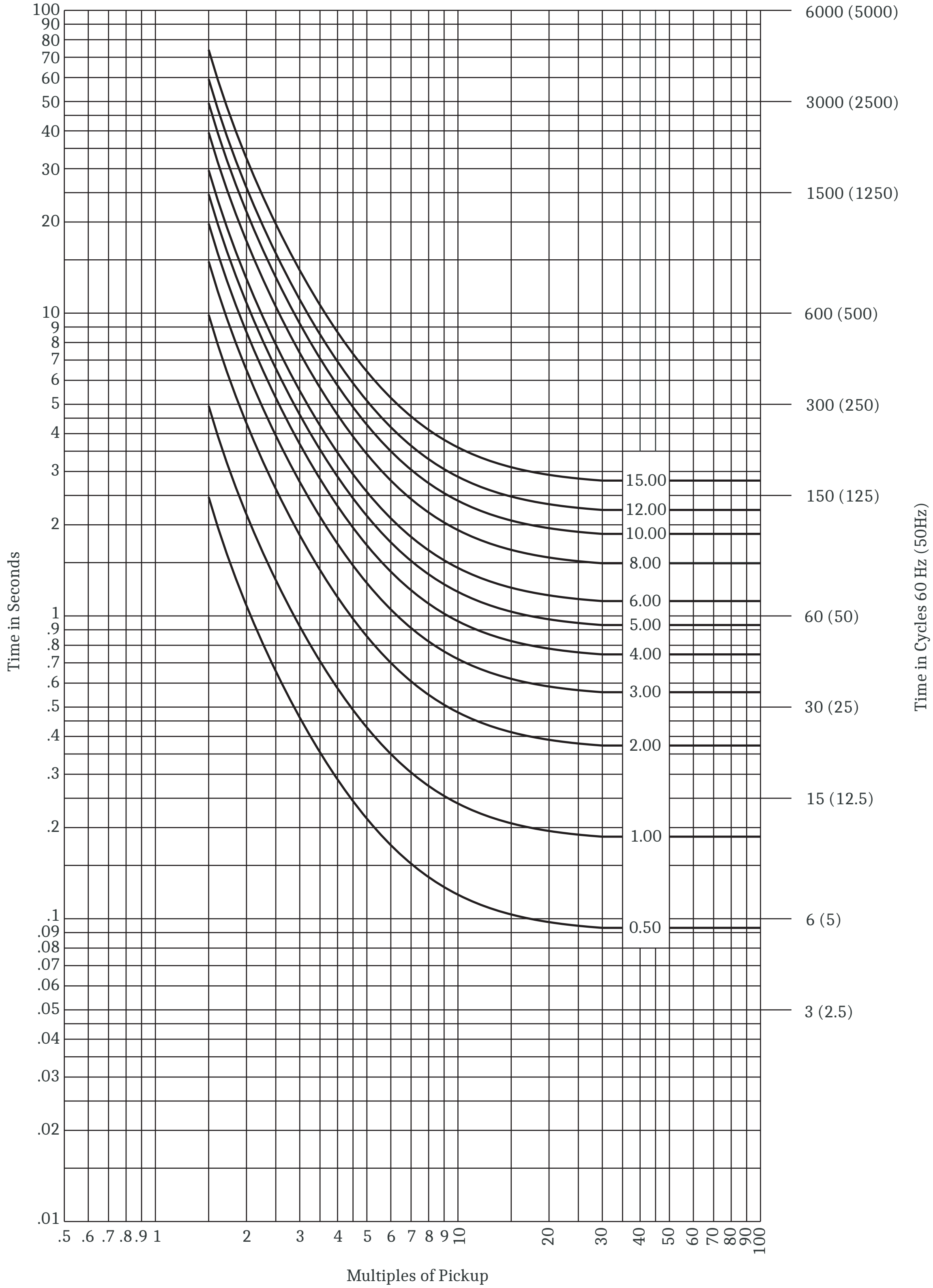

Figure 9.2 U.S. Inverse Curve: U2

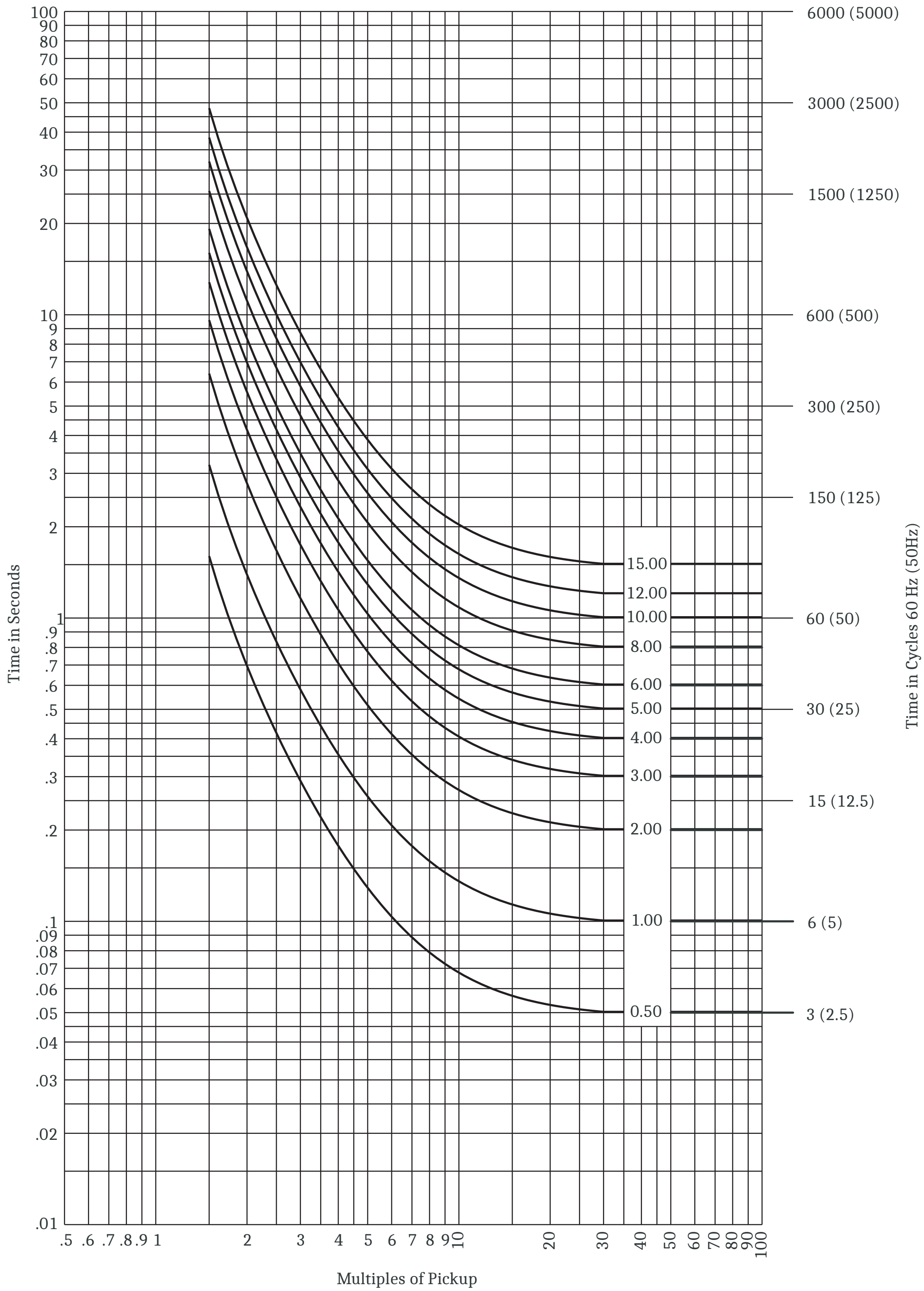

Figure 9.3 U.S. Very Inverse Curve: U3

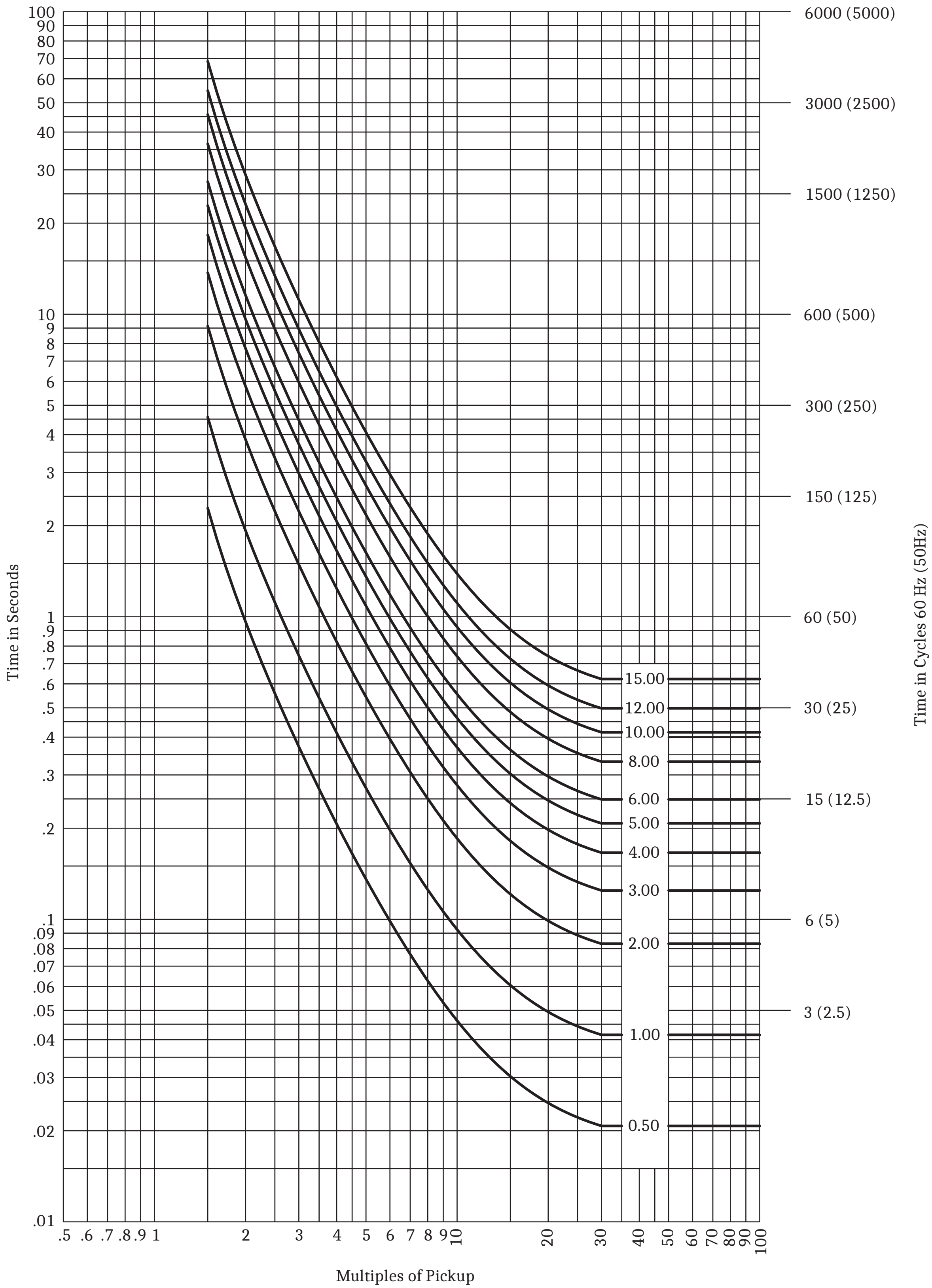

Figure 9.4 U.S. Extremely Inverse Curve: U4

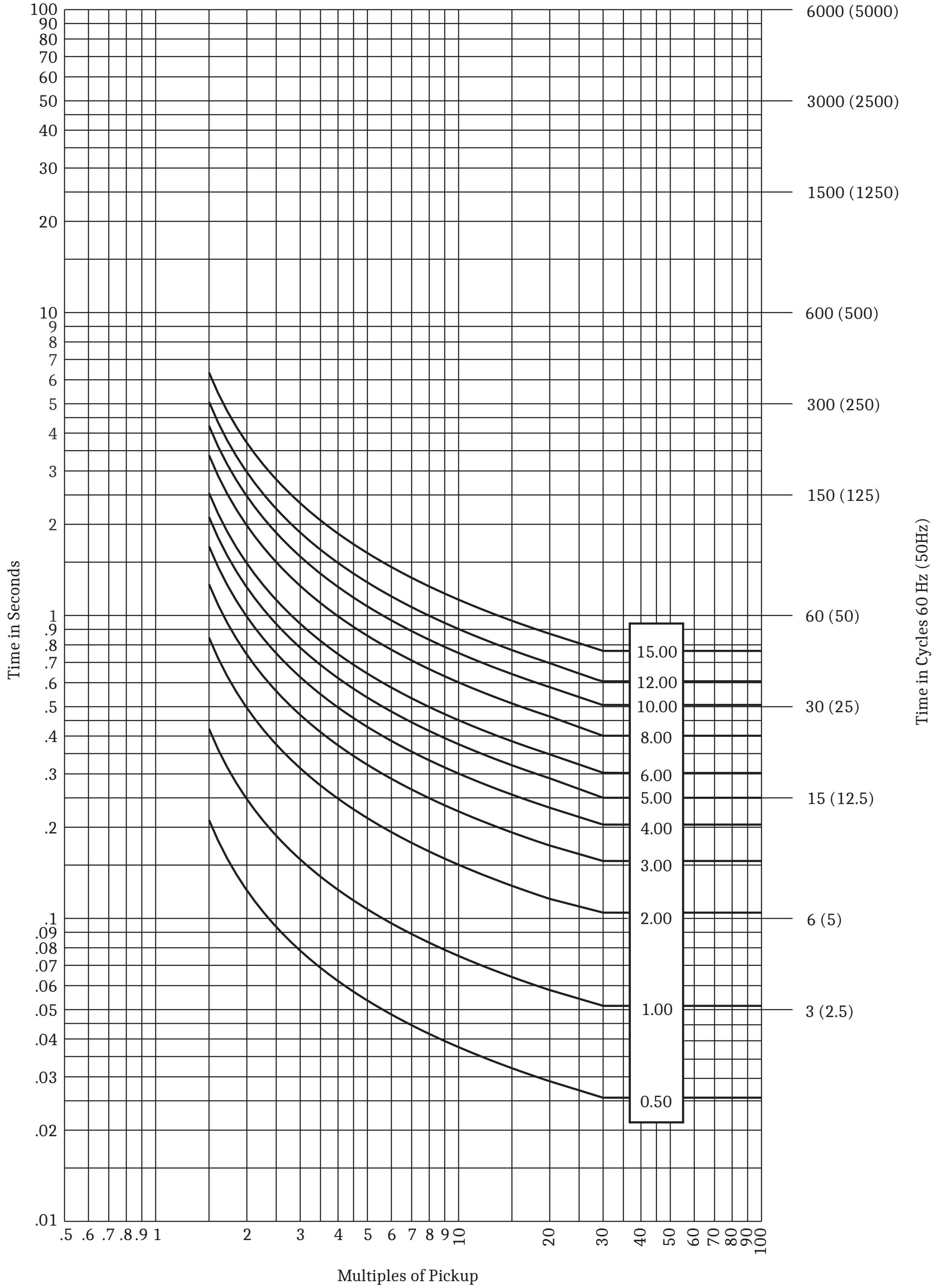

Figure 9.5 U.S. Short-Time Inverse Curve: U5

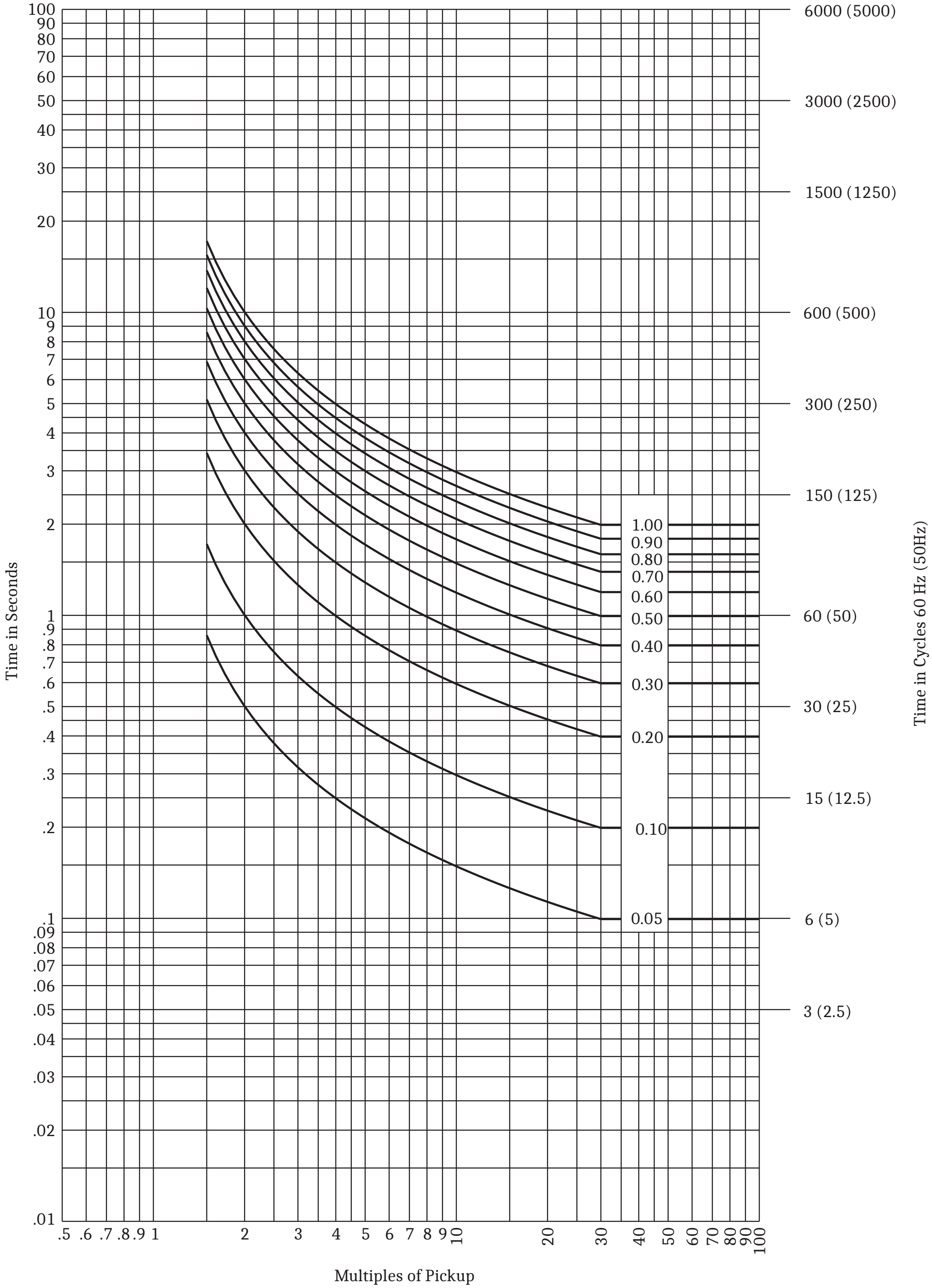

Figure 9.6 IEC Class A Curve (Standard Inverse): C1

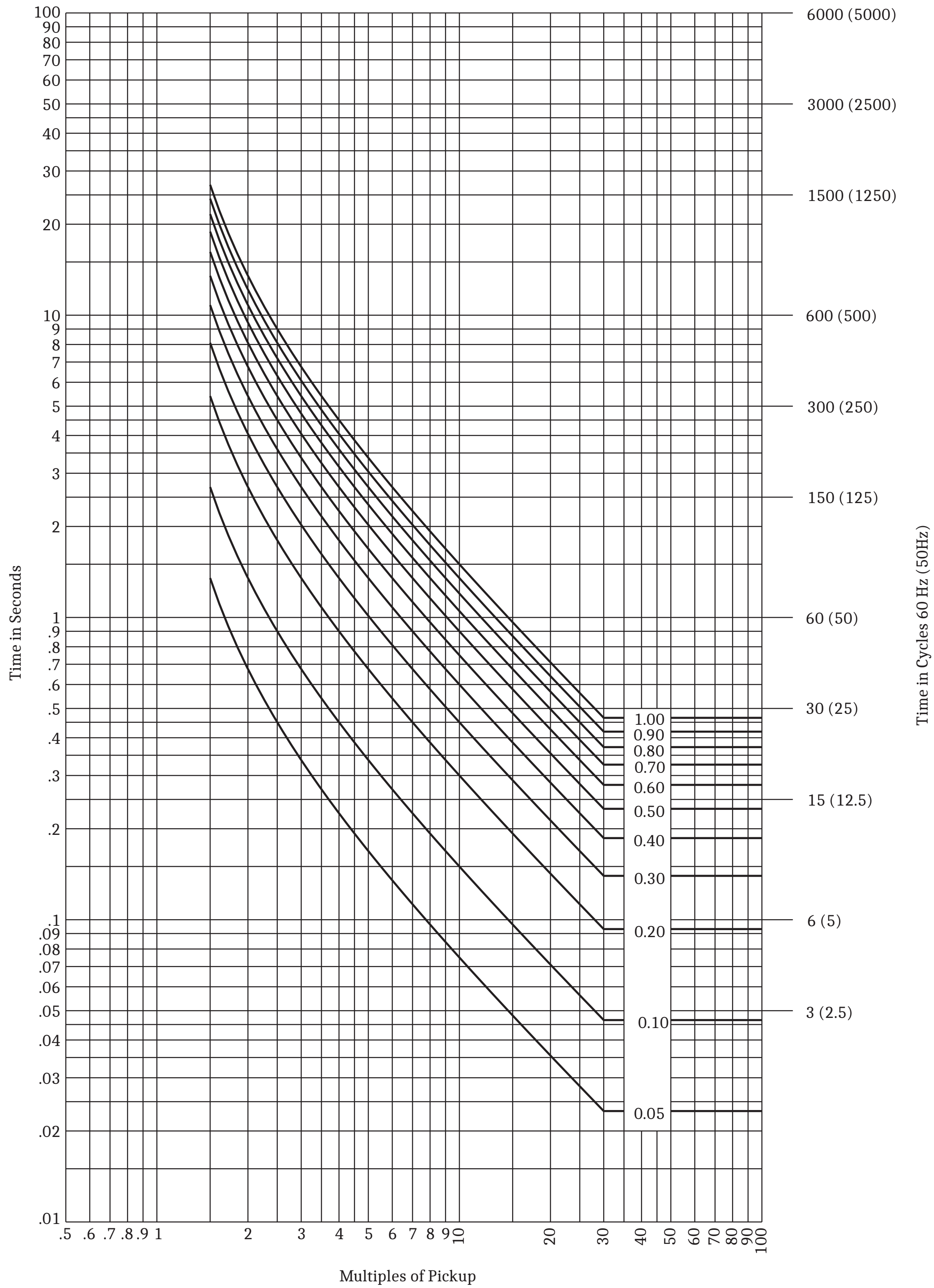

Figure 9.7 IEC Class B Curve (Very Inverse): C2

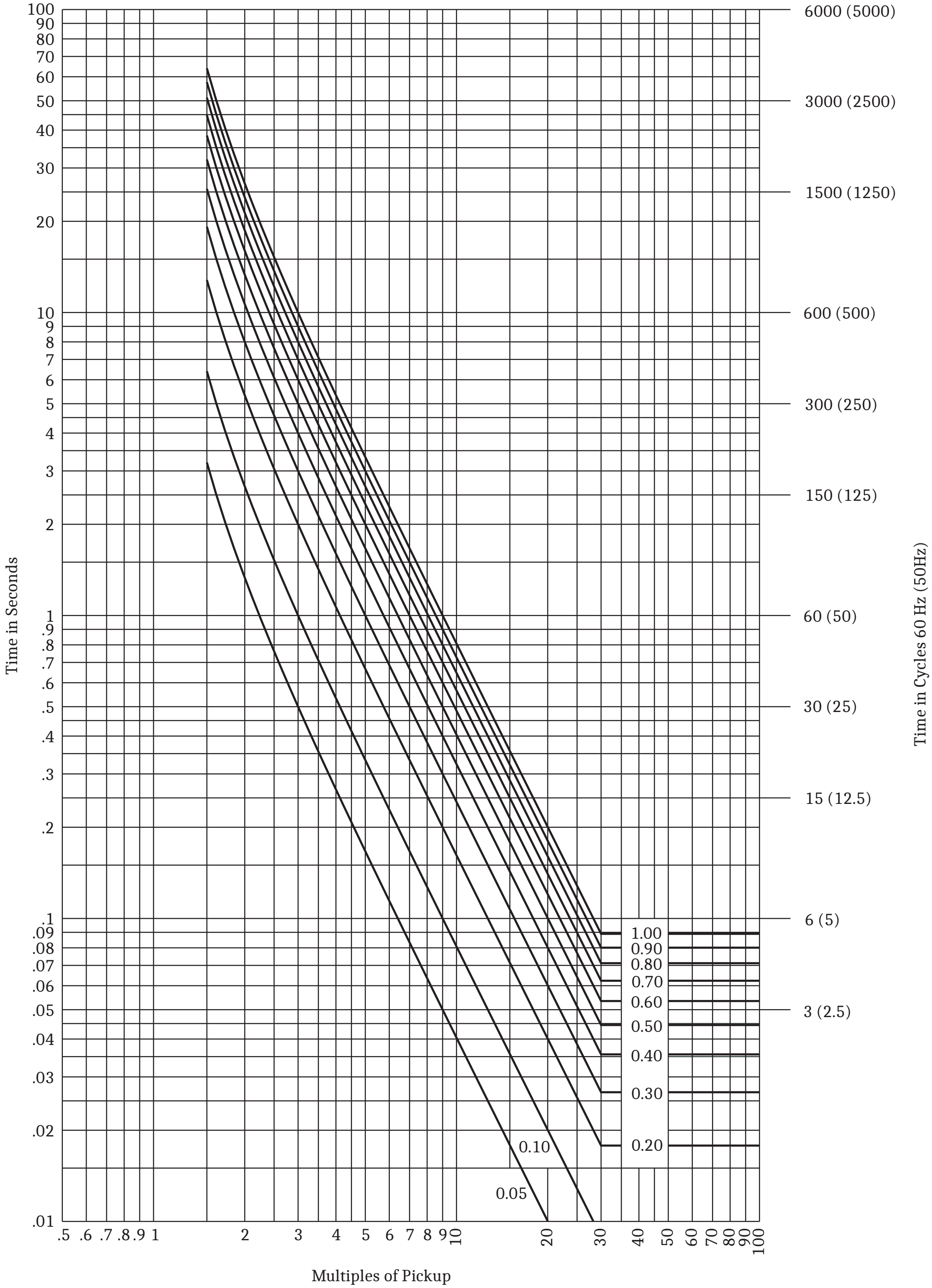

Figure 9.8 IEC Class C Curve (Extremely Inverse): C3

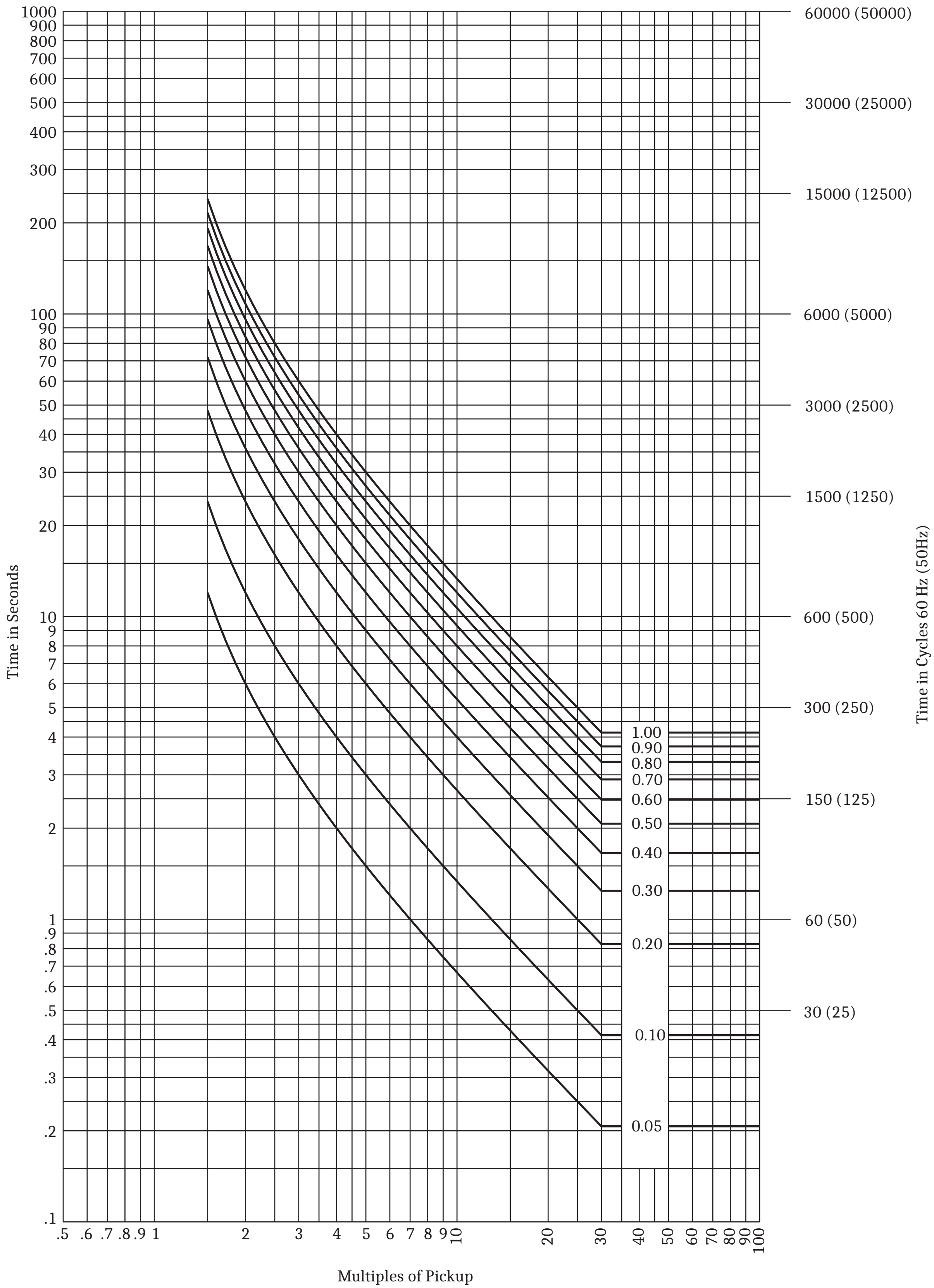

Figure 9.9 IEC Long-Time Inverse Curve: C4

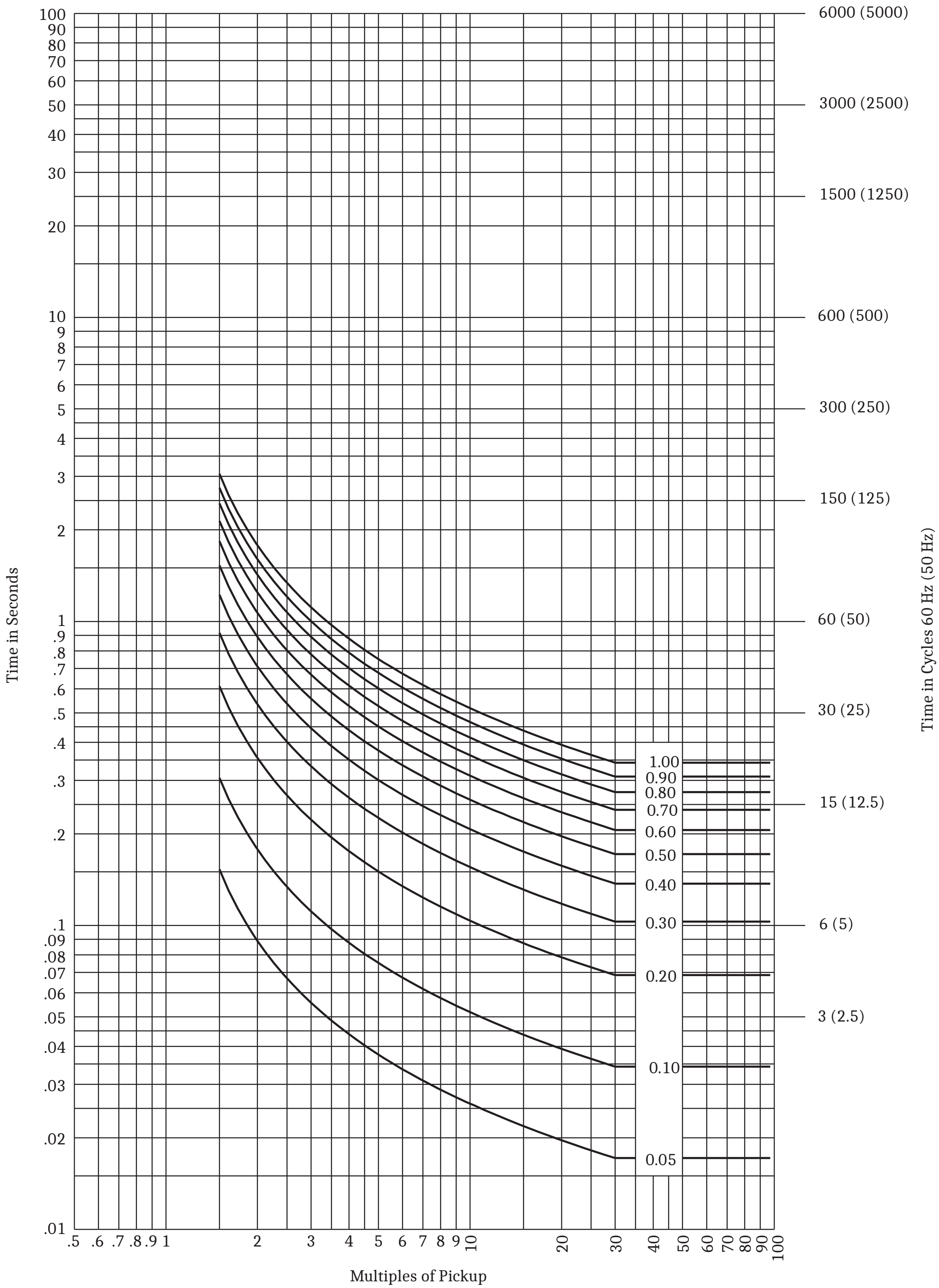

Figure 9.10 IEC Short-Time Inverse Curve: C5

Settings Explanations

Note that most of the settings in the settings sheets that follow include references for additional information. The following explanations are for settings that do not have reference information anywhere else in the instruction manual.

Identifier Labels

Refer to *Identifier Labels (see Identifier Labels on page 9.17)* on page SET.6.

The SEL-351 Relay has two identifier labels:

- the Relay Identifier (RID)
- the Terminal Identifier (TID)

The Relay Identifier is typically used to identify the relay or the type of protection scheme. Typical Terminal Identifiers include an abbreviation of the substation name and line terminal.

The relay tags each report (event report, meter report, etc.) with the Relay Identifier and Terminal Identifier. This allows you to distinguish the report as one generated for a specific breaker and substation.

RID and TID settings may include the following characters: 0–9, A–Z, -, /, ., space. These two settings cannot be made via the front-panel interface.

Current Transformer Ratios

Refer to *Current and Potential Transformer Ratios (see Settings Explanations on page 9.17)* on page SET.6.

Phase and neutral current transformer ratios are set independently. If neutral channel IN is connected residually with IA, IB, and IC, then set CTR and CTRN the same. Relay settings CTR and CTRN are used in relay event reports and metering functions to scale secondary current quantities into primary values.

For directional control on low-impedance grounded, Petersen Coil-grounded, and ungrounded/ high-impedance grounded systems, neutral channel IN is usually connected to a core-balance current transformer that encompasses the three phases (see *Figure 2.23–Figure 2.26*). This type of current transformer typically has a lower ratio than the phase current transformers, which allows for more sensitivity in ground fault detection. Core-balance current transformers are also used for nondirectional sensitive earth fault (SEF) protection (see *Figure 2.21*).

CT Sizing

Sizing a CT to avoid saturation for the maximum asymmetrical fault is ideal, but not always possible. This requires a CT ANSI voltage classification greater than (1 + X/R) times the burden voltage for the maximum symmetrical fault current, where X/R is the reactance-to-resistance ratio of the primary system.

The SEL-351 phase instantaneous overcurrent elements have an adaptive overcurrent algorithm, which is designed to help with saturated CT conditions. This is explained in *CT Saturation Protection* on page 3.7.

The phase instantaneous overcurrent elements work well with a variety of current transformers and high fault currents. SEL Application Guide *AG2005-04, Current Transformer Selection Criteria for Relays with Adaptive Overcurrent Elements*, available on the SEL website, explains how to select current transformers for use with the relay. Selecting CTs in accordance with these criteria ensures a two-cycle trip of an instantaneous element set at 80 A. While careful CT selection is important in all applications, take special care with low ratio current transformers (100/5 or less), low accuracy current transformers (C20 or less), or high fault currents (50kA or more).

Settings for Voltage Input Configuration

The SEL-351 has three Global settings and one Group setting related to the voltage connection to the power system. These provide flexibility by allowing the relay to be connected to potential transformers in several configurations, as explained below. *Table 9.6* through *Table 9.9* and *Figure 9.11* summarize the relay differences for each of these settings.

Refer to *Global Settings (Serial Port Command SET G and Front Panel)* on page SET.1.

PTCONN = (DELTA, WYE, SINGLE) selects the configuration for the voltage terminals **VA**, **VB**, **VC**, and **N**. See *Delta-Connected Voltages (Global Setting PTCONN = DELTA)* on page 2.12 for connection details.

- PTCONN = WYE is the factory default setting, and is the proper choice for connecting to systems with (three) wye-connected PTs. When selected, Relay Word bit WYE asserts, as shown in *Figure 9.11*.
- PTCONN = DELTA configures the relay for connection to (two) open-delta connected PTs. Some relay elements are unavailable when PTCONN = DELTA. When selected, Relay Word bit DELTA asserts, as shown in *Figure 9.11*.

NOTE: For relay installations with no voltage connection, setting PTCONN = SINGLE simplifies the setting procedure by hiding several settings.

- PTCONN = SINGLE configures the relay for connection to a single PT, or no voltage connection. Several relay settings and elements are unavailable when PTCONN = SINGLE. Global setting PHANTV is only available when PTCONN = SINGLE. When selected, Relay Word bit SINGLE asserts, as shown in *Figure 9.11*. Several Group enable settings are hidden from view when PTCONN = SINGLE, which can simplify the development of relay settings. The affected Group settings are listed in *Table 9.8*.

PHANTV = (VA, VB, VC, VAB, VBC, VCA, OFF), only accessible when PTCONN = SINGLE, selects the reference phase for the phantom metering function, or disables the feature. PHANTV only affects the metering function in the SEL-351, and is fully described in *Phantom Metering for Single-Phase Voltage Connections* on page 8.24.

- PHANTV = OFF is the factory default setting, and is also the setting value when PHANTV is unavailable (i.e., when PTCONN = WYE or DELTA).
- PHANTV = VA, VB, or VC configures the SEL-351 metering functions to interpret the voltage source connected to the **VA-N** terminals as line-to-neutral voltage V_A, V_B, or V_C, respectively, and create a balanced set of three-phase voltages for metering functions.

- PHANTV = VAB, VBC, or VCA configures the SEL-351 metering functions to interpret the voltage source connected to the **VA-N** terminals as line-to-line voltage V_{AB}, V_{BC}, or V_{CA}, respectively, and create a balanced set of three-phase voltages for metering functions.

VSCONN = (VS, 3V0) selects the configuration for the voltage terminals **VS-NS**. See *Potential Transformer Inputs* on page 2.11 for wiring details.

- VSCONN = VS is the factory default setting, and is the proper choice for applications that have a synchronizing reference voltage, or no voltage connected to the **VS-NS** terminals.
- VSCONN = 3V0 configures the relay to accept a zero-sequence voltage connection on the **VS-NS** terminals. This type of configuration is for broken-delta connected PTs, and is normally used in conjunction with Directional Sensitive Earth Fault (DSEF) elements, selected by Group setting ORDER = P, S, or U (see *Directional Control for Neutral-Ground and Residual-Ground Overcurrent Elements* on page 4.14). Some relay functions are unavailable when VSCONN = 3V0. When selected, Relay Word bit 3V0 asserts, as shown in *Figure 9.11*.

Refer to *Group n (Relay) Settings (Serial Port Command SET n and Front Panel)* on page SET.6.

VNOM = (OFF, 25.00–300.00 V sec) selects the nominal system voltage, as seen by the relay inputs **VA**, **VB**, **VC**, and **N** in V secondary. The relay uses this setting to determine the thresholds for the loss-of-potential logic, and the exact value entered does not affect metering or protection accuracy.

- VNOM = 67.00 is the factory default setting when PTCONN = WYE. Enter the nominal line-to-neutral secondary voltage of your system.
- VNOM = 116.05 is the factory default setting when PTCONN = DELTA. Enter the nominal line-to-line secondary voltage of your system.
- VNOM = OFF specifies that three-phase voltages have not been connected to the relay. This setting choice is not often manually entered, because the VNOM setting is not displayed when PTCONN = SINGLE, and is internally set to OFF. Several related Group settings are disabled by setting VNOM = OFF, including any elements that rely on calculated positive-, negative-, or zero-sequence voltage. These settings are not displayed when PTCONN = SINGLE. See *Table 9.8* and *Table 9.9* for a listing of affected settings.

Table 9.6 Main Relay Functions That Change With VSCONN, When PTCONN = WYE (Sheet 1 of 2)

Relay Function	When VSCONN=VS	When VSCONN=3V0
Zero-sequence voltage-polarized ground directional elements (ORDER setting choices “V”, “S”, and “U”)	Uses $3V_0$ calculated from V_A, V_B, V_C.	Uses V_S • (PTRS/PTR) as $3V_0$[a].
Wattmetric and incremental conductance elements (ORDER setting choice “P”).	Uses $3V_0$ calculated from V_A, V_B, V_C	Uses V_S • (PTRS/PTR) as $3V_0$[a].
Synchronism-check elements	Available	Not available
Three-phase power elements (EPWR = 3P1–3P4). See *Power Elements* on page 3.71.	No difference Uses a three-phase power formula, including $3V_0$ calculated from V_A, V_B, V_C.	

Table 9.6 Main Relay Functions That Change With VSCONN, When PTCONN = WYE (Sheet 2 of 2)

Relay Function	When VSCONN=VS	When VSCONN=3V0
Three-phase power metering (MW3P, MVAR3P, etc.)	No difference Uses the sum of the single-phase power calculations from V_A, V_B, V_C, I_A, I_B, I_C (primary values).	
Quantity "3V0" in Metering, Fast Meter, Load Profile Recorder (LDP), and Distributed Network Protocol (DNP).	No difference Uses $3V_0$ calculated from V_A, V_B, V_C (primary value).	
Quantity "VS" in Metering, Fast Meter, Load Profile, and DNP.	No difference Uses V_S as VS (primary value).	

[a] The PTRS/PTR adjustment brings the broken-delta $3V_0$ quantity to the same base voltage as the relay impedance settings, which are based on the V_A, V_B, V_C voltage base.

Table 9.7 Main Relay Functions That Change With VSCONN, When PTCONN = DELTA

Relay Function	When VSCONN=VS	When VSCONN=3V0
Zero-sequence voltage-polarized ground directional elements (ORDER setting choices "V", "S", and "U")	Not available	Uses VS • (PTRS/PTR) as $3V_0$[a].
Wattmetric and incremental conductance elements (ORDER setting choice "P")	Not available	Uses VS • (PTRS/PTR) as $3V_0$[a].
Synchronism-check elements	Available	Not available
Three-phase power elements (EPWR = 3P1–3P4). See *Power Elements* on page 3.71.	Uses a three-phase power formula, without $3V_0$[b].	Uses a three-phase power formula, including VS • (PTRS/PTR) as $3V_0$[c].
Three-phase power metering (MW3P, MVAR3P, etc.)	Uses a three-phase power formula, without $3V_0$ (primary value)[b].	Uses a three-phase power formula, including VS as $3V_0$ (primary value).
Quantity "3V0" in Metering, Fast Meter, Load Profile Recorder (LDP), Modbus, and Distributed Network Protocol (DNP)	No difference "3V0" is not shown or not available in **METER** command and LDP. Fast Meter, Modbus, and DNP return 3V0 = 0.00 kV	
Quantity "VS" in Metering, Fast Meter, Load Profile, Modbus, and DNP	No difference Uses V_S as VS (primary value)	

[a] The PTRS/PTR adjustment brings the broken-delta $3V_0$ quantity to the same base voltage as the relay impedance settings, which are based on the V_A, V_B, V_C voltage base.

[b] The three-phase power formula requires a $3V_0$ quantity to correct for any unbalanced conditions. In both cases noted in this table, the metering or power element accuracy will be reduced in conditions of system unbalance.

[c] The PTRS/PTR adjustment brings the broken-delta $3V_0$ quantity to the same base voltage as the relay phase voltages.

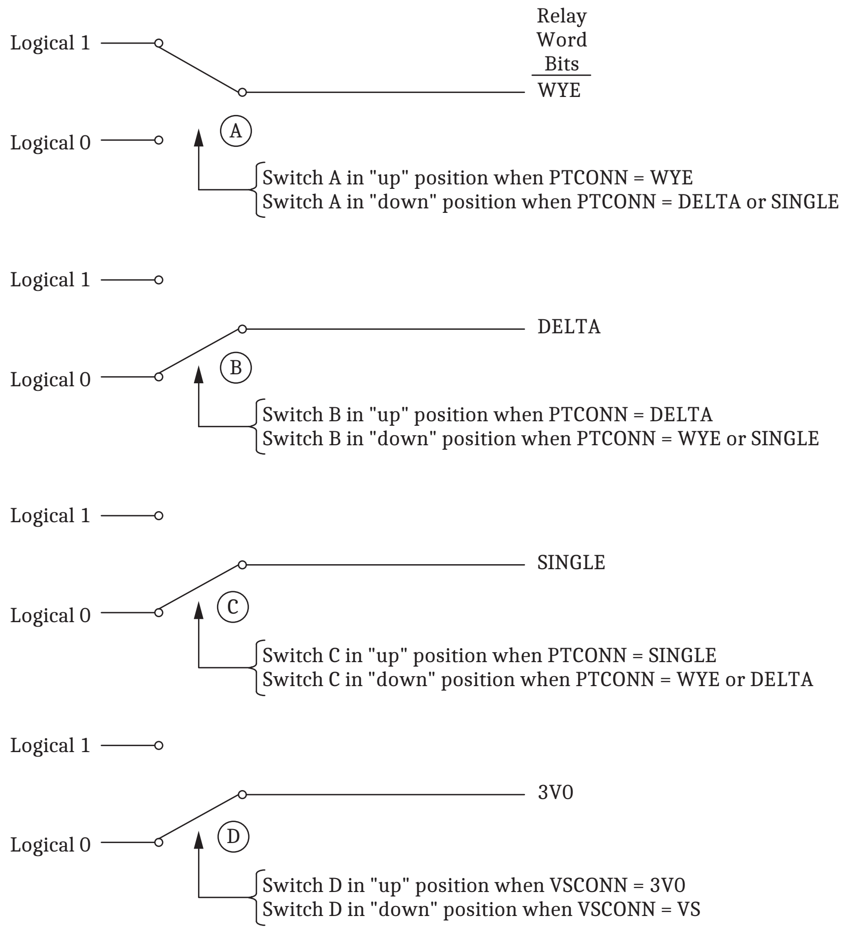

Figure 9.11 Operation of WYE, DELTA, SINGLE, and 3V0 Relay Word Bits

Table 9.8 Effect on Group Settings When PTCONN = SINGLE (Sheet 1 of 2)

Group Setting	Change	Reason
Identifier and Instrument Transformer Settings		
VNOM	Forced to OFF and hidden	Loss-of-Potential logic requires three-phase voltage.
Line Parameter Settings		
Z1MAG, Z1ANG, Z0MAG, Z0ANG, Z0SMAG, Z0SANG	Hidden	Impedance calculations require three-phase voltage.
Enable Settings		
E32	Setting may be forced to OFF and hidden	See VNOM = OFF columns of *Table 4.9* for details.
ELOAD, EFLOC, ELOP, ECOMM, ESSI	Forced to N and hidden	These functions require three-phase voltage.
EPWR	3P1–3P4 removed from setting range	The three-phase power elements require three-phase voltage.
Directional Element Settings (available when E32 = Y)		
ORDER	Q removed from setting range	Associated directional element requires three-phase voltage.
50P32P, Z2F, Z2R, a2, k2, 50QFP, 50QRP	Hidden	Associated directional elements require three-phase voltage.

Table 9.8 Effect on Group Settings When PTCONN = SINGLE (Sheet 2 of 2)

Group Setting	Change	Reason
Voltage Element Settings (available when EVOLT = Y)		
59N1P, 59N2P, 59QP, 59Q2P, 59V1P, 27PP, 27PP2P, 59PP, 59PP2P	Forced to OFF and hidden	Associated voltage elements require three-phase voltage.
Synchronism-Check Element Settings (available when E25 = Y)		
SYNCP	VA, VB, VC removed from setting range	See *Setting SYNCP* on page 3.37.

Table 9.9 Main Relay Functions That Change With VNOM = OFF

Relay Function	When VNOM = Numeric Value	When VNOM = OFF
Undervoltage block for frequency elements: 27B81 (*Figure 3.35* and *Figure 3.36*)	Requires three voltages to be greater than setting 27B81P in order to deassert	Requires only voltage VA-N to be greater than setting 27B81P in order to deassert
Load-encroachment logic (enable setting ELOAD)	Available	Not available
Negative-sequence and positive-sequence voltage-polarized directional elements	Available	32QE is disabled, F32P/R32P disabled, ground directional element ORDER setting choice “Q” not selectable
Phase and negative-sequence element directional control (*Figure 4.28–Figure 4.29*)	Available	Not available (defaults to “nondirectional” in levels DIR1–DIR4)
Loss-of-Potential Logic (enable setting ELOP)	Available	Not available; Output Relay Word bits disabled (LOP = logical 0, V1GOOD = logical 0)

Potential Transformer Ratios and PT Nominal Secondary Voltage Settings

Refer to *Current and Potential Transformer Ratios (see Settings Explanations on page 9.17)* on page SET.6.

Relay setting PTR is the overall potential ratio from the primary system to the relay phase voltage inputs **VA-VB–VC-N**. For example, on a 12.5 kV phase-to-phase primary system with wye-connected 7200:120 V PTs, the correct PTR setting is 60. For the same 12.5 kV system connected through 12470:115 V PTs in an open-delta configuration (Global setting PTCONN = DELTA, and the relay wired as shown in *Figure 2.27*), the correct PTR setting is 108.44.

NOTE: When PTCONN = SINGLE, the PTR setting is applied to all three voltage inputs (from the VA, VB, and VC terminals), even if a signal is not connected to all of them. This is visible in event reports, when the **VA**, **VB**, and **VC** analog values report what is actually measured on the terminals, scaled by PTR into kV primary.

Single-phase voltage connections follow the same rationale. For example, with a single-phase voltage connection to the **VA-N** terminals (PTCONN = SINGLE) from a 12.5 kV phase-to-phase primary system with a line-neutral connected 7200:120 V PT, the correct PTR setting is 60. For the same 12.5 kV system connected through 12470:115 V PTs in a line-to-line configuration to the **VA-N** terminals (PTCONN = SINGLE), the correct PTR setting is 108.44.

Relay setting PTRS is the overall potential ratio from the synchronizing or broken-delta voltage source to the relay **VS-NS** voltage inputs. For example, in a synchronism-check application (Global setting VSCONN = VS), with phase-to-ground voltage connected from a 12.5 kV phase-to-phase primary system through a 7200:120 V PT, the correct PTRS setting is 60.

In an application that uses a broken-delta PT connection to create a $3V_0$ zero-sequence voltage signal (Global setting VSCONN = 3V0, and the relay **VS-NS** terminals wired as shown in *Figure 2.26*), the step-down transformer, if present, must also be included in the overall PTRS ratio calculation. For example, if there are three PTs connected wye (primary)/broken delta (secondary) with ratios of 7200:120, and a 400:250 step-down instrumentation transformer in the circuit, the correct PTRS setting is 60 • 1.6 = 96.00.

Settings PTR and PTRS are used in event report and **METER** commands so that power system values can be reported in primary units.

Settings PTR and PTRS are also used when Global setting VSCONN = 3V0, to scale the measured VS voltage into the same voltage base as voltage inputs VA-VB–VC-N for certain functions, as shown in *Table 9.6* and *Table 9.7*. If no PTs are connected to voltage inputs VA-VB-VC-N, make setting PTR the same value as setting PTRS.

The ratio of the PTRS and PTR settings (PTRS/PTR) must be less than 1000 and greater than 0.001 when VSCONN = 3V0.

Relay setting VNOM is the nominal secondary voltage connected to voltage inputs VA-VB–VC-N. For wye-connected PTs, VNOM is a phase-to-neutral secondary voltage value. For open-delta connected PTs, VNOM is a phase-to-phase secondary voltage value.

For example, for a 10 kV (phase-to-phase) system with wye-connected PTs rated 7200:120 V (PTR = 60), the setting for VNOM would be:

$$10000\ \text{V}/(\sqrt{3} \cdot 60) = 96.22\ \text{V}$$

For a 12.5 kV (phase-to-phase) system with open-delta connected PTs rated 14000:115 V (PTR = 121.74), the setting for VNOM would be

$$12500\ \text{V}/121.74 = 102.68\ \text{V}$$

In the loss-of-potential logic (see *Figure 4.1* and accompanying text), setting VNOM scales certain voltage thresholds for voltage measurement comparisons. In *Table 9.9*, a setting of VNOM = OFF is shown to disable/turn-off a number of features. Effectively, setting VNOM = OFF signifies that a full three-phase voltage source is not connected to voltage inputs VA-VB–VC-N. Even with VNOM = OFF, voltage can still be connected to voltage inputs VA-VB–VC-N (e.g., single-phase voltage connected to voltage input VA-N), as discussed in the top of *Table 9.9* (for the undervoltage block for frequency elements) and demonstrated in *Figure 2.28*.

The SEL-351 automatically sets VNOM = OFF and hides the setting when Global setting PTCONN = SINGLE. See *Table 9.8* for a summary of the other changes caused by PTCONN = SINGLE.

Time and Date Management Settings

The SEL-351 supports several methods of updating the relay date and time.

For IRIG-B and Phasor Measurement Unit (PMU) synchrophasor applications, refer to *Configuring High-Accuracy Timekeeping* on page N.28.

For Simple Network Time Protocol (SNTP) applications, refer to *Simple Network Time Protocol (SNTP)* on page 10.17.

For time update from a DNP Master, see *Time Synchronization* on page L.9.

Coordinated Universal Time (UTC) Offset Setting

The SEL-351 has a Global setting UTC_OFF, settable from –24.00 to 24.00 hours, in 0.01 hour increments.

The relay HTTP (Web) Server uses the UTC_OFF setting to calculate UTC time-stamps in request headers.

The relay also uses the UTC_OFF setting to calculate local (relay) time from the UTC source when configured for Simple Network Time Protocol (SNTP) updating via Ethernet. When a time source other than SNTP is updating the relay time, the UTC_OFF setting is not considered because the other time sources are defined as local time. When using IEEE C37.118-compliant IRIG-B signals (Global setting IRIGC = C37.118), the relay uses the UTC-to-local time offset provided as part of the time message to determine the local time. If the IRIG signal is lost, Global setting UTC_OFF is used.

Set UTC_OFF properly even if you expect some other time source, such as IRIG-B, to correct for the offset. If the time source fails, the relay will revert to SNTP or internal time, and UTC_OFF will allow the relay to record and report the correct local time. If UTC_OFF is not set properly, some relay reports may show unexpected results.

Automatic Daylight-Saving Time Settings

The SEL-351 can automatically switch to and from daylight-saving time, as specified by the eight Global settings DST_BEGM through DST_ENDH. The first four settings control the month, week, day, and time that daylight-saving time commences, while the last four settings control the month, week, day, and time that daylight-saving time ceases.

Once configured, the SEL-351 will change to and from daylight-saving time every year at the specified time. Device Word bit DST asserts when daylight saving time is active.

The SEL-351 interprets the week number settings DST_BEGW and DST_ENDW (1–3, L = Last) as follows:

- ➤ The first seven days of the month are considered to be in week 1.
- ➤ The second seven days of the month are considered to be in week 2.
- ➤ The third seven days of the month are considered to be in week 3.
- ➤ The last seven days of the month are considered to be in week “L”.

This method of counting the weeks allows easy programming of statements like “the first Sunday”, “the second Saturday”, or “the last Tuesday” of a month.

As an example, consider the following settings:

DST_BEGM = **3**

DST_BEGW = **L**

DST_BEGD = **SUN**

DST_BEGH = **2**

DST_ENDM = **10**

DST_ENDW = **3**

DST_ENDD = **WED**

DST_ENDH = **3**

With these example settings, the relay will enter daylight-saving time on the last Sunday in March at 0200 h, and leave daylight-saving time on the third Wednesday in October at 0300 h. The relay asserts Relay Word bit DST when daylight-saving time is active.

When an IRIG-B time source is being used, the relay time follows the IRIG-B time, including daylight-saving time start and end, as commanded by the time source. If there is a discrepancy between the daylight-saving time settings and the received IRIG-B signal, the relay follows the IRIG-B signal

When using IEEE C37.118 compliant IRIG-B signals (e.g., Global setting IRIGC = C37.118), the relay automatically populates the DST Relay Word bit, regardless of the daylight-saving time settings.

When using regular IRIG-B signals (e.g., Global setting IRIGC = NONE), the relay only populates the DST Relay Word bit if the daylight-saving time settings are properly configured.

Set daylight-saving time beginning and ending properly even if you expect some other time source, such as IRIG-B, to correct for daylight-saving time. The relay relies on these settings for correct time should the time source fail (for IRIGC = C37.118) and to calculate UTC time correctly (when IRIGC = NONE). If daylight-saving time settings are not correct, some relay reports may show unexpected results. Use the **TIME DST** command to confirm the daylight-saving time settings and status.

Line Settings

Refer to *Line Settings (see Line Settings on page 9.25)* on page SET.6.

NOTE: The relay does not require line impedance settings when Global setting PTCONN = SINGLE, and hides these settings from the **SET** and **SHO** commands.

Line impedance settings Z1MAG, Z1ANG, Z0MAG, and Z0ANG are used in the fault locator (see *Fault Location* on page 12.8) and in automatically making directional element settings Z2F, Z2R, Z0F, and Z0R (see *Settings Made Automatically* on page 4.44). A corresponding line length setting (LL) is also used in the fault locator.

If the protected line belongs to a hybrid power system, such as shown in *Figure 4.34*, refer to *Z0MTA—Zero-Sequence Maximum Torque Angle* on page 4.56 for information on the Z0MTA setting.

On both hybrid and solidly-grounded power systems, Z0ANG must be set to the actual zero-sequence line angle to allow correct fault locator operation for forward faults involving ground.

The line impedance settings Z1MAG and Z0MAG are set in Ω secondary. Line impedance (Ω primary) is converted to Ω secondary:

Ω primary • (CTR/PTR) = Ω secondary

where:

CTR = phase (IA, IB, IC) current transformer ratio
PTR = phase (VA, VB, VC) potential transformer ratio

The zero-sequence line impedance setting Z0MAG is automatically scaled by the relay for use with neutral channel IN for directional control on low-impedance grounded systems. See Z0F and Z0R settings explanation in the latter part of *Section 4: Loss-of-Potential, Load-Encroachment, and Directional Element Logic*.

Line length setting LL is unitless and corresponds to the line impedance settings. For example, if a particular line length is 15 miles, enter the line impedance values (Ω secondary) and then enter the corresponding line length:

LL = **15.00** (miles)

If this length of line is measured in kilometers rather than miles, then enter:

LL = **24.14** (kilometers)

Delta-Connected PTs (PTCONN = DELTA)

NOTE: If Global setting VSCONN = 3V0, settings Z0SMAG and Z0SANG are not required, regardless of the PTCONN setting.

Additional zero-sequence source impedance settings Z0SMAG (magnitude, Ω secondary) and Z0SANG (angle, degrees) are required so that zero-sequence voltage can be derived for fault locating.

Enable Settings

Refer to *Global Settings (Serial Port Command SET G and Front Panel)* on page SET.1 and *Group n (Relay) Settings (Serial Port Command SET n and Front Panel)* on page SET.6.

The SEL-351 includes enable settings in the Global, Group, and Port settings classes. Several of these enable settings help limit the number of settings that must be entered when a feature is not required.

Global Enable Settings

The Global settings class contains five enable settings. These settings control other Global settings as follows:

➤ PTCONN: Phase PT Connection (DELTA,WYE,SINGLE). Affects some Global settings, and several Group settings.

➤ VSCONN: VS Channel Input (VS,3V0). Affects some Group settings.

➤ EBMON: Breaker Monitor (Y,N). Hides ten settings when set to N.

➤ EPMU: Synchronized Phasor Measurement (Y,N). Hides as many as 16 settings when set to N. Also affects Port enable settings PROTO and EPMIP.

➤ DST_BEGM: Month to Begin DST (NA, 1–12). Hides seven settings when set to NA.

Group (Relay) Enable Settings

Each Group settings class contains as many as 22 enable settings, depending on model. See *Group n (Relay) Settings (Serial Port Command SET n and Front Panel)* on page SET.6 for a full listing of the relay settings, and associated enable settings. The Relay enable settings are as follows:

➤ E50P, E50N, E50G, E50Q: Instantaneous/Definite-Time Overcurrent Elements

➤ E51P, E51N, E51G, E51Q: Time-Overcurrent Elements

➤ E50BF: Breaker Failure

➤ EHBL2: Second Harmonic Blocking

NOTE: Making Global setting PTCONN = SINGLE hides between four and six of the Group enable settings, depending on model.

➤ E32: Directional Control

➤ ELOAD: Load Encroachment

➤ ESOTF: Switch-Onto-Fault

➤ EDDSOTF: SOTF Disturbance Detector Supervision

➤ EVOLT: Voltage Elements

- E25: Synchronism Check
- EFLOC: Fault Location (does not hide any settings)
- ELOP: Loss-Of-Potential
- ECOMM: Communications-Assisted Trip Scheme
- E81: Frequency Elements
- E81R: Rate-of-Change-of-Frequency Elements
- E79: Reclosures
- ESV: SELOGIC Variable/Timers
- EDEM: Demand Metering (does not hide any settings)
- EPWR: Power Elements (only in Firmware Version 7)
- ESSI: Voltage Sag/Swell/Interruption (only in Firmware Version 7)

Port Enable Settings

Each Port settings class contains as many as five enable settings. These settings control other Port settings as follows.

Serial Port Settings (Port 1, 2, 3, or F)

NOTE: The Access jumper overrides the EPORT = N setting for the front-panel ports. Installing the Access jumper also causes the front-panel EIA-232 port to revert to factory default settings for PROTO, SPEED, BITS, PARITY, STOP, and RTSCTS when EPORT = N.

NOTE: The Access jumper overrides the MAXACC setting for any enabled ports, and allows the highest access level (C = Calibration).

- EPORT: Enable Port (Y, N). Disables the port and hides all port settings when set to N. The EPORT setting for Port F controls both the front-panel EIA-232 serial port F and the optional USB port.
- PROTO: Protocol. Controls availability of subsequent settings. When PROTO is set to SEL or LMD, another enable setting appears:

  MAXACC: Maximum Access Level (0, 1, B, 2, C). Selects highest access level allowed on port by limiting the availability of commands **ACC**, **BAC**, **2AC**, or **CAL**. The MAXACC for Port F can be set to 1, B, 2, or C, and affects both serial port F and the optional USB port.

Ethernet Port Settings (Port 5)

NOTE: When ETELNET = Y, the Access jumper overrides the MAXACC setting, and allows the Telnet session(s) to attain the highest access level (C = Calibration).

- EPORT: Enable Port (Y,N). Hides all port settings when set to N.
- ETELNET: Enable Telnet (Y,N). Hides six settings when set to N. When ETELNET is set to Y, another enable setting appears:

  MAXACC: Maximum Access Level (0, 1, B, 2, C). Selects highest access level allowed on a Telnet session by limiting the availability of commands **ACC**, **BAC**, **2AC**, or **CAL**.
- EFTPSERV: Enable FTP (Y, N). Hides three settings when set to N.
- EHTTP: Enable HTTP Server (Y, N). Hides five settings when set to N. When EHTTP is set to Y, another enable setting appears:

  HTTPACC: HTTP Maximum Access Level (1, 2). Selects highest access level allowed over the Web Server interface.
- E61850: Enable IEC 61850 Protocol (Y, N). Hides two settings when set to N (setting only present on relays ordered with IEC 61850).
- EDNP: Enable DNP Sessions (0–6). Controls availability of subsequent settings (as many as 31 settings per session).
- EPMIP: Enable PMU Processing (Y,N). Controls availability of as many as six subsequent settings.

- EMODBUS: Enable Modbus (0–3). Controls availability of as many as seven subsequent settings.
- ESNTP: Enable SNTP client (OFF, UNICAST, MANYCAST, BROADCAST). Controls availability of as many as five subsequent settings.

PC Software

These enable settings are also present in the SEL-351 driver for QuickSet. The effect of changing an enable setting is easy to see, because the associated setting field turns grey when it is unavailable. See *Appendix C: PC Software* for more information on QuickSet.

Optional USB Port

No port settings are required for the optional USB port. However, the USB port is controlled by the previously described Port F (front-panel EIA-232 serial port) settings EPORT and MAXACC.

The PC operating system should prompt for a USB driver when a PC is connected to the relay. See *Establishing Communications Using the USB Port* on page 10.2 for further details on using the USB port.

Other System Parameters

Refer to *Power System Configuration and Date Format (see Other System Parameters on page 9.28)* on page SET.1.

The Global settings NFREQ and PHROT allow you to configure the SEL-351 to your specific system.

Set NFREQ equal to your nominal power system frequency, either 50 Hz or 60 Hz.

Set PHROT equal to your power system phase rotation, either ABC or ACB.

Set DATE_F to format the date displayed in relay reports and the front-panel display. Set DATE_F to MDY to display dates in Month/Day/Year format; set DATE_F to YMD to display dates in Year/Month/Day format.

Settings Sheets

The settings sheets that follow include the definition and input range for each setting in the relay. Refer to *Specifications* on page 1.4 for information on 5 A nominal and 1 A nominal ordering options (and additional 0.2 A nominal and 0.05 A nominal options for neutral channel IN) and how they influence overcurrent element setting ranges.

SEL-351-5, -6, -7 Relay Settings Sheets

Global Settings (Serial Port Command SET G and Front Panel)

To avoid lost settings, enter Global settings first. Refer to *Make Global Settings (SET G) First* on page 9.3.

Voltage Input Configuration (see *Settings for Voltage Input Configuration* on page 9.18)

Note: Changing the setting value of PTCONN or VSCONN will cause the relay to display the following message:

```
WARNING!  The PTCONN or VSCONN setting was changed, which will cause
the Group, Logic, and Report settings to be reset to default values.
Save Changes(Y/N)? Y <Enter>
Are you sure (Y/N)? _
```

Phase Potential Transformer Connection (DELTA, WYE, SINGLE) **PTCONN :=** ____________

Make setting PHANTV when PTCONN = SINGLE.

Phantom Voltage From (VA, VB, VC, VAB, VBC, VCA, OFF) **PHANTV :=** ____________

VS Channel Input (VS, 3V0) **VSCONN :=** ____________

Settings Group Change Delay (see *Multiple Setting Groups* on page 7.17)

Group change delay (0.00–16000.00 cycles in 0.25 cycle steps) **TGR :=** ____________

Power System Configuration and Date Format (see *Other System Parameters* on page 9.28)

Nominal frequency (50 Hz, 60 Hz) **NFREQ :=** ____________

Phase rotation (ABC, ACB) **PHROT :=** ____________

Date format (MDY, YMD) **DATE_F :=** ____________

Front-Panel Display Operation (see *Section 11*)

Front-panel display time-out (OFF, 1–30 minutes in 1 minute steps) **FP_TO :=** ____________

Note: If FP_TO = OFF, no time-out occurs and display remains on last display screen (e.g., continually display metering). Setting FP_TO = 0 is the same as OFF and is stored internally as OFF.

Display update rate (1–60 seconds in 1 second steps) **SCROLD :=** ____________

Front-panel neutral/ground display (OFF, IN, IG) **FPNGD :=** ____________

Meter Cutoff Threshold (see *Section 8*)

Meter cutoff threshold (Y, N, E) **METHRES :=** ______

Event Report Parameters (see *Section 12*)

Length of event report (15, 30, 60 cycles) **LER :=** ______

Length of prefault in event report (1 to LER-1 cycles in 1-cycle steps) **PRE :=** ______

Fault Current to Display (FL, MAX) **FLTDISP :=** ______

Station DC Battery Monitor (see *Figure 8.11* and *Figure 8.12*)

DC battery instantaneous undervoltage pickup (OFF, 20.00–300.00 Vdc in 0.02 V steps) **DCLOP :=** ______

DC battery instantaneous overvoltage pickup (OFF, 20.00–300.00 Vdc in 0.02 V steps) **DCHIP :=** ______

Optoisolated Input Timers (see *Figure 7.1*)

Input IN101 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps) **IN101D :=** ______

Input IN102 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps) **IN102D :=** ______

Input IN103 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps) **IN103D :=** ______

Input IN104 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps) **IN104D :=** ______

Input IN105 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps) **IN105D :=** ______

Input IN106 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps) **IN106D :=** ______

Optoisolated Input Timers—Extra I/O Board Options 2, 4, or 6 (see *Figure 7.2*)

Input IN201 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps) **IN201D :=** ______

Input IN202 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps) **IN202D :=** ______

Input IN203 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps) **IN203D :=** ______

Input IN204 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps) **IN204D :=** ______

Input IN205 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps) **IN205D :=** ______

Input IN206 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps) **IN206D :=** ______

Input IN207 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps)	**IN207D :=** ________
Input IN208 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps)	**IN208D :=** ________

Optoisolated Input Timers—Extra I/O Board Option 4

Input IN209 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps)	**IN209D :=** ________
Input IN210 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps)	**IN210D :=** ________
Input IN211 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps)	**IN211D :=** ________
Input IN212 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps)	**IN212D :=** ________
Input IN213 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps)	**IN213D :=** ________
Input IN214 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps)	**IN214D :=** ________
Input IN215 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps)	**IN215D :=** ________
Input IN216 debounce time (AC, 0.00–2.00 cycles in 0.25-cycle steps)	**IN216D :=** ________

Breaker Monitor Settings (see *Breaker Monitor* on page 8.1)

Breaker monitor enable (Y, N)	**EBMON :=** ________

Make the following settings if EBMON = Y.

Close/Open set point 1—max. (0–65000 operations)	**COSP1 :=** ________
Close/Open set point 2—mid. (0–65000 operations)	**COSP2 :=** ________
Close/Open set point 3—min. (0–65000 operations)	**COSP3 :=** ________
kA Interrupted set point 1—min. (0.00–999.00 kA primary in 0.01 kA steps)	**KASP1 :=** ________
kA Interrupted set point 2—mid. (0.00–999.00 kA primary in 0.01 kA steps)	**KASP2 :=** ________
kA Interrupted set point 3—max. (0.00–999.00 kA primary in 0.01 kA steps)	**KASP3 :=** ________
Electrical Slow Trip Alarm Threshold (1–999 ms in 1 ms steps)	**ESTRT :=** ________
Electrical Slow Close Alarm Threshold (1–999 ms in 1 ms steps)	**ESCLT :=** ________
Mechanical Slow Trip Alarm Threshold (1–999 ms in 1 ms steps)	**MSTRT :=** ________
Mechanical Slow Close Alarm Threshold (1–999 ms in 1 ms steps)	**ESCLT :=** ________

Notes:

- ➤ COSP1 must be set greater than COSP2.
- ➤ COSP2 must be set greater than or equal to COSP3.
- ➤ KASP1 must be set less than KASP2.
- ➤ If COSP2 is set the same as COSP3, then KASP2 must be set the same as KASP3.
- ➤ KASP3 must be set at least 5 times (but no more than 100 times) the KASP1 setting value.

Synchronized Phasor Settings (see *Appendix N*)

Synchronized Phasor Measurement (Y, N) **EPMU :=** ____________

Note: Make the following setting if EPMU = Y.

Message Format (C37.118, FM) **MFRMT :=** ____________

Note: C38.118 is an IEEE Standard. "FM" is SEL Fast Message. When PTCONN = DELTA or SINGLE, MFRMT is automatically set to "C37.118".

C37.118 Settings

Make the following settings when EPMU = Y and MFRMT = C37.118.

Message Rate (messages per second) **MRATE :=** ____________
(1, 2, 4, 5, 10, 12, 15, 20, 30, 60 when NFREQ = 60)
(1, 2, 5, 10, 25, 50 when NFREQ = 50)

Phasor Measurement Unit (PMU) Application (F, N) **PMAPP :=** ____________

Note: F = Fast Response, N = Narrow Bandwidth

Frequency-Based Phasor Compensation (Y, N) **PHCOMP :=** ____________

Station Name (16 characters, mixed case) **PMSTN :=** ________________________

Note: Cannot contain the following characters: ? / \ < > * | : ; [ ] $ % { }.

Phasor Measurement Unit (PMU) Hardware ID (1–65534) **PMID :=** ____________

Phasor Data Set, Voltages **PHDATAV :=** ____________
(V1, PH, ALL, NA when PTCONN = WYE or DELTA)
(ALL, NA when PTCONN = SINGLE)

Phase Voltage Angle Compensation Factor **VPCOMP :=** ____________
(–179.99 to +180 degrees in 0.01 degree steps)

VS Voltage Angle Compensation Factor **VSCOMP :=** ____________
(–179.99 to +180 degrees in 0.01 degree steps)

Phasor Data Set, Currents (I1, PH, ALL, NA) **PHDATAI :=** ____________

Phase Current Angle Compensation Factor **IPCOMP :=** ____________
(–179.99 to +180 degrees in 0.01 degree steps)

Neutral (IN) Current Angle Compensation Factor **INCOMP :=** ____________
(–179.99 to +180 degrees in 0.01 degree steps)

Make settings PHNR and PHFMT when PHDATAV ≠ NA or PHDATAI ≠ NA.

Phasor Numeric Representation (I = Integer, F = Floating Point) **PHNR :=** ____________

Phasor Format **PHFMT :=** ____________
(R = Rectangular coordinates, P = Polar coordinates)

Frequency Numeric Representation (I = Integer, F = Floating Point) **FNR :=** ____________

Number of 16-bit Digital Status Words (0, 1) **NUMDSW :=** ____________

SEL Fast Message Settings

Make the following settings when EPMU = Y and MFRMT = FM.

Phasor Measurement Unit (PMU) Hardware ID (0 to 4294967295)	**PMID :=** ____________
Phasor Data Set, Voltages (V1, ALL)	**PHDATAV :=** ____________
Voltage Angle Compensation Factor (–179.99 to +180 degrees in 0.01 degree steps)	**VCOMP :=** ____________

Make setting PHDATAI when PHDATAV = ALL.

Phasor Data Set, Currents (ALL, NA)	**PHDATAI :=** ____________
Current Angle Compensation Factor (–179.99 to +180 degrees in 0.01 degree steps)	**ICOMP :=** ____________

DNP (see *Appendix D*)

Event Summary Lock Period (0 to 1000 seconds)	**EVELOCK :=** ____________
DNP Session Time Base (LOCAL, UTC)	**DNPSRC :=** ____________
DNP BO Close/Trip Behavior (SET, PULSE)	**BOOPTCC :=** ____________
DNP BO Pulse On Behavior (SET, PULSE)	**BOOPPUL :=** ____________

Time and Date Management (see *Section 10* and *Appendix N*)

IRIG-B Control Bits Definition (NONE, C37.118)	**IRIGC :=** ____________

Note: When MFRMT = C37.118, IRIGC is automatically set to "C37.118".

Offset from UTC (–24.00 to 24.00 hours in 0.01 hour steps)	**UTC_OFF :=** ____________

Daylight-Saving Time Settings (see *Automatic Daylight-Saving Time Settings* on page 9.24)

Month to Begin DST (NA, 1–12)	**DST_BEGM :=** ____________

Make the following settings when DST_BEGM ≠ NA.

Week of the Month to Begin DST (1–3, L = Last)	**DST_BEGW :=** ____________
Day of the Week to Begin DST (SUN–SAT)	**DST_BEGD :=** ____________
Local Hour to Begin DST (0–23)	**DST_BEGH :=** ____________
Month to End DST (NA, 1–12)	**DST_ENDM :=** ____________
Week of the Month to End DST (1–3, L = Last)	**DST_ENDW :=** ____________
Day of the Week to End DST (SUN–SAT)	**DST_ENDD :=** ____________
Local Hour to End DST (0–23)	**DST_ENDH :=** ____________

Group n (Relay) Settings (Serial Port Command SET n and Front Panel)

To avoid lost settings, enter Global settings first (*Global Settings (Serial Port Command SET G and Front Panel)* on page SET.1). Refer to *Make Global Settings (SET G) First* on page 9.3.

Identifier Labels (see *Identifier Labels* on page 9.17)

Relay Identifier (30 characters) (0–9, A–Z, -, /, ., space)

RID := ________________________________

Terminal Identifier (30 characters) (0–9, A–Z, -, /, ., space)

TID := ________________________________

Current and Potential Transformer Ratios (see *Settings Explanations* on page 9.17)

Phase (IA, IB, IC) Current Transformer Ratio (1–6000 in steps of 1) **CTR :=** ____________

Neutral (IN) Current Transformer Ratio (1–10000 in steps of 1) **CTRN :=** ____________

Phase (VA, VB, VC; wye-connected) or
Phase-to-Phase (VAB, VBC, VCA; delta-connected) or
VA Terminal PT Ratio (PTCONN = SINGLE)
Potential Transformer Ratio (1.00–10000.00 in steps of 0.01) **PTR :=** ____________

Synchronism Voltage (VS) Potential Transformer Ratio
(1.00–10000.00 in steps of 0.01) **PTRS :=** ____________

Make the following setting when Global setting PTCONN = WYE or DELTA.

PT Nominal Voltage (line-to-neutral [wye-connected] or
line-to-line [delta-connected])
(OFF, 25.00–300.00 V secondary in 0.013 V steps) **VNOM :=** ____________

Note: When PTCONN = SINGLE, VNOM is automatically set to OFF and hidden.

Line Settings (see *Line Settings* on page 9.25)

Make the following settings when Global setting PTCONN = WYE or DELTA.

Positive-sequence line impedance magnitude
(0.10–510.00 Ω secondary [5 A nom.])
(0.50–2550.00 Ω secondary [1 A nom.] in 0.01 Ω steps) **Z1MAG :=** ____________

Positive-sequence line impedance angle (5.00–90.00 degrees in 0.01 degree steps) **Z1ANG :=** ____________

Zero-sequence line impedance magnitude
(0.10–510.00 Ω secondary [5 A nom.])
(0.50–2550.00 Ω secondary [1 A nom.] in 0.01 Ω steps) **Z0MAG :=** ____________

Zero-sequence line impedance angle (5.00–90.00 degrees in 0.01 degree steps) **Z0ANG :=** ____________

Make settings Z0SMAG and Z0SANG when Global settings PTCONN = DELTA and VSCONN = VS.

Zero-sequence source impedance magnitude (delta-connected voltages)
(0.10–510.00 Ω secondary [5 A nom.])
(0.50–2550.00 Ω secondary [1 A nom.] in 0.01 Ω steps) **Z0SMAG :=** ____________

Zero-sequence source impedance angle (delta-connected voltages) (0.00–90.00 degrees in 0.01 degree steps) **Z0SANG :=** ____________

Line length (0.10–999.00, unitless in steps of 0.01) **LL :=** ____________

Instantaneous/Definite-Time Overcurrent Enable Settings

Phase element levels (N, 1–6) (see *Figure 3.1*, *Figure 3.2*, *Figure 3.3*, and *Figure 3.7*) **E50P :=** ____________

Neutral-ground element levels—channel IN (N, 1–6) (see *Figure 3.8* and *Figure 3.9*) **E50N :=** ____________

Residual-ground element levels (N, 1–6) (see *Figure 3.10* and *Figure 3.11*) **E50G :=** ____________

Negative-sequence element levels (N, 1–6) (see *Figure 3.12* and *Figure 3.13*) **E50Q :=** ____________

Time-Overcurrent Enable Settings

Phase elements (N, 1, 2) (see *Table 3.1*, *Figure 3.14*, *Figure 3.15*, *Figure 3.16*, and *Figure 3.17*) **E51P :=** ____________

Neutral-ground elements—channel IN (Y, N) (see *Figure 3.18*) **E51N :=** ____________

Residual ground elements (N, 1, 2) (see *Figure 3.19* and *Figure 3.20*) **E51G :=** ____________

Negative-sequence elements (Y, N) (see *Figure 3.21*) **E51Q :=** ____________

Other Enable Settings

Breaker Failure (Y, N) **E50BF :=** ____________

Second Harmonic Blocking (Y, N) **EHBL2 :=** ____________

Make the following setting when Global setting PTCONN = WYE or DELTA, or when PTCONN = SINGLE and the relay has a 1 A or 5 A nominal neutral rating or when PTCONN = SINGLE and VSCONN = 3V0.

Directional control (Y, AUTO, N) (see *Directional Control Settings* on page 4.43) **E32 :=** ____________

Note: When Global setting PTCONN = SINGLE and VSCONN = 3V0, E32 cannot be set to "AUTO".

Note: When VNOM = OFF, Global setting VSCONN = VS, and the relay has a 0.2 A or 0.05 A nominal neutral rating, E32 cannot be set to "Y" or "AUTO".

Make setting ELOAD when Global setting PTCONN = WYE or DELTA.

Load encroachment (Y, N) (see *Figure 4.6*) **ELOAD :=** ____________

Note: If VNOM = OFF, ELOAD cannot be set to "Y".

Switch-onto-fault (Y, N) (see *Figure 5.3*) **ESOTF :=** ____________

Make setting EDDSOTF when ESOTF = Y.

SOTF Disturbance Detector Supervision (Y, N) **EDDSOTF :=** ____________

Voltage elements (Y, N) (see *Figure 3.23*, *Figure 3.24*, *Figure 3.25*, *Figure 3.26*, and *Figure 3.27*) **EVOLT :=** ____________

Synchronism check (Y, N) (see *Figure 3.29* and *Figure 3.30*) **E25 :=** ____________

Note: When Global setting VSCONN = 3V0, setting E25 can only be set to "N".

Make settings EFLOC, ELOP, and ECOMM when Global setting PTCONN = WYE or DELTA.

Fault location (Y, N) (see *Fault Location* on page 12.8) **EFLOC :=** ____________

Note: If VNOM = OFF, EFLOC cannot be set to "Y".

Loss-of-potential (Y, Y1, N) (see *Figure 4.1*)	**ELOP :=** ______

Note: If VNOM = OFF, ELOP cannot be set to "Y" or "Y1".

Communications-assisted trip scheme (N, DCB, POTT, DCUB1, DCUB2) (see *Communications-Assisted Trip Logic—General Overview* on page 5.13)	**ECOMM :=** ______
Frequency elements (N, 1–6) (see *Figure 3.40*)	**E81 :=** ______
Rate-of-Change of Frequency (N, 1–4)	**E81R :=** ______
Reclosures (N, 1– 4, C1–C4) (see *Reclosing Relay* on page 6.12)	**E79 :=** ______
SELOGIC Control Equation Variable Timers (N, 1–16) (see *Figure 7.24* and *Figure 7.25*)	**ESV :=** ______
Demand Metering (THM = Thermal, ROL = Rolling) (see *Figure 8.14*)	**EDEM :=** ______
Power Elements (only available in Firmware Version 7) (N, 1–4, 3P1–3P4) when Global setting PTCONN = WYE, or (N, 3P1–3P4) when Global setting PTCONN = DELTA, or (N, 1–4) when Global setting PTCONN = SINGLE	**EPWR :=** ______

Make the following setting when Global setting PTCONN = WYE or DELTA.

Voltage Sag/Swell/Interruption (Y, N) (only available in Firmware Version 7) (see *Figure 3.42*, *Figure 3.43*, and *Figure 3.44*)	**ESSI :=** ______

Phase Instantaneous/Definite-Time Overcurrent Elements (see *Figure 3.1*, *Figure 3.2*, and *Figure 3.3*)

Note: Number of phase element pickup settings dependent on E50P = 1–6.

Pickup (OFF, 0.25–100.00 A secondary [5 A nom.], 0.05–20.00 A secondary [1 A nom.] in 0.01 A steps)	**50P1P :=** ______
Pickup (OFF, 0.25–100.00 A secondary [5 A nom.], 0.05–20.00 A secondary [1 A nom.] in 0.01 A steps)	**50P2P :=** ______
Pickup (OFF, 0.25–100.00 A [secondary [5 A nom.], 0.05–20.00 A secondary [1 A nom.] in 0.01 A steps)	**50P3P :=** ______
Pickup (OFF, 0.25–100.00 A secondary [5 A nom.], 0.05–20.00 A secondary [1 A nom.] in 0.01 A steps)	**50P4P :=** ______
Pickup (OFF, 0.25–100.00 A secondary [5 A nom.], 0.05–20.00 A secondary [1 A nom.] in 0.01 A steps)	**50P5P :=** ______
Pickup (OFF, 0.25–100.00 A secondary [5 A nom.], 0.05–20.00 A secondary [1 A nom.] in 0.01 A steps)	**50P6P :=** ______

Phase Definite-Time Overcurrent Elements (see *Figure 3.3*)

Note: Number of phase element pickup settings dependent on E50P = 1–6; all four time delay settings are enabled if E50P ≥ 4.

Time delay (0.00–16000.00 cycles in 0.25-cycle steps) **67P1D :=** ______________

Time delay (0.00–16000.00 cycles in 0.25-cycle steps) **67P2D :=** ______________

Time delay (0.00–16000.00 cycles in 0.25-cycle steps) **67P3D :=** ______________

Time delay (0.00–16000.00 cycles in 0.25-cycle steps) **67P4D :=** ______________

Phase-to-Phase Instantaneous Overcurrent Elements (see *Figure 3.7*)

Note: Number of phase-to-phase element pickup settings dependent on E50P = 1–6; all four pickup settings are enabled if E50P ≥ 4.

Pickup (OFF, 1.00–170.00 A secondary [5 A nom.], 0.20–34.00 A secondary [1 A nom.] in 0.01 A steps) **50PP1P :=** ______________

Pickup (OFF, 1.00–170.00 A secondary [5 A nom.], 0.20–34.00 A secondary [1 A nom.] in 0.01 A steps) **50PP2P :=** ______________

Pickup (OFF, 1.00–170.00 A secondary [5 A nom.], 0.20–34.00 A secondary [1 A nom.] in 0.01 A steps) **50PP3P :=** ______________

Pickup (OFF, 1.00–170.00 A secondary [5 A nom.], 0.20–34.00 A secondary [1 A nom.] in 0.01 A steps) **50PP4P :=** ______________

Neutral Ground Instantaneous/Definite-Time Overcurrent Elements—Channel IN (see *Figure 3.8* and *Figure 3.9*)

Note: Number of neutral ground element pickup settings dependent on E50N = 1–6.

Pickup (OFF, 0.250–100.000 A secondary [5 A nom.], 0.050–20.000 A secondary [1 A nom.], 0.005–2.500 A secondary [0.2 A nom.], 0.005–1.500 A secondary [0.05 A nom.] in 0.001 A steps) **50N1P :=** ______________

Pickup (OFF, 0.250–100.000 A secondary [5 A nom.], 0.050–20.000 A secondary [1 A nom.], 0.005–2.500 A secondary [0.2 A nom.], 0.005–1.500 A secondary [0.05 A nom.] in 0.001 A steps) **50N2P :=** ______________

Pickup (OFF, 0.250–100.000 A secondary [5 A nom.], 0.050–20.000 A secondary [1 A nom.], 0.005–2.500 A secondary [0.2 A nom.], 0.005–1.500 A secondary [0.05 A nom.] in 0.001 A steps) **50N3P :=** ______________

Pickup (OFF, 0.250–100.000 A secondary [5 A nom.], 0.050–20.000 A secondary [1 A nom.], 0.005–2.500 A secondary [0.2 A nom.], 0.005–1.500 A secondary [0.05 A nom.] in 0.001 A steps) **50N4P :=** ______________

Pickup (OFF, 0.250–100.000 A secondary [5 A nom.], 0.050–20.000 A secondary [1 A nom.], 0.005–2.500 A secondary [0.2 A nom.], 0.005–1.500 A secondary [0.05 A nom.] in 0.001 A steps) **50N5P :=** ______________

Pickup (OFF, 0.250–100.000 A secondary [5 A nom.], 0.050–20.000 A secondary [1 A nom.], 0.005–2.500 A secondary [0.2 A nom.], 0.005–1.500 A secondary [0.05 A nom.] in 0.001 A steps) **50N6P :=** ______________

Neutral Ground Definite-Time Overcurrent Elements (see *Figure 3.8*)

Note: Number of neutral ground element time delay settings dependent on E50N = 1–6; all four time delay settings are enabled if E50N ≥ 4.

Time delay (0.00–16000.00 cycles in 0.25-cycle steps) **67N1D :=** ____________

Time delay (0.00–16000.00 cycles in 0.25-cycle steps) **67N2D :=** ____________

Time delay (0.00–16000.00 cycles in 0.25-cycle steps) **67N3D :=** ____________

Time delay (0.00–16000.00 cycles in 0.25-cycle steps) **67N4D :=** ____________

Residual Ground Instantaneous/Definite-Time Overcurrent Elements (see *Figure 3.10* and *Figure 3.11*)

Note: Number of residual ground element pickup settings dependent on E50G.

Pickup **50G1P :=** ____________
(OFF, 0.050–100.000 A secondary in 0.01 A steps [5 A nom.],
0.010–20.000 A secondary in 0.002 A steps [1 A nom.])

Pickup **50G2P :=** ____________
(OFF, 0.050–100.000 A secondary in 0.01 A steps [5 A nom.],
0.010–20.000 A secondary in 0.002 A steps [1 A nom.])

Pickup **50G3P :=** ____________
(OFF, 0.050–100.000 A secondary in 0.01 A steps [5 A nom.],
0.010–20.000 A secondary in 0.002 A steps [1 A nom.])

Pickup **50G4P :=** ____________
(OFF, 0.050–100.000 A secondary in 0.01 A steps [5 A nom.],
0.010–20.000 A secondary in 0.002 A steps [1 A nom.])

Pickup **50G5P :=** ____________
(OFF, 0.050–100.000 A secondary in 0.01 A steps [5 A nom.],
0.010–20.000 A secondary in 0.002 A steps [1 A nom.])

Pickup **50G6P :=** ____________
(OFF, 0.050–100.000 A secondary in 0.01 A steps [5 A nom.],
0.010–20.000 A secondary in 0.002 A steps [1 A nom.])

Residual Ground Definite-Time Overcurrent Elements (see *Figure 3.10*)

Note: Number of residual ground element time delay settings dependent on E50G = 1–6; all four time delay settings are enabled if E50G ≥ 4.

Time delay (0.00–16000.00 cycles in 0.25-cycle steps) **67G1D :=** ____________

Time delay (0.00–16000.00 cycles in 0.25-cycle steps) **67G2D :=** ____________

Time delay (0.00–16000.00 cycles in 0.25-cycle steps) **67G3D :=** ____________

Time delay (0.00–16000.00 cycles in 0.25-cycle steps) **67G4D :=** ____________

Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements (see *Figure 3.12* and *Figure 3.13*)

Important: See *Appendix G: Setting Negative-Sequence Overcurrent Elements* for information on setting negative-sequence overcurrent elements.

Note: Number of negative-sequence element time delay settings dependent on E50Q.

Pickup (OFF, 0.25–100.00 A secondary [5 A nom.], 0.05–20.00 A secondary [1 A nom.] in 0.01 A steps) **50Q1P :=** ______

Pickup (OFF, 0.25–100.00 A secondary [5 A nom.], 0.05–20.00 A secondary [1 A nom.] in 0.01 A steps) **50Q2P :=** ______

Pickup (OFF, 0.25–100.00 A secondary [5 A nom.], 0.05–20.00 A secondary [1 A nom.] in 0.01 A steps) **50Q3P :=** ______

Pickup (OFF, 0.25–100.00 A secondary [5 A nom.], 0.05–20.00 A secondary [1 A nom.] in 0.01 A steps) **50Q4P :=** ______

Pickup (OFF, 0.25–100.00 A secondary [5 A nom.], 0.05–20.00 A secondary [1 A nom.] in 0.01 A steps) **50Q5P :=** ______

Pickup (OFF, 0.25–100.00 A secondary [5 A nom.], 0.05–20.00 A secondary [1 A nom.] in 0.01 A steps) **50Q6P :=** ______

Negative-Sequence Definite-Time Overcurrent Elements (see *Figure 3.12*)

Important: See *Appendix G: Setting Negative-Sequence Overcurrent Elements* for information on setting negative-sequence overcurrent elements.

Note: Number of negative-sequence element time delay settings dependent on E50Q = 1–6; all four time delay settings are enabled if E50Q ≥ 4.

Time delay (0.00–16000.00 cycles in 0.25-cycle steps) **67Q1D :=** ______

Time delay (0.00–16000.00 cycles in 0.25-cycle steps) **67Q2D :=** ______

Time delay (0.00–16000.00 cycles in 0.25-cycle steps) **67Q3D :=** ______

Time delay (0.00–16000.00 cycles in 0.25-cycle steps) **67Q4D :=** ______

Phase Time-Overcurrent Element (see *Figure 3.14*)

Make the following settings if E51P = 1 or 2.

Pickup (OFF, 0.25–16.00 A secondary [5 A nom.], 0.05–3.20 A secondary [1 A nom.] in 0.01 A steps) **51PP :=** ______

Curve (U1–U5, C1–C5; see *Figure 9.1–Figure 9.10*) **51PC :=** ______

Time-Dial **51PTD := ____________**
(0.50–15.00 for curves U1–U5, 0.05–1.00 for curves C1–C5, in steps of 0.01)

Electromechanical Reset (Y, N) **51PRS := ____________**

A-Phase Time-Overcurrent Element (see *Figure 3.15*)

Make the following settings if E51P = 2.

Pickup **51AP := ____________**
(OFF, 0.25–16.00 A secondary [5 A nom.],
0.05–3.20 A secondary [1 A nom.] in 0.01 A steps)

Curve **51AC := ____________**
(U1–U5, C1–C5; see *Figure 9.1–Figure 9.10*)

Time-Dial **51ATD := ____________**
(0.50–15.00 for curves U1–U5, 0.05–1.00 for curves C1–C5,
in steps of 0.01)

Electromechanical Reset (Y, N) **51ARS := ____________**

B-Phase Time-Overcurrent Element (see *Figure 3.16*)

Make the following settings if E51P = 2.

Pickup **51BP := ____________**
(OFF, 0.25–16.00 A secondary [5 A nom.],
0.05–3.20 A secondary [1 A nom.] in 0.01 A steps)

Curve **51BC := ____________**
(U1–U5, C1–C5; see *Figure 9.1–Figure 9.10*)

Time-Dial **51BTD := ____________**
(0.50–15.00 for curves U1–U5, 0.05–1.00 for curves C1–C5,
in steps of 0.01)

Electromechanical Reset (Y, N) **51BRS := ____________**

C-Phase Time-Overcurrent Element (see *Figure 3.17*)

Make the following settings if E51P = 2.

Pickup **51CP := ____________**
(OFF, 0.25–16.00 A secondary [5 A nom.],
0.05–3.20 A secondary [1 A nom.] in 0.01 A steps)

Curve **51CC := ____________**
(U1–U5, C1–C5; see *Figure 9.1–Figure 9.10*)

Time-Dial **51CTD := ____________**
(0.50–15.00 for curves U1–U5, 0.05–1.00 for curves C1–C5,
in steps of 0.01)

Electromechanical Reset (Y, N) **51CRS := ____________**

Neutral-Ground Time-Overcurrent Element—Channel IN (see *Figure 3.18*)

Make the following settings if E51N = 1 or 2.

Pickup (OFF, 0.250–16.000 A secondary [5 A nom.], 0.050–3.200 A secondary [1 A nom.], 0.005–0.640 A secondary [0.2 A nom.], 0.005–0.160 A secondary [0.05 A nom.] in 0.001 A steps)	**51NP :=** ____________
Curve (U1–U5, C1–C5; see *Figure 9.1–Figure 9.10*)	**51NC :=** ____________
Time-Dial (0.50–15.00 for curves U1–U5, 0.05–1.00 for curves C1–C5, in steps of 0.01)	**51NTD :=** ____________
Electromechanical Reset (Y, N)	**51NRS :=** ____________

Residual-Ground Time-Overcurrent Elements (see *Figure 3.19*)

Make the following settings if E51G = 1 or 2.

Pickup (OFF, 0.10–16.00 A secondary [5 A nom.], 0.02–3.20 A secondary [1 A nom] in 0.01 A steps)	**51GP :=** ____________
Curve (U1–U5, C1–C5; see *Figure 9.1–Figure 9.10*)	**51GC :=** ____________
Time-Dial (0.50–15.00 for curves U1–U5, 0.05–1.00 for curves C1–C5, in steps of 0.01)	**51GTD :=** ____________
Electromechanical Reset (Y, N)	**51GRS :=** ____________

Make the following settings if E51G = 2.

Pickup (OFF, 0.10–16.00 A secondary [5 A nom.], 0.02–3.20 A secondary [1 A nom] in 0.01 A steps)	**51G2P :=** ____________
Curve (U1–U5, C1–C5; see *Figure 9.1–Figure 9.10*)	**51G2C :=** ____________
Time-Dial (0.50–15.00 for curves U1–U5, 0.05–1.00 for curves C1–C5, in steps of 0.01)	**51G2TD :=** ____________
Electromechanical Reset (Y, N)	**51G2RS :=** ____________

Negative-Sequence Time-Overcurrent Element (see *Figure 3.21*)

Important: See *Appendix G: Setting Negative-Sequence Overcurrent Elements* for information on setting negative-sequence overcurrent elements.

Make the following settings if E51Q = Y.

Pickup (OFF, 0.25–16.00 A secondary [5 A nom.], 0.05–3.20 A secondary [1 A nom.] in 0.01 A steps)	**51QP :=** ____________
Curve (U1–U5, C1–C5; see *Figure 9.1–Figure 9.10*)	**51QC :=** ____________
Time-Dial (0.50–15.00 for curves U1–U5, 0.05–1.00 for curves C1–C5, in steps of 0.01)	**51QTD :=** ____________
Electromechanical Reset (Y, N)	**51QRS :=** ____________

Breaker Failure Settings

Make the following settings if E50BF = Y:

Phase Fault Current Pickup (OFF, 0.5–100 A, secondary in 0.01 A steps) **50BFP :=** ______

Breaker Failure Time Delay (0.00–16000 cycles in 0.25 cycle steps) **BFPU :=** ______

Retrip Time Delay (0.00–16000 cycles in 0.25 cycle steps) **RTPU :=** ______

Second Harmonic Blocking Settings

Make the following settings if EHBL2 = Y:

Second Harmonic Pickup (5–100% in 1% steps) **HBL2P :=** ______

Second Harmonic Pickup Delay (0.00–16000 cycles in 0.25 cycle steps) **HBL2PU :=** ______

Second Harmonic Dropout Delay (0.00–16000 cycles in 0.25 cycle steps) **HBL2DO :=** ______

Load-Encroachment Elements (see *Figure 4.6*)

Make the following settings if ELOAD = Y (not available when Global setting PTCONN = SINGLE).

Forward load impedance **ZLF :=** ______
(0.09–128.00 Ω secondary in 0.016 Ω steps [5 A nom.])
(0.45–640.00 Ω secondary in 0.078 Ω steps [1 A nom.])

Reverse load impedance **ZLR :=** ______
(0.09–128.00 Ω secondary in 0.016 Ω steps [5 A nom.])
(0.45–640.00 Ω secondary in 0.078 Ω steps [1 A nom.])

Positive forward load angle (–90.00 to +90.00 degrees in 0.015 degree steps) **PLAF :=** ______

Negative forward load angle (–90.00 to +90.00 degrees in 0.015 degree steps) **NLAF :=** ______

Positive reverse load angle (+90.00 to +270.00 degrees in 0.015 degree steps) **PLAR :=** ______

Negative reverse load angle (+90.00 to +270.00 degrees in 0.015 degree steps) **NLAR :=** ______

Directional Elements (see *Directional Control Settings* on page 4.43)

Make settings DIR1–DIR4 and ORDER if E32 = Y or AUTO.

Level 1 direction: Forward, Reverse, None (F, R, N) **DIR1 :=** ______

Level 2 direction: Forward, Reverse, None (F, R, N) **DIR2 :=** ______

Level 3 direction: Forward, Reverse, None (F, R, N) **DIR3 :=** ______

Level 4 direction: Forward, Reverse, None (F, R, N) **DIR4 :=** ______

Ground directional element priority (see ranges below) **ORDER :=** ______

Note: The setting range for ORDER depends on the relay model, the VNOM setting, and Global settings. See *Table 4.5* for full details.

Relays with 5 A or 1 A nominal neutral (IN) rating:
(Combination of Q, V, I, or OFF)

Relays with 0.2 A nominal neutral (IN) rating:
(Combination of Q, V, P, S, U, or OFF)

Relays with 0.05 A nominal neutral (IN) rating:
(Combination of Q, V, or OFF)

Note: Setting option Q is not available when PTCONN = SINGLE or VNOM = OFF.

Note: Setting options V, S, P, and U are not available when (PTCONN = DELTA or VNOM = OFF) and VSCONN = VS.

Make setting 50P32P if E32 = (Y or AUTO) and ELOAD = N, when Global PTCONN ≠ SINGLE.

Phase directional element three-phase current pickup (0.50–10.00 A [5 A nom.], 0.10–2.00 A [1 A nom.] in 0.01 A steps) **50P32P :=** ____________

Make the following settings if E32 = Y. If E32 = AUTO, these settings are made automatically. When Global setting PTCONN = SINGLE, these settings are hidden.

Forward directional Z2 threshold (–128.00–128.00 Ω secondary [5 A nom.] in 0.02 Ω steps) (–640.00–640.00 Ω secondary [1 A nom.] in 0.1 Ω steps) **Z2F :=** ____________

Reverse directional Z2 threshold (–128.00–128.00 Ω secondary [5 A nom.] in 0.02 Ω steps) (–640.00–640.00 Ω secondary [1 A nom.] in 0.1 Ω steps) **Z2R :=** ____________

Forward directional negative-sequence current pickup (0.25–5.00 A secondary [5 A nom.], 0.05–1.00 A secondary [1 A nom.] in 0.01 A steps) **50QFP :=** ____________

Reverse directional negative-sequence current pickup (0.25–5.00 A secondary [5 A nom.], 0.05–1.00 A secondary [1 A nom.] in 0.01 A steps) **50QRP :=** ____________

Positive-sequence current restraint factor, I2/I1 (0.02–0.50, unitless in steps of 0.01) **a2 :=** ____________

Zero-sequence current restraint factor, I2/I0 (0.10–1.20, unitless in steps of 0.01) **k2 :=** ____________

Make settings 50GFP, 50GRP, and a0 if E32 = Y and ORDER contains V or I. If E32 = AUTO and ORDER contains V or I, these settings are made automatically.

Forward directional residual ground pickup (0.05–5.00 A secondary [5 A nom.], 0.01–1.00 A secondary [1 A nom.] in 0.01 A steps) **50GFP :=** ____________

Reverse directional residual ground pickup (0.05–5.00 A secondary [5 A nom.], 0.01–1.00 A secondary [1 A nom.] in 0.01 A steps) **50GRP :=** ____________

Make setting KGN when ORDER contains “I” and E32 = Y.

Neutral Restraint Factor, IG/IN (OFF, 0.001–0.100, unitless in steps of 0.001) **KGN :=** ____________

Make setting INMTA when KGN ≠ OFF.

Neutral Maximum Torque Angle (0.00–85.00 degrees in steps of 0.01 degrees) **INMTA :=** ____________

Positive-sequence current restraint factor, I0/I1 (0.02–0.5, unitless when KGN = OFF) (0.001–0.5, unitless when KGN ≠ OFF) **a0 :=** ____________

Make settings Z0F and Z0R if E32 = Y and ORDER contains V or S. If E32 = AUTO and ORDER contains (V or S), these settings are made automatically.

Forward directional Z0 threshold (–128.00–128.00 Ω secondary in 0.02 Ω steps [5 A nom.]) (–640.00–640.00 Ω secondary in 0.1 Ω steps [1 A nom.]) **Z0F :=** ____________

Reverse directional Z0 threshold (–128.00–128.00 Ω secondary in 0.02 Ω steps [5 A nom.]) (–640.00–640.00 Ω secondary in 0.1 Ω steps [1 A nom.]) **Z0R :=** ____________

Make setting Z0MTA if E32 = Y and ORDER contains V or S.

Zero-Sequence Maximum Torque Angle (–90 to –5.00 degrees and 5.00 to 90 degrees in 0.01 degree steps) **Z0MTA :=** ______

Make settings 50NFP, 50NRP, and a0N if E32 = (Y or AUTO) and ORDER contains (U or S).

Forward Directional IN Pickup (0.005–5.000 A secondary in 0.001 A steps) **50NFP :=** ______

Reverse Directional IN Pickup (0.005–5.000 A secondary in 0.001 A steps) **50NRP :=** ______

Positive-Sequence Restraint Factor, IN/I1 (0.001–0.500, unitless in steps of 0.001) **a0N :=** ______

Wattmetric Element Settings (Petersen Coil Grounded System; see *Directional Control Settings* on page 4.43)

Make the following settings if E32 = (Y or AUTO) and ORDER contains P.

Wattmetric 3V0 Overvoltage Pickup (1.00–430.00 V secondary) **59RES :=** ______

Forward Wattmetric Pickup, (0.001–150 W secondary) **32WFP :=** ______

Reverse Wattmetric Pickup, (0.001–150 W secondary) **32WRP :=** ______

Wattmetric Delay (30–999999.00 cycles in 0.25 cycle steps) **32WD :=** ______

Voltage Elements (see *Figure 3.23*, *Figure 3.24*, *Figure 3.25*, *Figure 3.26*, and *Figure 3.27*)

Make the following settings if EVOLT = Y and Global Setting PTCONN = WYE or SINGLE.

Phase undervoltage pickup (OFF, 0.00–300.00 V secondary in 0.01 V steps) **27P1P :=** ______

Phase undervoltage pickup (OFF, 0.00–300.00 V secondary in 0.01 V steps) **27P2P :=** ______

Phase overvoltage pickup (OFF, 0.00–300.00 V secondary in 0.01 V steps) **59P1P :=** ______

Phase overvoltage pickup (OFF, 0.00–300.00 V secondary in 0.01 V steps) **59P2P :=** ______

Make the following settings if EVOLT = Y and Global setting PTCONN = WYE.

Zero-sequence (3V0) overvoltage pickup (OFF, 0.00–300.00 V secondary, in 0.02 V steps) **59N1P :=** ______

Zero-sequence (3V0) overvoltage pickup (OFF, 0.00–300.00 V secondary, in 0.02 V steps) **59N2P :=** ______

Negative-sequence (V2) overvoltage pickup (OFF, 0.00–200.00 V secondary in 0.01 V steps) **59QP :=** ______

Positive-sequence (V1) overvoltage pickup (OFF, 0.00–300.00 V secondary, in 0.013 V steps) **59V1P :=** ______

Make the following settings if EVOLT = Y and Global setting PTCONN = WYE or SINGLE.

Channel VS undervoltage pickup (OFF, 0.00–300.00 V secondary in 0.01 V steps) **27SP :=** ______

Channel VS overvoltage pickup (OFF, 0.00–300.00 V secondary in 0.01 V steps) **59S1P :=** ______

Channel VS overvoltage pickup (OFF, 0.00–300.00 V secondary in 0.01 V steps) **59S2P :=** ______

Make the following settings if EVOLT = Y and Global setting PTCONN = WYE.

Phase-to-phase undervoltage pickup (OFF, 0.00–520.00 V secondary, in 0.02 V steps) **27PP :=** ______________

Phase-to-phase overvoltage pickup (OFF, 0.00–520.00 V secondary, in 0.02 V steps) **59PP :=** ______________

Make the following settings if EVOLT = Y and Global Setting PTCONN = DELTA.

Negative-sequence (V2) overvoltage pickup (OFF, 0.00–120.00 V secondary in 0.01 V steps) **59QP :=** ______________

Negative-sequence (V2) overvoltage pickup (OFF, 0.00–120.00 V secondary in 0.01 V steps) **59Q2P :=** ______________

Positive-sequence (V1) overvoltage pickup (OFF, 0.00–170.00 V secondary in 0.013 V steps) **59V1P :=** ______________

Channel VS undervoltage pickup (OFF, 0.00–300.00 V secondary in 0.01 V steps) **27SP :=** ______________

Channel VS overvoltage pickup (OFF, 0.00–300.00 V secondary in 0.01 V steps) **59S1P :=** ______________

Channel VS overvoltage pickup (OFF, 0.00–300.00 V secondary in 0.01 V steps) **59S2P :=** ______________

Phase-to-phase undervoltage pickup (OFF, 0.00–300.00 V secondary in 0.01 V steps) **27PP :=** ______________

Phase-to-phase undervoltage pickup (OFF, 0.00–300.00 V secondary in 0.01 V steps) **27PP2P :=** ______________

Phase-to-phase overvoltage pickup (OFF, 0.00–300.00 V secondary in 0.01 V steps) **59PP :=** ______________

Phase-to-phase overvoltage pickup (OFF, 0.00–300.00 V secondary in 0.01 V steps) **59PP2P :=** ______________

Synchronism-Check Elements (see *Figure 3.29* and *Figure 3.30*)

Make the following settings if E25 = Y.

Voltage window—low threshold (0.00–300.00 V secondary in 0.01 V steps) **25VLO :=** ______________

Voltage window—high threshold (0.00–300.00 V secondary in 0.01 V steps) **25VHI :=** ______________

Voltage ratio correction factor (0.50–2.00 unitless in steps of 0.01) **25RCF :=** ______________

Maximum slip frequency (0.005–1.000 Hz in 0.001 Hz steps) **25SF :=** ______________

Note: When TCLOSD is greater than 30 cycles (NFREQ = 60 Hz) or greater than 25 cycles (NFREQ = 50 Hz), 25SF must be set less than or equal to 0.5 Hz.

Maximum angle 1 (0.00–80.00 degrees in 1 degree steps) **25ANG1 :=** ______________

Maximum angle 2 (0.00–80.00 degrees in 1 degree steps) **25ANG2 :=** ______________

Synchronizing phase **SYNCP :=** ______________

(Global setting PTCONN = WYE: VA, VB, VC or 0° to 330° in 30° steps; degree option is for VS not in phase with VA, VB, or VC—set with respect to VS constantly lagging VA)

(Global setting PTCONN = DELTA: VAB, VBC, VCA or 0° to 330° in 30° steps; degree option is for VS not in phase with VAB, VBC, or VCA—set with respect to VS constantly lagging VAB)

(Global setting PTCONN = SINGLE: 0° to 330° in 30° steps, set with respect to VS constantly lagging the voltage connected to the VA-N terminal)

Breaker close time for angle compensation (0.00–60.00 cycles when NFREQ = 60 Hz, 0.00–50.00 cycles when NFREQ = 50 Hz, in 0.25-cycle steps)	**TCLOSD :=** ______

Frequency Elements (see *Figure 3.35*–*Figure 3.40*)

Make the following settings if E81 = 1–6.

Phase undervoltage block (25.00–300.00 V secondary in 0.01 V steps)	**27B81P :=** ______
Level 1 pickup (OFF, 40.10–65.00 Hz in 0.01 Hz steps)	**81D1P :=** ______
Level 1 time delay (2.00–16000.00 cycles in 0.25-cycle steps)	**81D1D :=** ______
Level 2 pickup (OFF, 40.10–65.00 Hz in 0.01 Hz steps)	**81D2P :=** ______
Level 2 time delay (2.00–16000.00 cycles in 0.25-cycle steps)	**81D2D :=** ______
Level 3 pickup (OFF, 40.10–65.00 Hz in 0.01 Hz steps)	**81D3P :=** ______
Level 3 time delay (2.00–16000.00 cycles in 0.25-cycle steps)	**81D3D :=** ______
Level 4 pickup (OFF, 40.10–65.00 Hz in 0.01 Hz steps)	**81D4P :=** ______
Level 4 time delay (2.00–16000.00 cycles in 0.25-cycle steps)	**81D4D :=** ______
Level 5 pickup (OFF, 40.10–65.00 Hz in 0.01 Hz steps)	**81D5P :=** ______
Level 5 time delay (2.00–16000.00 cycles in 0.25-cycle steps)	**81D5D :=** ______
Level 6 pickup (OFF, 40.10–65.00 Hz in 0.01 Hz steps)	**81D6P :=** ______
Level 6 time delay (2.00–16000.00 cycles in 0.25-cycle steps)	**81D6D :=** ______

Rate-of-Change-of-Frequency Element Settings

Make the following settings if E81R = 1–4.

Level 1 Pickup (OFF, 0.10–15 Hz/second in 0.01 Hz/second steps)	**81R1P :=** ______
Level 1 Trend (INC, DEC, ABS)	**81R1TRND :=** ______
Level 1 Timer Pickup (0.10–60 seconds in 0.01 second steps)	**81R1PU :=** ______
Level 1 Timer Dropout (0.00–60 seconds in 0.01 second steps)	**81R1DO :=** ______
Level 2 Pickup (OFF, 0.10–15 Hz/second in 0.01 Hz/second steps)	**81R2P :=** ______
Level 2 Trend (INC, DEC, ABS)	**81R2TRND :=** ______
Level 2 Timer Pickup (0.10–60 seconds in 0.01 second steps)	**81R2PU :=** ______
Level 2 Timer Dropout (0.00–60 seconds in 0.01 second steps)	**81R2DO :=** ______
Level 3 Pickup (OFF, 0.10–15 Hz/second in 0.01 Hz/second steps)	**81R3P :=** ______
Level 3 Trend (INC, DEC, ABS)	**81R3TRND :=** ______
Level 3 Timer Pickup (0.10–60 seconds in 0.01 second steps)	**81R3PU :=** ______
Level 3 Timer Dropout (0.00–60 seconds in 0.01 second steps)	**81R3DO :=** ______
Level 4 Pickup (OFF, 0.10–15 Hz/second in 0.01 Hz/second steps)	**81R4P :=** ______
Level 4 Trend (INC, DEC, ABS)	**81R4TRND :=** ______
Level 4 Timer Pickup (0.10–60 seconds in 0.01 second steps)	**81R4PU :=** ______
Level 4 Timer Dropout (0.00–60 seconds in 0.01 second steps)	**81R4DO :=** ______

Reclosing Relay (see *Table 6.2*)

Make the following settings if E79 = 1–4.

Open interval 1 time (0.00–999999.00 cycles in 0.25-cycle steps)	**79OI1 :=** ______
Open interval 2 time (0.00–999999.00 cycles in 0.25-cycle steps)	**79OI2 :=** ______
Open interval 3 time (0.00–999999.00 cycles in 0.25-cycle steps)	**79OI3 :=** ______
Open interval 4 time (0.00–999999.00 cycles in 0.25-cycle steps)	**79OI4 :=** ______
Reset time from reclose cycle (0.00–999999.00 cycles in 0.25-cycle steps)	**79RSD :=** ______
Reset time from lockout (0.00–999999.00 cycles in 0.25-cycle steps)	**79RSLD :=** ______
Reclose supervision time limit (OFF, 0.00–999999.00 cycles in 0.25-cycle steps) (set 79CLSD = 0.00 for most applications; see *Figure 6.3*)	**79CLSD :=** ______

Switch-Onto-Fault (see *Figure 5.3*)

Make the following settings if ESOTF = Y.

Close enable time delay (OFF, 0.00–16000.00 cycles in 0.25-cycle steps)	**CLOEND :=** ______
52 A enable time delay (OFF, 0.00–16000.00 cycles in 0.25-cycle steps)	**52AEND :=** ______
SOTF duration (0.50–16000.00 cycles in 0.25-cycle steps)	**SOTFD :=** ______

POTT Trip Scheme Settings (Also Used in DCUB Trip Schemes; see *Figure 5.6*)

Make the following settings if ECOMM = POTT, DCUB1, or DCUB2.

Zone (level) 3 reverse block time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**Z3RBD :=** ______
Echo block time delay (OFF, 0.00–16000.00 cycles in 0.25-cycle steps)	**EBLKD :=** ______
Echo time delay pickup (OFF, 0.00–16000.00 cycles in 0.25-cycle steps)	**ETDPU :=** ______
Echo duration time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**EDURD :=** ______
Weak-infeed enable (Y, N)	**EWFC :=** ______

Additional DCUB Trip Scheme Settings (see *Figure 5.10*)

Make the following settings if ECOMM = DCUB1 or DCUB2.

Guard present security time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**GARD1D :=** ______
DCUB disabling time delay (0.25–16000.00 cycles in 0.25-cycle steps)	**UBDURD :=** ______
DCUB duration time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**UBEND :=** ______

DCB Trip Scheme Settings (see *Figure 5.14*)

Make the following settings if ECOMM = DCB.

Zone (level) 3 reverse pickup time delay (0.00–16000.00 cycles in 0.25-cycle steps) **Z3XPU :=** ____________

Zone (level) 3 reverse dropout extension (0.00–16000.00 cycles in 0.25-cycle steps) **Z3XD :=** ____________

Block trip receive extension (0.00–16000.00 cycles in 0.25-cycle steps) **BTXD :=** ____________

Level 2 phase short delay (0.00–60.00 cycles in 0.25-cycle steps) **67P2SD :=** ____________

Level 2 neutral ground short delay (0.00–60.00 cycles in 0.25-cycle steps) **67N2SD :=** ____________

Level 2 residual ground short delay (0.00–60.00 cycles in 0.25-cycle steps) **67G2SD :=** ____________

Level 2 negative-sequence short delay (0.00–60.00 cycles in 0.25-cycle steps) **67Q2SD :=** ____________

Demand Metering Settings (see *Figure 8.14* and *Figure 8.16*)

Make the following settings, whether EDEM = THM or ROL.

Time constant (5, 10, 15, 30, 60 minutes) **DMTC :=** ____________

Phase pickup (OFF, 0.50–16.00 A secondary [5 A nom.], 0.10–3.20 A secondary [1 A nom.] in 0.01 A steps) **PDEMP :=** ____________

Neutral-ground pickup-channel IN (OFF, 0.500–16.000 A secondary in 0.005 A steps [5 A nom.], 0.100–3.200 A secondary in 0.001 A steps [1 A nom.], 0.005–0.640 A secondary in 0.001 A steps [0.2 A nom.], 0.005–0.160 A secondary in 0.001 A steps [0.05 A nom.]) **NDEMP :=** ____________

Residual-ground pickup (OFF, 0.10–16.00 A secondary [5 A nom.], 0.02–3.20 A secondary [1 A nom.] in 0.01 A steps) **GDEMP :=** ____________

Negative-sequence pickup (OFF, 0.50–16.00 A secondary [5 A nom.], 0.10–3.20 A secondary [1 A nom.] in 0.01 A steps) **QDEMP :=** ____________

Other Settings

Make the following settings—they have no controlling enable setting.

Minimum trip duration time (4.00–16000.00 cycles in 0.25-cycle steps; see *Figure 5.1*) **TDURD :=** ____________

Close failure time delay (OFF, 0.00–16000.00 cycles in 0.25-cycle steps; see *Figure 6.2*) **CFD :=** ____________

Three-pole open time delay (0.00–60.00 cycles in 0.25-cycle steps) (usually set for no more than a few cycles; see *Figure 5.3*) **3POD :=** ____________

Load detection phase pickup (OFF, 0.25–100.00 A secondary [5 A nom.], 0.05–20.00 A secondary [1 A nom.] in 0.01 A steps; see *Figure 5.3*) **50LP :=** ____________

SELOGIC Control Equation Variable Timers (see *Figure 7.24* and *Figure 7.25*)

The number of timer pickup/dropout settings is dependent on ESV = 1–16.

SV1 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps) **SV1PU :=** ______________

SV1 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps) **SV1DO :=** ______________

SV2 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps) **SV2PU :=** ______________

SV2 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps) **SV2DO :=** ______________

SV3 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps) **SV3PU :=** ______________

SV3 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps) **SV3DO :=** ______________

SV4 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps) **SV4PU :=** ______________

SV4 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps) **SV4DO :=** ______________

SV5 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps) **SV5PU :=** ______________

SV5 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps) **SV5DO :=** ______________

SV6 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps) **SV6PU :=** ______________

SV6 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps) **SV6DO :=** ______________

SV7 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV7PU :=** ______________

SV7 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV7DO :=** ______________

SV8 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV8PU :=** ______________

SV8 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV8DO :=** ______________

SV9 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV9PU :=** ______________

SV9 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV9DO :=** ______________

SV10 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV10PU :=** ______________

SV10 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV10DO :=** ______________

SV11 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV11PU :=** ______________

SV11 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV11DO :=** ______________

SV12 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV12PU :=** ______________

SV12 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV12DO :=** ______________

SV13 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV13PU :=** ______________

SV13 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV13DO :=** ______________

SV14 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV14PU :=** ______________

SV14 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV14DO :=** ______________

SV15 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV15PU :=** ______________

SV15 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV15DO :=** ______________

SV16 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV16PU :=** ______________

SV16 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps) **SV16DO :=** ______________

Power Elements (Available in Firmware Version 7; see *Figure 3.46* and *Figure 3.47*)

The number of power element settings is dependent on preceding enable setting EPWR = 1–4, 3P1–3P4.

Make setting PWR1P if EPWR = 1–4.

Per-Phase Power Element Pickup **PWR1P :=** __________
(OFF, 0.33–13000.00 VA secondary per phase in 0.01 VA steps [5 A nom.])
(OFF, 0.07–2600.00 VA secondary per phase in 0.01 VA steps [1 A nom.])

Make setting 3PWR1P if EPWR = 3P1–3P4).

Three-Phase Power Element Pickup **3PWR1P :=** __________
(OFF, 1.00–39000.00 VA secondary three-phase in 0.01 VA steps [5 A nom.])
(OFF, 0.20–7800.00 VA secondary three-phase in 0.01 VA steps [1 A nom.])

Pwr Ele. Type (+WATTS, –WATTS, +VARS, –VARS) **PWR1T :=** __________

Pwr Ele. Time Delay (0.00–16000.00 cycles) **PWR1D :=** __________

Make setting PWR2P if EPWR = 2–4.

Per-Phase Power Element Pickup **PWR2P :=** __________
(OFF, 0.33–13000.00 VA secondary per phase in 0.01 VA steps [5 A nom.])
(OFF, 0.07–2600.00 VA secondary per phase in 0.01 VA steps [1 A nom.])

Make setting 3PWR2P if EPWR = 3P2–3P4.

Three-Phase Power Element Pickup **3PWR2P :=** __________
(OFF, 1.00–39000.00 VA secondary three-phase in 0.01 VA steps [5 A nom.])
(OFF, 0.20–7800.00 VA secondary three-phase in 0.01 VA steps [1 A nom.])

Pwr Ele. Type (+WATTS, –WATTS, +VARS, –VARS) **PWR2T :=** __________

Pwr Ele. Time Delay (0.00–16000.00 cycles) **PWR2D :=** __________

Make setting 3PWR3P if EPWR = 3–4.

Per-Phase Power Element Pickup **PWR3P :=** __________
(OFF, 0.33–13000.00 VA secondary per phase in 0.01 VA steps [5 A nom.])
(OFF, 0.07–2600.00 VA secondary per phase in 0.01 VA steps [1 A nom.])

Make setting 3PWR3P if EPWR = 3P3–3P4.

Three-Phase Power Element Pickup **3PWR3P :=** __________
(OFF, 1.00–39000.00 VA secondary three-phase in 0.01 VA steps [5 A nom.])
(OFF, 0.20–7800.00 VA secondary three-phase in 0.01 VA steps [1 A nom.])

Pwr Ele. Type (+WATTS, –WATTS, +VARS, –VARS) **PWR3T :=** __________

Pwr Ele. Time Delay (0.00–16000.00 cycles) **PWR3D :=** __________

Make setting PWR4P if EPWR = 4.

Per-Phase Power Element Pickup **PWR4P :=** __________
(OFF, 0.33–13000.00 VA secondary per phase in 0.01 VA steps [5 A nom.])
(OFF, 0.07–2600.00 VA secondary per phase in 0.01 VA steps [1 A nom.])

Make setting 3PWR4P if EPWR = 3P4.

Three-Phase Power Element Pickup **3PWR4P :=** __________
(OFF, 1.00–39000.00 VA secondary three-phase in 0.01 VA steps [5 A nom.])
(OFF, 0.20–7800.00 VA secondary three-phase in 0.01 VA steps [1 A nom.])

Pwr Ele. Type (+WATTS, –WATTS, +VARS, –VARS) **PWR4T :=** __________

Pwr Ele. Time Delay (0.00–16000.00 cycles) **PWR4D :=** __________

Voltage Sag/Swell/Interrupt (Available in Firmware Version 7; see *Figure 3.42*, *Figure 3.43*, *Figure 3.44*)

Make the following settings if ESSI = Y.

Percent Phase Interruption Pickup (Global Setting PTCONN = WYE) or Percent Line-to-Line Interruption Pickup (Global Setting PTCONN = DELTA) (OFF, 5.00–95.00 in steps of 0.01; cannot be set higher than VSAG)	**VINT :=** ____________
Percent Phase Voltage Sag Pickup (Global Setting PTCONN = WYE) or Percent Line-to-Line Voltage Sag Pickup (Global Setting PTCONN = DELTA) (OFF, 10.00–95.00 in steps of 0.01)	**VSAG :=** ____________
Percent Phase Voltage Swell Pickup (Global Setting PTCONN = WYE) or Percent Line-to-Line Voltage Swell Pickup (Global Setting PTCONN = DELTA) (OFF; 105.00–180.00 in steps of 0.01)	**VSWELL :=** ____________

SELOGIC Control Equation Settings (Serial Port Command SET L)

SELOGIC control equation settings consist of Relay Word bits (see *Table D.1*) and SELOGIC control equation operators * (AND), + (OR), ! (NOT), / (rising edge), \ (falling edge), and ( ) (parentheses). Numerous SELOGIC control equation settings examples are given in *Section 3: Overcurrent, Harmonic Blocking, Voltage, Synchronism Check, Frequency, and Power Elements* through *Section 8: Breaker Monitor, Metering, and Load Profile Functions*. SELOGIC control equation settings can also be set directly to 1 (logical 1) or 0 (logical 0). *Appendix F: Setting SELOGIC Control Equations* gives SELOGIC control equation details, examples, and limitations.

Trip Logic Equations (see *Figure 5.1*)

Other trip conditions	**TR :=** ____________
Trip conditions qualified by disturbance detector	**TRQUAL :=** ____________
Communications-assisted trip conditions	**TRCOMM :=** ____________
Switch-onto-fault trip conditions	**TRSOTF :=** ____________
Direct transfer trip conditions	**DTT :=** ____________
Unlatch trip conditions	**ULTR :=** ____________

Communications-Assisted Trip Scheme Input Equations

Permissive trip 1 (used for ECOMM = POTT, DCUB1, or DCUB2; see *Figure 5.5*, *Figure 5.7*, and *Figure 5.10*	**PT1 :=** ____________
Loss-of-guard 1 (used for ECOMM = DCUB1 or DCUB2; see *Figure 5.10*)	**LOG1 :=** ____________
Permissive trip 2 (used for ECOMM = DCUB2; see *Figure 5.5* and *Figure 5.10*)	**PT2 :=** ____________
Loss of guard 2 (used for ECOMM = DCUB2; see *Figure 5.10*)	**LOG2 :=** ____________
Block trip (used for ECOMM = DCB; see *Figure 5.14*)	**BT :=** ____________

Close Logic Equations (see *Figure 6.2*)

Circuit breaker status (used in *Figure 5.3* also)	**52A :=** ________________
Close conditions (other than automatic reclosing)	**CL :=** ________________
Unlatch close conditions	**ULCL :=** ________________

Reclosing Relay Equations (see *Reclosing Relay* on page 6.12)

Reclose initiate	**79RI :=** ________________
Reclose initiate supervision	**79RIS :=** ________________
Drive-to-lockout	**79DTL :=** ________________
Drive-to-last shot	**79DLS :=** ________________
Skip shot	**79SKP :=** ________________
Stall open interval timing	**79STL :=** ________________
Block reset timing	**79BRS :=** ________________
Sequence coordination	**79SEQ :=** ________________
Reclose supervision (see *Figure 6.3*)	**79CLS :=** ________________

Latch Bits Set/Reset Equations (see *Figure 7.12*)

Set Latch Bit LT1	**SET1 :=** ________________
Reset Latch Bit LT1	**RST1 :=** ________________
Set Latch Bit LT2	**SET2 :=** ________________
Reset Latch Bit LT2	**RST2 :=** ________________
Set Latch Bit LT3	**SET3 :=** ________________
Reset Latch Bit LT3	**RST3 :=** ________________
Set Latch Bit LT4	**SET4 :=** ________________
Reset Latch Bit LT4	**RST4 :=** ________________
Set Latch Bit LT5	**SET5 :=** ________________
Reset Latch Bit LT5	**RST5 :=** ________________
Set Latch Bit LT6	**SET6 :=** ________________
Reset Latch Bit LT6	**RST6 :=** ________________
Set Latch Bit LT7	**SET7 :=** ________________
Reset Latch Bit LT7	**RST7 :=** ________________
Set Latch Bit LT8	**SET8 :=** ________________
Reset Latch Bit LT8	**RST8 :=** ________________
Set Latch Bit LT9	**SET9 :=** ________________
Reset Latch Bit LT9	**RST9 :=** ________________
Set Latch Bit LT10	**SET10 :=** ________________
Reset Latch Bit LT10	**RST10 :=** ________________

Set Latch Bit LT11	**SET11 :=** ________________
Reset Latch Bit LT11	**RST11 :=** ________________
Set Latch Bit LT12	**SET12 :=** ________________
Reset Latch Bit LT12	**RST12 :=** ________________
Set Latch Bit LT13	**SET13 :=** ________________
Reset Latch Bit LT13	**RST13 :=** ________________
Set Latch Bit LT14	**SET14 :=** ________________
Reset Latch Bit LT14	**RST14 :=** ________________
Set Latch Bit LT15	**SET15 :=** ________________
Reset Latch Bit LT15	**RST15 :=** ________________
Set Latch Bit LT16	**SET16 :=** ________________
Reset Latch Bit LT16	**RST16 :=** ________________

Torque-Control Equations for Inst./Def.-Time Overcurrent Elements

Note: Torque-control equation settings cannot be set directly to logical 0.

Level 1 phase (see *Figure 3.3*)	**67P1TC :=** ________________
Level 2 phase (see *Figure 3.3*)	**67P2TC :=** ________________
Level 3 phase (see *Figure 3.3*)	**67P3TC :=** ________________
Level 4 phase (see *Figure 3.3*)	**67P4TC :=** ________________
Level 1 neutral ground (see *Figure 3.8*)	**67N1TC :=** ________________
Level 2 neutral ground (see *Figure 3.8*)	**67N2TC :=** ________________
Level 3 neutral ground (see *Figure 3.8*)	**67N3TC :=** ________________
Level 4 neutral ground (see *Figure 3.8*)	**67N4TC :=** ________________
Level 1 residual ground (see *Figure 3.10*)	**67G1TC :=** ________________
Level 2 residual ground (see *Figure 3.10*)	**67G2TC :=** ________________
Level 3 residual ground (see *Figure 3.10*)	**67G3TC :=** ________________
Level 4 residual ground (see *Figure 3.10*)	**67G4TC :=** ________________
Level 1 negative-sequence (see *Figure 3.12*)	**67Q1TC :=** ________________
Level 2 negative-sequence (see *Figure 3.12*)	**67Q2TC :=** ________________
Level 3 negative-sequence (see *Figure 3.12*)	**67Q3TC :=** ________________
Level 4 negative-sequence (see *Figure 3.12*)	**67Q4TC :=** ________________

Torque-Control Equations for Time-Overcurrent Elements

Note: Torque-control equation settings cannot be set directly to logical 0.

A-phase (see *Figure 3.15*)	**51ATC :=** ________________
B-phase (see *Figure 3.16*)	**51BTC :=** ________________
C-phase (see *Figure 3.17*)	**51CTC :=** ________________
Phase (see *Figure 3.14*)	**51PTC :=** ________________

Neutral Ground (see *Figure 3.18*)	**51NTC :=**	____________
Residual Ground (see *Figure 3.19*)	**51GTC :=**	____________
Residual Ground (see *Figure 3.20*)	**51G2TC :=**	____________
Negative-Sequence (see *Figure 3.21*)	**51QTC :=**	____________

Other Torque Control

Second Harmonic Blocking	**HBL2TC :=**	____________
Rate-of-Change of Frequency	**81RTC :=**	____________

Breaker Failure Equations

Breaker Failure Initiate	**BFI :=**	____________
Breaker Failure Trip	**BFTR :=**	____________
Breaker Failure Unlatch Trip	**BFULTR :=**	____________

Logic Variable Equations (see *Figure 7.27*)

Logic Variable LV1	**LV1 :=**	____________
Logic Variable LV2	**LV2 :=**	____________
Logic Variable LV3	**LV3 :=**	____________
Logic Variable LV4	**LV4 :=**	____________
Logic Variable LV5	**LV5 :=**	____________
Logic Variable LV6	**LV6 :=**	____________
Logic Variable LV7	**LV7 :=**	____________
Logic Variable LV8	**LV8 :=**	____________
Logic Variable LV9	**LV9 :=**	____________
Logic Variable LV10	**LV10 :=**	____________
Logic Variable LV11	**LV11 :=**	____________
Logic Variable LV12	**LV12 :=**	____________
Logic Variable LV13	**LV13 :=**	____________
Logic Variable LV14	**LV14 :=**	____________
Logic Variable LV15	**LV15 :=**	____________
Logic Variable LV16	**LV16 :=**	____________
Logic Variable LV17	**LV17 :=**	____________
Logic Variable LV18	**LV18 :=**	____________
Logic Variable LV19	**LV19 :=**	____________
Logic Variable LV20	**LV20 :=**	____________
Logic Variable LV21	**LV21 :=**	____________
Logic Variable LV22	**LV22 :=**	____________
Logic Variable LV23	**LV23 :=**	____________

Logic Variable LV24	**LV24 :=** ________
Logic Variable LV25	**LV25 :=** ________
Logic Variable LV26	**LV26 :=** ________
Logic Variable LV27	**LV27 :=** ________
Logic Variable LV28	**LV28 :=** ________
Logic Variable LV29	**LV29 :=** ________
Logic Variable LV30	**LV30 :=** ________
Logic Variable LV31	**LV31 :=** ________
Logic Variable LV32	**LV32 :=** ________

SELOGIC Control Equation Variable Timer Input Equations (see *Figure 7.24* and *Figure 7.25*)

SELOGIC Control Equation Variable SV1	**SV1 :=** ________
SELOGIC Control Equation Variable SV2	**SV2 :=** ________
SELOGIC Control Equation Variable SV3	**SV3 :=** ________
SELOGIC Control Equation Variable SV4	**SV4 :=** ________
SELOGIC Control Equation Variable SV5	**SV5 :=** ________
SELOGIC Control Equation Variable SV6	**SV6 :=** ________
SELOGIC Control Equation Variable SV7	**SV7 :=** ________
SELOGIC Control Equation Variable SV8	**SV8 :=** ________
SELOGIC Control Equation Variable SV9	**SV9 :=** ________
SELOGIC Control Equation Variable SV10	**SV10 :=** ________
SELOGIC Control Equation Variable SV11	**SV11 :=** ________
SELOGIC Control Equation Variable SV12	**SV12 :=** ________
SELOGIC Control Equation Variable SV13	**SV13 :=** ________
SELOGIC Control Equation Variable SV14	**SV14 :=** ________
SELOGIC Control Equation Variable SV15	**SV15 :=** ________
SELOGIC Control Equation Variable SV16	**SV16 :=** ________

Output Contact Equations (see *Figure 7.28*)

Output Contact OUT101	**OUT101 :=** ________
Output Contact OUT102	**OUT102 :=** ________
Output Contact OUT103	**OUT103 :=** ________
Output Contact OUT104	**OUT104 :=** ________
Output Contact OUT105	**OUT105 :=** ________
Output Contact OUT106	**OUT106 :=** ________
Output Contact OUT107	**OUT107 :=** ________
Output Contact ALARM	**ALRMOUT :=** ________

Output Contact Equations—Extra I/O Board Options 2, 4, and 6 (see *Figure 7.29*)

Output Contact OUT201	**OUT201 :=** ________________
Output Contact OUT202	**OUT202 :=** ________________
Output Contact OUT203	**OUT203 :=** ________________
Output Contact OUT204	**OUT204 :=** ________________

Output Contact Equations—Extra I/O Board Options 2 and 6 (see *Figure 7.29*)

Output Contact OUT205	**OUT205 :=** ________________
Output Contact OUT206	**OUT206 :=** ________________
Output Contact OUT207	**OUT207 :=** ________________
Output Contact OUT208	**OUT208 :=** ________________
Output Contact OUT209	**OUT209 :=** ________________
Output Contact OUT210	**OUT210 :=** ________________
Output Contact OUT211	**OUT211 :=** ________________
Output Contact OUT212	**OUT212 :=** ________________

Display Point Equations (see *Rotating Display* on page 7.37 and *Rotating Display* on page 11.10)

Display Point DP1	**DP1 :=** ________________
Display Point DP2	**DP2 :=** ________________
Display Point DP3	**DP3 :=** ________________
Display Point DP4	**DP4 :=** ________________
Display Point DP5	**DP5 :=** ________________
Display Point DP6	**DP6 :=** ________________
Display Point DP7	**DP7 :=** ________________
Display Point DP8	**DP8 :=** ________________
Display Point DP9	**DP9 :=** ________________
Display Point DP10	**DP10 :=** ________________
Display Point DP11	**DP11 :=** ________________
Display Point DP12	**DP12 :=** ________________
Display Point DP13	**DP13 :=** ________________
Display Point DP14	**DP14 :=** ________________
Display Point DP15	**DP15 :=** ________________
Display Point DP16	**DP16 :=** ________________

Setting Group Selection Equations (see *Table 7.4*)

Select Setting Group 1	**SS1 :=**	________
Select Setting Group 2	**SS2 :=**	________
Select Setting Group 3	**SS3 :=**	________
Select Setting Group 4	**SS4 :=**	________
Select Setting Group 5	**SS5 :=**	________
Select Setting Group 6	**SS6 :=**	________

Other Equations

Event report trigger conditions (see *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*)	**ER :=**	________
Fault indication (used in INST, A, B, and C target logic and other relay functions, see *SELOGIC Control Equation Setting FAULT* on page 5.39)	**FAULT :=**	________
Block synchronism-check elements (see *Figure 3.29*)	**BSYNCH :=**	________
Close bus monitor (see *Figure 5.3*)	**CLMON :=**	________
Breaker monitor trip initiation (see *Figure 8.3*)	**BKMON :=**	________
Breaker monitor close initiation (see *Mechanical and Electrical Operate Timers and Alarms* on page 8.12)	**BKCLS :=**	________
Enable for zero-sequence voltage-polarized, sensitive neutral, and channel IN current-polarized directional elements (see *Figure 4.12*)	**E32IV :=**	________
Block loss-of-potential conditions (see *Figure 4.1*)	**LOPBLK :=**	________
Software alarm conditions	**SALARM :=**	________

Reset Equations (see *Section 5*, *Section 8*, and *Section 12*)

Reset Targets	**RSTTRGT :=**	________
Reset Demand Metering	**RST_DEM :=**	________
Reset Peak Demand Metering	**RST_PDM :=**	________
Reset Breaker Monitor	**RST_BK :=**	________
Reset Event History	**RST_HIS :=**	________
Reset Energy Metering	**RST_ENE :=**	________
Reset Max/Min Metering	**RST_MML :=**	________
Reset Hardware Alarm	**RST_HAL :=**	________
Reset DNP Event Queue	**RSTDNPE :=**	________

Phasor Measurement Unit (PMU) Trigger Equations (see *Appendix N*)

PMU Trigger	**PMTRIG :=**	________
Trigger Reason Bit 1	**TREA1 :=**	________

Trigger Reason Bit 2	**TREA2 :=** ____________
Trigger Reason Bit 3	**TREA3 :=** ____________
Trigger Reason Bit 4	**TREA4 :=** ____________

MIRRORED BITS Transmit Equations (Available in Firmware Versions 6 and 7; see *Appendix H*)

Channel A, transmit bit 1	**TMB1A :=** ____________
Channel A, transmit bit 2	**TMB2A :=** ____________
Channel A, transmit bit 3	**TMB3A :=** ____________
Channel A, transmit bit 4	**TMB4A :=** ____________
Channel A, transmit bit 5	**TMB5A :=** ____________
Channel A, transmit bit 6	**TMB6A :=** ____________
Channel A, transmit bit 7	**TMB7A :=** ____________
Channel A, transmit bit 8	**TMB8A :=** ____________
Channel B, transmit bit 1	**TMB1B :=** ____________
Channel B, transmit bit 2	**TMB2B :=** ____________
Channel B, transmit bit 3	**TMB3B :=** ____________
Channel B, transmit bit 4	**TMB4B :=** ____________
Channel B, transmit bit 5	**TMB5B :=** ____________
Channel B, transmit bit 6	**TMB6B :=** ____________
Channel B, transmit bit 7	**TMB7B :=** ____________
Channel B, transmit bit 8	**TMB8B :=** ____________

Report Settings (Serial Port Command SET R)

Sequential Events Recorder (SER) Trigger Lists (see *Sequential Events Recorder (SER) Report* on page 12.31)

Sequential Events Recorder settings are made of three trigger lists. Each trigger list can include as many as 24 Relay Word bits (see *Table D.1*) delimited by commas or spaces. Enter NA to remove a list of these Relay Word bit settings.

SER Trigger List 1

SER1 := = ____________

____

____

SER Trigger List 2

SER2 := ____________

____

____

SER Trigger List 3

SER3 := ______________________________

____

____

Load Profile Settings (see *Load Profile Report (Available in Firmware Versions 6 and 7)* on page 8.45)

Load profile list (15 elements max., enter NA to null)

LDLIST := ______________________________

____

Note: LDLIST may contain any of the elements listed in *Table E.1* that have an "x" in the Load Profile column.

Load Profile Acquisition Rate (5, 10, 15, 30, 60 min) **LDAR :=** ______________

Text Label Settings (Serial Port Command SET T)

Enter the following characters: 0–9, A–Z, -, /, ., space for each text label setting, subject to the specified character limit. Enter NA to null a label.

Local Bit Labels (see *Table 7.1* and *Table 7.2*)

Local Bit LB1 Name (14 characters) **NLB1 :=** ______________

Clear Local Bit LB1 Label (7 characters) **CLB1 :=** ______________

Set Local Bit LB1 Label (7 characters) **SLB1 :=** ______________

Pulse Local Bit LB1 Label (7 characters) **PLB1 :=** ______________

Local Bit LB2 Name (14 characters) **NLB2 :=** ______________

Clear Local Bit LB2 Label (7 characters) **CLB2 :=** ______________

Set Local Bit LB2 Label (7 characters) **SLB2 :=** ______________

Pulse Local Bit LB2 Label (7 characters) **PLB2 :=** ______________

Local Bit LB3 Name (14 characters) **NLB3 :=** ______________

Clear Local Bit LB3 Label (7 characters) **CLB3 :=** ______________

Set Local Bit LB3 Label (7 characters) **SLB3 :=** ______________

Pulse Local Bit LB3 Label (7 characters) **PLB3 :=** ______________

Local Bit LB4 Name (14 characters) **NLB4 :=** ______________

Clear Local Bit LB4 Label (7 characters) **CLB4 :=** ______________

Set Local Bit LB4 Label (7 characters) **SLB4 :=** ______________

Pulse Local Bit LB4 Label (7 characters) **PLB4 :=** ______________

Local Bit LB5 Name (14 characters) **NLB5 :=** ______________

Clear Local Bit LB5 Label (7 characters) **CLB5 :=** ______________

Set Local Bit LB5 Label (7 characters)	**SLB5 :=** ____
Pulse Local Bit LB5 Label (7 characters)	**PLB5 :=** ____
Local Bit LB6 Name (14 characters)	**NLB6 :=** ____
Clear Local Bit LB6 Label (7 characters)	**CLB6 :=** ____
Set Local Bit LB6 Label (7 characters)	**SLB6 :=** ____
Pulse Local Bit LB6 Label (7 characters)	**PLB6 :=** ____
Local Bit LB7 Name (14 characters)	**NLB7 :=** ____
Clear Local Bit LB7 Label (7 characters)	**CLB7 :=** ____
Set Local Bit LB7 Label (7 characters)	**SLB7 :=** ____
Pulse Local Bit LB7 Label (7 characters)	**PLB7 :=** ____
Local Bit LB8 Name (14 characters)	**NLB8 :=** ____
Clear Local Bit LB8 Label (7 characters)	**CLB8 :=** ____
Set Local Bit LB8 Label (7 characters)	**SLB8 :=** ____
Pulse Local Bit LB8 Label (7 characters)	**PLB8 :=** ____
Local Bit LB9 Name (14 characters)	**NLB9 :=** ____
Clear Local Bit LB9 Label (7 characters)	**CLB9 :=** ____
Set Local Bit LB9 Label (7 characters)	**SLB9 :=** ____
Pulse Local Bit LB9 Label (7 characters)	**PLB9 :=** ____
Local Bit LB10 Name (14 characters)	**NLB10 :=** ____
Clear Local Bit LB10 Label (7 characters)	**CLB10 :=** ____
Set Local Bit LB10 Label (7 characters)	**SLB10 :=** ____
Pulse Local Bit LB10 Label (7 characters)	**PLB10 :=** ____
Local Bit LB11 Name (14 characters)	**NLB11 :=** ____
Clear Local Bit LB11 Label (7 characters)	**CLB11 :=** ____
Set Local Bit LB11 Label (7 characters)	**SLB11 :=** ____
Pulse Local Bit LB11 Label (7 characters)	**PLB11 :=** ____
Local Bit LB12 Name (14 characters)	**NLB12 :=** ____
Clear Local Bit LB12 Label (7 characters)	**CLB12 :=** ____
Set Local Bit LB12 Label (7 characters)	**SLB12 :=** ____
Pulse Local Bit LB12 Label (7 characters)	**PLB12 :=** ____
Local Bit LB13 Name (14 characters)	**NLB13 :=** ____
Clear Local Bit LB13 Label (7 characters)	**CLB13 :=** ____
Set Local Bit LB13 Label (7 characters)	**SLB13 :=** ____
Pulse Local Bit LB13 Label (7 characters)	**PLB13 :=** ____
Local Bit LB14 Name (14 characters)	**NLB14 :=** ____
Clear Local Bit LB14 Label (7 characters)	**CLB14 :=** ____
Set Local Bit LB14 Label (7 characters)	**SLB14 :=** ____
Pulse Local Bit LB14 Label (7 characters)	**PLB14 :=** ____

Local Bit LB15 Name (14 characters)	**NLB15 :=** ____________
Clear Local Bit LB15 Label (7 characters)	**CLB15 :=** ____________
Set Local Bit LB15 Label (7 characters)	**SLB15 :=** ____________
Pulse Local Bit LB15 Label (7 characters)	**PLB15 :=** ____________
Local Bit LB16 Name (14 characters)	**NLB16 :=** ____________
Clear Local Bit LB16 Label (7 characters)	**CLB16 :=** ____________
Set Local Bit LB16 Label (7 characters)	**SLB16 :=** ____________
Pulse Local Bit LB16 Label (7 characters)	**PLB16 :=** ____________

Display Point Labels (see *Rotating Display* on page 7.37 and *Rotating Display* on page 11.10)

Display if DP1 = logical 1 (16 characters)	**DP1_1 :=** ____________
Display if DP1 = logical 0 (16 characters)	**DP1_0 :=** ____________
Display if DP2 = logical 1 (16 characters)	**DP2_1 :=** ____________
Display if DP2 = logical 0 (16 characters)	**DP2_0 :=** ____________
Display if DP3 = logical 1 (16 characters)	**DP3_1 :=** ____________
Display if DP3 = logical 0 (16 characters)	**DP3_0 :=** ____________
Display if DP4 = logical 1 (16 characters)	**DP4_1 :=** ____________
Display if DP4 = logical 0 (16 characters)	**DP4_0 :=** ____________
Display if DP5 = logical 1 (16 characters)	**DP5_1 :=** ____________
Display if DP5 = logical 0 (16 characters)	**DP5_0 :=** ____________
Display if DP6 = logical 1 (16 characters)	**DP6_1 :=** ____________
Display if DP6 = logical 0 (16 characters)	**DP6_0 :=** ____________
Display if DP7 = logical 1 (16 characters)	**DP7_1 :=** ____________
Display if DP7 = logical 0 (16 characters)	**DP7_0 :=** ____________
Display if DP8 = logical 1 (16 characters)	**DP8_1 :=** ____________
Display if DP8 = logical 0 (16 characters)	**DP8_0 :=** ____________
Display if DP9 = logical 1 (16 characters)	**DP9_1 :=** ____________
Display if DP9 = logical 0 (16 characters)	**DP9_0 :=** ____________
Display if DP10 = logical 1 (16 characters)	**DP10_1 :=** ____________
Display if DP10 = logical 0 (16 characters)	**DP10_0 :=** ____________
Display if DP11 = logical 1 (16 characters)	**DP11_1 :=** ____________
Display if DP11 = logical 0 (16 characters)	**DP11_0 :=** ____________
Display if DP12 = logical 1 (16 characters)	**DP12_1 :=** ____________
Display if DP12 = logical 0 (16 characters)	**DP12_0 :=** ____________
Display if DP13 = logical 1 (16 characters)	**DP13_1 :=** ____________
Display if DP13 = logical 0 (16 characters)	**DP13_0 :=** ____________
Display if DP14 = logical 1 (16 characters)	**DP14_1 :=** ____________

Display if DP14 = logical 0 (16 characters) **DP14_0 :=** ______________

Display if DP15 = logical 1 (16 characters) **DP15_1 :=** ______________

Display if DP15 = logical 0 (16 characters) **DP15_0 :=** ______________

Display if DP16 = logical 1 (16 characters) **DP16_1 :=** ______________

Display if DP16 = logical 0 (16 characters) **DP16_0 :=** ______________

Reclosing Relay Labels (see *Functions Unique to the Front-Panel Interface* on page 11.5)

Reclosing Relay Last Shot Label (14 char.) **79LL :=** ______________

Reclosing Relay Shot Counter Label (14 char.) **79SL :=** ______________

Port n Settings (for Serial Ports 1, 2, 3 and F) (Serial Port SET P n Command and Front Panel)

Make Port 1 settings only if the relay is ordered with the optional EIA-485 port or SEL-2812-compatible fiber-optic port.

Port Enable Settings

Enable Port (Y, N) **EPORT :=** ______

Note: Setting EPORT = N completely disables the serial port, and hides all remaining port settings.

Note: The front-panel (Port F) EPORT setting controls both the EIA-232 serial port and the optional USB port.

Note: If the Access jumper is not installed when EPORT is set to N on the front port and all other ports are disabled, or MAXACC < 2 on all enabled ports, the port can only be reenabled via the HMI or by installing the Access jumper and cycling power.

Protocol Selection

Protocol (SEL, LMD, DNP, MOD, MBA, MBB, MB8A, MB8B, PMU) **PROTO :=** ______

Note: Modbus protocol (PROTO = MOD) cannot be selected for the front-panel serial port (Port F).

Set PROTO = SEL for standard SEL ASCII protocol. Refer to *Section 10: Communications* for details on SEL ASCII protocol.

Set PROTO = LMD for SEL Distributed Port Switch Protocol (LMD). Refer to *Appendix I: SEL Distributed Port Switch Protocol* for details on the LMD protocol.

Set PROTO = DNP for Distributed Network Protocol (DNP). As many as six DNP sessions are available, shared between the serial ports and the Ethernet port. Refer to *Appendix L: DNP3 Communications* for details on DNP protocol.

Set PROTO = MOD for Modbus communications. As many as three Modbus sessions are available, shared between the serial ports and the Ethernet port. Refer to *Appendix O: Modbus RTU and TCP Communications* for details on Modbus protocol.

Set PROTO = MBA, MBB, MB8A, or MB8B for MIRRORED BITS, available on SEL-351-6 and SEL-351-7 relays. Only one port can be set to MBA or MB8A at a time. Only one port can be set to MBB or MB8B at a time. Refer to *Appendix H: MIRRORED BITS Communications (in Firmware Versions 6 and 7)* for details on MIRRORED BITS.

Set PROTO = PMU for IEEE C37.118 Synchrophasors. You must first make Global setting EPMU = Y and MFRMT = C37.118 to make this setting available. For SEL Fast Message Synchrophasors (MFRMT = FM), use PROTO = SEL instead. See *Appendix N: Synchrophasors* for details.

Make the following setting when PROTO = SEL or LMD on Port 1, 2, or 3.

Maximum Access Level (0, 1, B, 2, C) **MAXACC :=** ______

Note: The MAXACC setting controls the availability of **ACC**, **BAC**, **2AC**, and **CAL** commands on this port.

Note: MAXACC for Port F (only) can be set to 1, B, 2, or C, and affects both serial port F and the optional USB port.

SEL Protocol Settings

Make the following settings when PROTO = SEL.

Baud Rate (300, 1200, 2400, 4800, 9600, 19200, 38400, 57600) **SPEED :=** ______

Data Bits (6, 7, 8) **BITS :=** ______

Parity (O, E, N) {Odd, Even, None} **PARITY :=** ______

Stop Bits (1, 2) **STOP :=** ______

Enable Hardware Handshaking (Y, N) **RTSCTS :=** ______

Set RTSCTS = Y to enable hardware handshaking. With RTSCTS = Y, the relay will not send characters until the CTS input is asserted. Also, if the relay is unable to receive characters, it deasserts the RTS line (see *Hardware Handshaking* on page 10.10).

Note: The RTSCTS setting is not available on Port 1.

Minutes to Port Time-out (0–30 minutes) **T_OUT :=** ______

Set T_OUT to the number of minutes of serial port inactivity for an automatic log off. Set T_OUT = 0 for no port time out.

Send Auto Messages to Port (Y, N, DTA) **AUTO :=** ______

Set AUTO = Y to allow automatic messages at the serial port. Set AUTO = DTA to use the serial port with an SEL-DTA2 Display/Transducer Adapter. See *Serial Port and Telnet Session Automatic Messages* on page 10.23.

Fast Operate Enable (Y, N) **FASTOP :=** ______

Set FASTOP = Y to enable binary Fast Operate messages at the serial port. Set FASTOP = N to block binary Fast Operate messages. Refer to *Appendix J: Configuration, Fast Meter, and Fast Operate Commands* for the description of the SEL-351 Relay Fast Operate commands.

SEL LMD Protocol Settings

Make the following settings when PROTO = LMD.

LMD Prefix (@, #, $, %, &)	**PREFIX :=** ____________
LMD Address (1–99)	**ADDR :=** ____________
LMD Settling Time (0.00–30.00 seconds in 0.01 second steps)	**SETTLE :=** ____________
Baud Rate (300, 1200, 2400, 4800, 9600, 19200, 38400, 57600)	**SPEED :=** ____________
Data Bits (6, 7, 8)	**BITS :=** ____________
Parity (O, E, N) {Odd, Even, None}	**PARITY :=** ____________
Stop Bits (1, 2)	**STOP :=** ____________
Minutes to Port Time-out (0–30 minutes in 1 minute steps)	**T_OUT :=** ____________

Set T_OUT to the number of minutes of serial port inactivity for an automatic log off. Set T_OUT = 0 for no port time out.

Send Auto Messages to Port (Y, N, DTA) **AUTO :=** ____________

Set AUTO = Y to allow automatic messages at the serial port. Set AUTO = DTA to use the serial port with an SEL-DTA2 Display/Transducer Adapter. See *Serial Port and Telnet Session Automatic Messages* on page 10.23.

Fast Operate Enable (Y, N) **FASTOP :=** ____________

Set FASTOP = Y to enable binary Fast Operate messages at the serial port. Set FASTOP = N to block binary Fast Operate messages. Refer to *Appendix J: Configuration, Fast Meter, and Fast Operate Commands* for the description of the SEL-351 Relay Fast Operate commands.

PMU Protocol Port Settings

Make the following settings when PROTO = PMU.

Baud Rate (300, 1200, 2400, 4800, 9600, 19200, 38400, 57600) **SPEED :=** ____________

Note: Global Synchrophasor settings for message size and rate may restrict the minimum SPEED setting. See *Appendix N: Synchrophasors* for details.

Stop Bits (1, 2)	**STOP :=** ____________
Enable Hardware Handshaking (Y, N)	**RTSCTS :=** ____________

Set RTSCTS = Y to enable hardware handshaking. With RTSCTS = Y, the relay will not send characters until the CTS input is asserted. Also, if the relay is unable to receive characters, it deasserts the RTS line (see *Hardware Handshaking* on page 10.10).

Note: The RTSCTS setting is not available on Port 1.

Fast Operate Enable (Y, N) **FASTOP :=** ____________

Set FASTOP = Y to enable binary Fast Operate messages at the serial port. Set FASTOP = N to block binary Fast Operate messages. Refer to *Appendix J: Configuration, Fast Meter, and Fast Operate Commands* for the description of the SEL-351 Relay Fast Operate commands.

SEL MIRRORED BITS Protocol Settings

Make the following settings when PROTO = MBA, MBB, MB8A, MB8B.

Baud Rate (300, 1200, 2400, 4800, 9600, 19200, 38400, 57600) **SPEED :=** ________

Enable Hardware Handshaking (Y, N, MBT) **RTSCTS :=** ________

Set RTSCTS = Y to enable hardware handshaking. With RTSCTS = Y, the relay will not send characters until the CTS input is asserted. Also, if the relay is unable to receive characters, it deasserts the RTS line (see *Hardware Handshaking* on page 10.10). See *Appendix H: MIRRORED BITS Communications (in Firmware Versions 6 and 7)* for information on the MBT setting choice.

Note: The RTSCTS setting is not available on Port 1. The MBT setting option is only available when PROTO = MBA or MBB, and SPEED = 9600.

MIRRORED BITS Transmit Identifier (1–4) **TXID :=** ________

MIRRORED BITS Receive Identifier (1–4) **RXID :=** ________

MIRRORED BITS Rx Bad Pickup Time (1–10000 seconds in 1 second steps) **RBADPU :=** ________

PPM MIRRORED BITS Channel Bad Pickup (1–10000) **CBADPU :=** ________

MIRRORED BITS Receive Default String (string of 1s, 0s, or Xs) **RXDFLT :=** ________
Display order: 87654321

MIRRORED BITS RMB1 Pickup Debounce Messages (1–8) **RMB1PU :=** ________

MIRRORED BITS RMB1 Dropout Debounce Messages (1–8) **RMB1DO :=** ________

MIRRORED BITS RMB2 Pickup Debounce Messages (1–8) **RMB2PU :=** ________

MIRRORED BITS RMB2 Dropout Debounce Messages (1–8) **RMB2DO :=** ________

MIRRORED BITS RMB3 Pickup Debounce Messages (1–8) **RMB3PU :=** ________

MIRRORED BITS RMB3 Dropout Debounce Messages (1–8) **RMB3DO :=** ________

MIRRORED BITS RMB4 Pickup Debounce Messages (1–8) **RMB4PU :=** ________

MIRRORED BITS RMB4 Dropout Debounce Messages (1–8) **RMB4DO :=** ________

MIRRORED BITS RMB5 Pickup Debounce Messages (1–8) **RMB5PU :=** ________

MIRRORED BITS RMB5 Dropout Debounce Messages (1–8) **RMB5DO :=** ________

MIRRORED BITS RMB6 Pickup Debounce Messages (1–8) **RMB6PU :=** ________

MIRRORED BITS RMB6 Dropout Debounce Messages (1–8) **RMB6DO :=** ________

MIRRORED BITS RMB7 Pickup Debounce Messages (1–8) **RMB7PU :=** ________

MIRRORED BITS RMB7 Dropout Debounce Messages (1–8) **RMB7DO :=** ________

MIRRORED BITS RMB8 Pickup Debounce Messages (1–8) **RMB8PU :=** ________

MIRRORED BITS RMB8 Dropout Debounce Messages (1–8) **RMB8DO :=** ________

See *Appendix H: MIRRORED BITS Communications (in Firmware Versions 6 and 7)* for full settings explanations and other required settings.

DNP Settings

Make the following settings when PROTO = DNP.

Baud Rate (300, 1200, 2400, 4800, 9600, 19200, 38400, 57600) **SPEED :=** ________

Parity (O, E, N) {Odd, Even, None} **PARITY :=** ________

Stop Bits (1, 2) **STOP :=** ________

DNP Address (0–65519) **DNPADR :=** ________

DNP Address to Report to (0–65519) **REPADR :=** ________

DNP Session Map (1–3) **DNPMAP :=** ________

Analog Input Default Variation (1–6) **DVARAI :=** ____________

Class for Binary Event Data (0–3) **ECLASSB :=** ____________

Class for Counter Event Data (0–3) **ECLASSC :=** ____________

Class for Analog Event Data (0–3) **ECLASSA :=** ____________

Currents Scaling Decimal Places (0–3) **DECPLA :=** ____________

Voltages Scaling Decimal Places (0–3) **DECPLV :=** ____________

Miscellaneous Data Scaling Decimal Places (0–3) **DECPLM :=** ____________

Make the following two settings when ECLASSA > 0.

Amperes Reporting Deadband Counts (0–32767) **ANADBA :=** ____________

Volts Reporting Deadband Counts (0–32767) **ANADBV :=** ____________

Make the following setting when ECLASSA > 0 or ECLASSC > 0.

Miscellaneous Data Reporting Deadband Counts (0–32767) **ANADBM :=** ____________

Minutes for Request Interval (I, M, 1–32767) **TIMERQ :=** ____________

Note: TIMERQ = I: Disables time sync requests and ignores syncs from master.

Note: TIMERQ = M: Disables time sync requests and processes time syncs from master.

Note: TIMERQ = m = 1–32767: Relay requests a time sync every m minutes.

Seconds to Select/Operate Time-out (0.0–30.0 seconds in 0.1 second steps) **STIMEO :=** ____________

Data Link Retries (0–15) **DRETRY :=** ____________

Make the following setting when DRETRY > 0.

Seconds to Data Link Time-out (0–5 seconds in 1 second steps) **DTIMEO :=** ____________

Event Message Confirm Time-out (1–50 seconds in 1 second steps) **ETIMEO :=** ____________

Make the following setting when ECLASSB > 0, ECLASSC > 0 or ECLASSA > 0.

Enable Unsolicited Reporting (Y, N) **UNSOL :=** ____________

Make the following five settings when UNSOL = Y.

Enable Unsolicited Reporting at Power-Up (Y, N) **PUNSOL :=** ____________

Number of Events to Transmit On (1–200) **NUM1EVE :=** ____________

Oldest Event to Transmit On (0.0–99999.0 seconds in 0.1 second steps) **AGE1EVE :=** ____________

Unsolicited Message Maximum Retry Attempts (2–10) **URETRY :=** ____________

Unsolicited Message Offline Time-out (1–5000 seconds in 1 second steps) **UTIMEO :=** ____________

Note: UTIMEO must be greater than ETIMEO.

Minimum Seconds from DCD to Transmit (0.00–1.00 seconds in 0.01 second steps) **MINDLY :=** ____________

Maximum Seconds from DCD to Transmit (0.00–1.00 seconds in 0.01 second steps) **MAXDLY :=** ____________

Note: MAXDLY must be greater than MINDLY.

Settle Time from RTS ON to Transmit (OFF, 0.00–30.00 seconds in 0.01 second steps) **PREDLY :=** ____________

Make the following setting when PREDLY ≠ OFF.

Settle Time from Transmit to RTS OFF (0.00–30.00 seconds in 0.01 second steps) **PSTDLY :=** ____________

Event Min Fault Loc (OFF, –10000.0 to 10000.0 in steps of 0.1) **MINDIST :=** ____________

Event Max Fault Loc (OFF, –10000.0 to 10000.0 in steps of 0.1) **MAXDIST :=** ____________

Note: MAXDIST must be greater than MINDIST.

Event Mode (SINGLE, MULTI) **EVEMODE :=** ____________

Event Report Type (TRIP, ALL) **RPEVTYP :=** ____________

See *Appendix L: DNP3 Communications* for full settings explanations and other required settings.

Modbus Protocol Settings

Make the following settings when PROTO = MOD.

Baud Rate (300, 1200, 2400, 4800, 9600, 19200, 38400, 57600) **SPEED :=** ____________

Parity (O, E, N) {Odd, Even, None} **PARITY :=** ____________

Modbus Slave ID (1–247) **SLAVEID :=** ____________

See *Appendix O: Modbus RTU and TCP Communications* for full settings explanations and other required settings.

Port 5 Settings (for Ethernet Port 5, or 5A and 5B) (Serial Port SET P 5 Command)

Port Enable Setting

Enable Port (Y, N) **EPORT :=** ____________

Note: Setting EPORT = N completely disables the Ethernet port, and hides all remaining port settings.

Ethernet Port Settings

IP addresses are entered using zzz = 1–126, 128–223; yyy = 0–255; xxx = 0–255; www = 0–255.

Device IP Address (zzz.yyy.xxx.www) **IPADDR :=** ________________________

Subnet Mask (yyy.yyy.xxx.www) **SUBNETM :=** ________________________

Default Router (zzz.yyy.xxx.www) **DEFRTR :=** ________________________

Note: Setting DEFRTR = 0.0.0.0 disables the default router.

Enable TCP Keep-Alive (Y, N) **ETCPKA :=** ____________

TCP Keep-Alive is enabled with default KAIDLE, KAINTV, and KACNT settings for PMU sessions even when ETCPKA = N.

Make the following three settings when ETCPKA = Y.

TCP Keep-Alive Idle Range (1–20 seconds in 1 second steps) **KAIDLE :=** ____________

TCP Keep-Alive Interval Range (1–20 seconds in 1 second steps) **KAINTV :=** ____________

TCP Keep-Alive Count Range (1–20) **KACNT :=** ____________

Make the following setting when the relay has dual Ethernet.

Operating Mode (FIXED, FAILOVER, SWITCHED, PRP) **NETMODE :=** ____________

Make the following setting when NETMODE = FAILOVER.

Failover Time-out (OFF, 0.10–65.00 seconds in 0.01 second steps) **FTIME :=** ____________

Make the following setting when NETMODE = FIXED or FAILOVER.

Primary Net Port (A, B) **NETPORT :=** ____________

Make the following three settings when NETMODE = PRP.

PRP Entry Timeout (400–10000 ms) **PRPTOUT :=** ____________

PRP Destination Address LSB (0–255) **PRPADDR :=** ____________

PRP Supervision TX Interval (1–10 s) **PRPINTV :=** ____________

Make the following settings for each enabled port when the relay has dual 10/100BASE-T (copper).

Port 5A Speed (AUTO, 10, 100 Mbps) **NET5ASPD :=** ____________

Port 5B Speed (AUTO, 10, 100 Mbps) **NET5BSPD :=** ____________

Make the following setting when the relay has single 10/100BASE-T (copper).

Port 5 Speed (AUTO, 10, 100 Mbps) **NET5SPD :=** ____________

Telnet Settings

Enable Telnet (Y, N) **ETELNET :=** ____________

Make the following settings when ETELNET = Y.

Maximum Access Level (0, 1, B, 2, C) **MAXACC :=** ____________

Note: The MAXACC setting controls the availability of the **ACC**, **BAC**, **2AC**, and **CAL** commands in the Telnet session.

Telnet Port (23, 1025–65534) **TPORT :=** ____________

Telnet Connect Banner (254 characters maximum, NA to NULL, mixed case. Use "\n" to create a new line.)

TCBAN := ____

____

Telnet Port Time-out (1–30 minutes) **TIDLE :=** ____________

Send Auto Messages to Port (Y, N) **AUTO :=** ____________

Set AUTO = Y to allow automatic messages on the Telnet session (similar to serial port auto message—see *Serial Port and Telnet Session Automatic Messages* on page 10.23).

Fast Operate Enable (Y, N) **FASTOP :=** ____________

Set FASTOP = Y to enable binary Fast Operate messages on the Telnet session. Set FASTOP = N to block binary Fast Operate messages. Refer to *Appendix J: Configuration, Fast Meter, and Fast Operate Commands* for the description of the SEL-351 Relay Fast Operate commands.

See *Section 10: Communications* for full settings explanations and other required settings.

File Transfer Protocol (FTP) Server Settings

Enable FTP (Y, N) **EFTPSERV :=** ____________

Make the following settings when EFTPSERV = Y.

FTP User Name (20 characters maximum) **FTPUSER :=** ____________________

FTP Connect Banner (254 characters maximum, NA to NULL, mixed case. Use "\n" to create a new line.)

FTPCBAN := ____

____

FTP Idle Timeout (5–255 minutes) **FTPIDLE :=** ____________

Hypertext Transfer Protocol (HTTP) Web Server Settings

Enable HTTP Server (Y, N) **EHTTP :=** ____________

Make the following settings when EHTTP = Y.

HTTP Maximum Access Level (1, 2) **HTTPACC :=** ____________

TCP/IP Port (1–65535) **HTTPPORT :=** ____________

Note: HTTPPORT may not be set to reserved port numbers 20, 21, 102, 502, or the same as other settings listed in *Table SET.1*.

HTTP Connect Banner (254 characters maximum, NA to NULL, mixed case. Use "\n" to create a new line.)

HTTPBAN := ____

____

HTTP Web Server Timeout (1–30 minutes) **HTTPIDLE :=** ____________

Firmware Upgrade Front-Panel Confirmation (Y, N) **FWFPC :=** ____________

IEC 61850 Protocol Settings (Ordering Option)

Enable IEC 61850 Protocol (Y, N) **E61850 :=** ____________

Make the following settings when E61850 = Y.

Enable IEC 61850 GSE (Y, N) **EGSE :=** ____________

Enable MMS File Services (Y, N) **EMMSFS :=** ____________

Ethernet DNP Settings

Enable DNP Sessions (0–6) **EDNP :=** ____________

Note: As many as six total serial and Ethernet DNP sessions are allowed. When EDNP > 3, no Ethernet Modbus sessions are allowed.

Make the following settings when EDNP > 0.

DNP TCP and UDP Port (1–65534) **DNPNUM :=** ____________

Note: DNPNUM may not be set to reserved port numbers 20, 21, 102, 502, or the same as other settings listed in *Table SET.1*.

DNP Address (0–65519) **DNPADR :=** ____________

DNP Master n Settings (Repeat for n = 1–6; to EDNP Value)

Make the following settings when EDNP > 0.

IP Address (zzz.yyy.xxx.www) **DNPIP*n* :=** ____________

The DNP IP address of each session (DNPIP1, DNPIP2, etc.) must be unique.

Transport Protocol (UDP, TCP) **DNPTR*n* :=** ____________

Make the following setting when DNPTR*n* = UDP.

UDP Response Port (REQ, 1–65534) **DNPUDP*n* :=** ____________

Note: DNPUDPn = REQ directs response to same port message was received from.

DNP Address to Report to (0–65519) **REPADR*n* :=** ____________

DNP Session Map (1–3) **DNPMAP*n* :=** ____________

Analog Input Default Variation (1–6) **DVARAI*n* :=** ______

Class for Binary Event Data (0–3) **ECLASSB*n* :=** ______

Class for Counter Event Data (0–3) **ECLASSC*n* :=** ______

Class for Analog Event Data (0–3) **ECLASSA*n* :=** ______

Currents Scaling Decimal Places (0–3) **DECPLA*n* :=** ______

Voltages Scaling Decimal Places (0–3) **DECPLV*n* :=** ______

Miscellaneous Data Scaling Decimal Places (0–3) **DECPLM*n* :=** ______

Make the following two settings when ECLASSA*n* > 0.

Amperes Reporting Deadband Counts (0–32767) **ANADBA*n* :=** ______

Volts Reporting Deadband Counts (0–32767) **ANADBV*n* :=** ______

Make the following setting when ECLASSA*n* > 0 or ECLASSC*n* > 0.

Miscellaneous Data Reporting Deadband Counts (0–32767) **ANADBM*n* :=** ______

Minutes for Request Interval (I, M, 1–32767) **TIMERQ*n* :=** ______

Note: TIMERQn = I: Disables time sync requests and ignores syncs from master.

Note: TIMERQn = M: Disables time sync requests and processes time syncs from master.

Note: TIMERQn = m = 1–32767: Relay requests a time sync every m minutes.

Seconds to Select/Operate Time-out (0.0–30.0 seconds in 0.1 second steps) **STIMEO*n* :=** ______

Make the following setting when DNPTR*n* = TCP.

Seconds to Send Data Link Heartbeat (0–7200 seconds in 1 second steps) **DNPINA*n* :=** ______

Event Message Confirm Time-out (1–50 seconds in 1 second steps) **ETIMEO*n* :=** ______

Make the following setting when ECLASSB*n* > 0, ECLASSC*n* > 0, or ECLASSA*n* > 0.

Enable Unsolicited Reporting (Y, N) **UNSOL*n* :=** ______

Make the following five settings when UNSOL*n* = Y.

Enable Unsolicited Reporting at Power-Up (Y, N) **PUNSOL*n* :=** ______

Number of Events to Transmit On (1–200) **NUM1EVE*n* :=** ______

Oldest Event to Tx On (0.0–99999.0 seconds in 0.1 second steps) **AGE1EVE*n* :=** ______

Unsolicited Message Max Retry Attempts (2–10) **URETRY*n* :=** ______

Unsolicited Message Offline Time-out (1–5000 seconds in 1 second steps) **UTIMEO*n* :=** ______

Note: UTIMEOn must be greater than ETIMEOn.

Event Min Fault Loc (OFF, –10000.0 to 10000.0 in steps of 0.1) **MINDIST*n* :=** ______

Event Max Fault Loc (OFF, –10000.0 to 10000.0 in steps of 0.1) **MAXDIST*n* :=** ______

Note: MAXDISTn must be greater than MINDISTn.

Event Mode (SINGLE, MULTI) **EVEMODE*n* :=** ______

Event Report Type (TRIP, ALL) **RPEVTYP*n* :=** ______

Ethernet Synchrophasor Settings

Make the following settings when Global settings EPMU = Y and MFRMT = C37.118.

Enable PMU Processing (Y, N) **EPMIP :=** ______

PMU Output 1 Settings

Make the following setting when EPMIP = Y.

PMU Output 1 Transport Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U) **PMOTS1 :=** ____________

Make the following settings when PMOTS1 ≠ OFF.

PMU Output 1 Client IP (Remote) Address (zzz.yyy.xxx.www) **PMOIPA1 :=** ________________________

Note: PMOIPA1 cannot be set to the same address as IPADDR. IP addresses from 224.0.0.1 through 239.255.255.255 are also valid when PMOTS1 = UDP_S. IP address 255.255.255.255 is also valid when PMOTS1 = UDP_S or TCP.

Make the following settings when PMOTS1 ≠ UDP_S.

PMU Output 1 TCP/IP (Local) Port Number (1–65534) **PMOTCP1 :=** ____________

Note: PMOTCP1 cannot be set to the same number as PMOTCP2.

Note: PMOTCP1 cannot be set to 20, 21, 102, 502, or the same as the other settings listed in *Table SET.1*.

Make the following setting when PMOTS1 = UDP_S, UDP_T, or UDP_U.

PMU Output 1 UDP/IP Data (Remote) Port Number (1–65534) **PMOUDP1 :=** ____________

PMU Output 2 Settings

Note: Make the following setting when EPMIP = Y (and E61850 = N on relays ordered with IEC 61850 protocol).

PMU Output 2 Transport Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U) **PMOTS2 :=** ____________

Make the following setting when PMOTS2 ≠ OFF.

PMU Output 2 Client IP (Remote) Address (zzz.yyy.xxx.www) **PMOIPA2 :=** ________________________

Note: PMOIPA2 cannot be set to the same address as IPADDR. IP addresses from 224.0.0.1 through 239.255.255.255 are also valid when PMOTS2 = UDP_S. IP address 255.255.255.255 is also valid when PMOTS2 = UDP_S or TCP.

Make the following setting when PMOTS2 ≠ UDP_S.

PMU Output 2 TCP/IP (Local) Port Number (1–65534) **PMOTCP2 :=** ____________

Note: PMOTCP2 cannot be set to the same number as PMOTCP1.

Note: PMOTCP2 cannot be set to 20, 21, 102, 502, or the same as the other settings listed in *Table SET.1*.

Make the following setting when PMOTS2 = UDP_S, UDP_T, or UDP_U.

PMU Output 2 UDP/IP Data (Remote) Port Number (1–65534) **PMOUDP2 :=** ____________

Ethernet Modbus Settings

Enable Modbus (0–3) **EMODBUS :=** ____________

Note: As many as three total serial and Ethernet Modbus sessions are allowed. EMODBUS must be set to 0 when EDNP > 3.

Make the following settings when EMODBUS ≥ 1.

Ethernet Modbus Settings: Master 1

IP Address (zzz.yyy.xxx.www) **MODIP1 :=** ____________________

Note: MODIP1, MODIP2, and MODIP3 cannot share an address (except 0.0.0.0).

Modbus Session Time-out (15–900 seconds in 1 second steps) **MTIMEO1 :=** __________

Make the following settings when EMODBUS ≥ 2.

Ethernet Modbus Settings: Master 2

IP Address (zzz.yyy.xxx.www) **MODIP2 :=** ____________________

Note: MODIP1, MODIP2, and MODIP3 cannot share an address (except 0.0.0.0).

Modbus Session Time-out (15–900 seconds in 1 second steps) **MTIMEO2 :=** __________

Make the following settings when EMODBUS = 3.

Ethernet Modbus Settings: Master 3

IP Address (zzz.yyy.xxx.www) **MODIP3 :=** ____________________

Note: MODIP1, MODIP2, and MODIP3 cannot share an address (except 0.0.0.0).

Modbus Session Time-out (15–900 seconds in 1 second steps) **MTIMEO3 :=** __________

SNTP Client Protocol Settings

Enable SNTP Client (OFF, UNICAST, MANYCAST, BROADCAST) **ESNTP :=** ____________________

Make the following settings when ESNTP ≠ OFF.

Primary Server IP Address (zzz.yyy.xxx.www) **SNTPPSIP :=** ____________________

Note: To accept updates from any server when ESNTP = BROADCAST, set SNTPPSIP to 0.0.0.0. Only IP addresses in the range 224.0.0.1 through 239.255.255.255 are valid when ESNTP = MANYCAST.

Make the following setting when ESNTP = UNICAST.

Backup Server IP Address (zzz.yyy.xxx.www) **SNTPBSIP :=** ____________________

SNTP IP (Local) Port Number (1–65534) **SNTPPORT :=** __________

Note: SNTPPORT cannot be set to the same value as DNPNUM when EDNP > 0.

SNTP Update Rate (15–3600 seconds in 1 second steps) **SNTPRATE :=** __________

Make the following setting when ESNTP = UNICAST or MANYCAST.

SNTP Timeout (5–20 seconds in 1 second steps) **SNTPTO :=** __________

Note: SNTPTO must be less than setting SNTPRATE.

Port Number Settings Must Be Unique

When making the SEL-351 Port 5 settings, port number settings cannot be used for more than one protocol. The relay checks all of the settings shown in *Table SET.1* before saving changes. If a port number is used more than once, the relay will display an error message, and return to the first setting that contains the duplicate value.

Table SET.1 Port Number Settings That Must Be Unique

Setting	Name	Setting Required When...
TPORT	Telnet Port	ETELNET = Y
HTTPPORT	TCP/IP Port	EHTTP = Y
DNPNUM	DNP TCP and UDP Port	EDNP > 0
PMOTCP1	PMU Output 1 TCP/IP (Local) Port Number	PMOTS1 = TCP, UDP_T, or UDP_U
PMOTCP2	PMU Output 2 TCP/IP (Local) Port Number	PMOTS2 = TCP, UDP_T, or UDP_U

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SECTION 10

Communications

Introduction

The SEL-351 Relay has as many as seven communications ports, as shown in *Table 10.1*. Use the communications ports to establish local and remote communications with the relay using numerous communications protocols.

Table 10.1 SEL-351 Communications Ports

Port Number	Type	Location	Standard/Optional
1	EIA-485 Serial or SEL-2812-Compatible Fiber-Optic	Rear	Optional
2	EIA-232 Serial	Rear	Standard
3	EIA-232 Serial	Rear	Standard
4 or F	EIA-232 Serial	Front	Standard
5	Single Ethernet	Rear	Standard
5A/5B	Dual Ethernet	Rear	Optional
N/A	USB	Front	Optional

The first part of this section shows how to establish local communications with the relay using serial, USB, Ethernet ports and the SEL ASCII communications protocol, or the built-in, read-only web server. Other parts of this section provide reference information to help you use relay communications ports to establish local and remote communications for engineering access, SCADA communications, teleprotection, and synchrophasor data collection. Use of actual communications protocols such as IEC 61850, DNP, Modbus, or SEL MIRRORED BITS is covered in various appendices of this manual.

Establishing Communications Using a Serial Port

Use the front serial port and any terminal emulation program or the ACSELERATOR QuickSet SEL-5030 Software to begin communicating with the relay. Connect SEL cable C234A between the relay and a personal computer. The serial port default communications parameters are:

- Baud Rate = 9600
- Data Bits = 8
- Parity = N
- Stop Bits = 1

Use the **SET P** command to change the relay communications port parameters.

Establishing Communications Using the USB Port

USB Port Overview

The USB port has no settings, and is faster than the serial ports, especially for operations requiring transport of large blocks of data such as long event reports or firmware upgrades.

Each time you connect a relay to your PC USB port, Windows determines if a driver has already been installed and is ready for use. There are three possibilities:

1. Connect a PC for the first time to a relay USB port.

   Windows launches the **Found New Hardware Wizard**. The wizard guides you through the USB driver installation process and creates a new virtual COM port (e.g., COM 4).

   See *Detailed Instructions for USB Port Driver Installation* on page 10.3 below before connecting the relay to your PC USB port.

2. Reconnect a PC to a relay USB port using a different physical USB port on a PC (i.e., same PC, different physical USB port on the PC).

   Windows launches the **Found New Hardware Wizard**. Select **Install the software automatically (Recommended)** and click **Next**. Windows locates the required INF file and driver, and creates a new virtual COM port (e.g., COM 5).

   Windows creates a new virtual COM port (e.g., COM 6, COM 7) each time you connect a relay to a physical USB port that has not previously been connected to a relay. The virtual COM port number remains associated with the same physical USB port until you uninstall the driver.

3. Reconnect a PC to a relay USB port using a physical USB port on the PC that has already been connected to a relay (i.e., same PC, same physical USB port on the PC).

   Windows recognizes that the driver is already installed, and creates the same virtual COM port created the first time you connected a relay to that particular physical USB port (e.g., COM 4). No action is required on your part.

The USB driver exposes normal communications port settings to the personal computer operating system, such as baud rate, parity, etc. to maintain compatibility with many PC applications. Changing these settings in the PC does not change how the relay USB port operates. You may use a PC Terminal Emulator program or dedicated software to connect to the SEL-351 via USB port. The USB port offers a subset of the functionality of a standard serial port—see *Table 10.7* for details.

USB uses a connection based protocol. Under certain circumstances, such as power cycling the relay, the USB connection may be terminated. If the USB connection is terminated it may be necessary to reconnect to the relay using the PC application software, or disconnect and then reconnect the USB connector at either the PC or the relay.

QuickSet is more tolerant to unexpected USB device disconnections than most other PC applications. While using QuickSet, it is possible to disconnect the USB cable from one relay and move it to another relay without the need to restart the application, reselect the COM port, or even disconnect and reconnect at the application level.

Detailed Instructions for USB Port Driver Installation

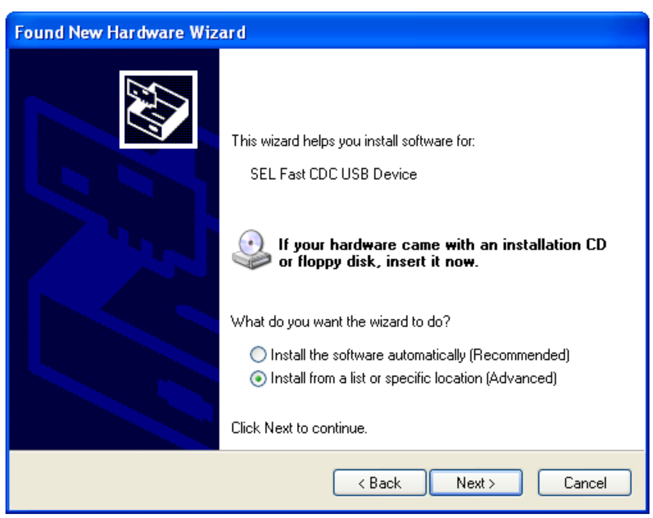
The following detailed instructions for USB driver installation are specifically for the Windows XP operating system. Some steps may be different and some screens may be changed for other Windows operating systems.

Step 1. Retrieve the USB driver file "SEL Fast CDC USB Device.INF" from the SEL-351 product page on the SEL website (selinc.com). Place the INF file in any convenient directory, such as C:\SEL\Drivers\Relay_USB.

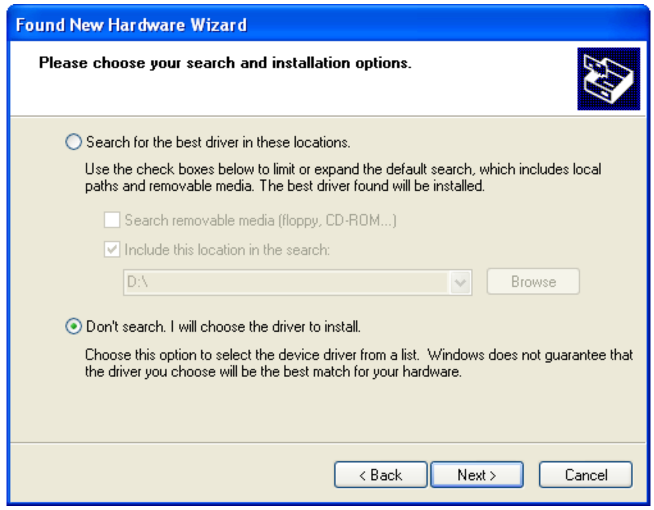
NOTE: The SEL-351 USB driver is different than the driver used for SEL EIA-232 serial to USB converter cable C662, and is different from the driver used for the SEL-2440 Discrete Programmable Automation Controller.

Step 2. Connect the relay to your PC with SEL Cable C664, or any standard A to B USB cable. Your PC will recognize that a new device has been connected, and will start the **Found New Hardware Wizard**. Select **No, not this time** and click **Next**. Some Windows XP systems will skip this screen and go to the screen shown in *Step 3*.

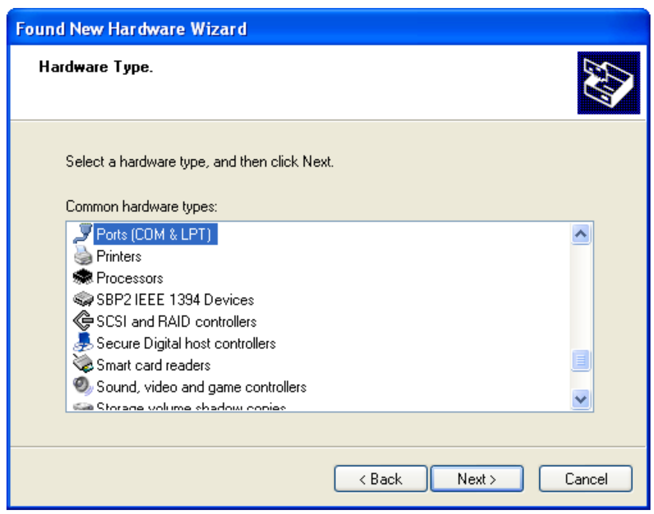
Step 3. Select **Install from a list or specific location (Advanced)**. Click **Next**.



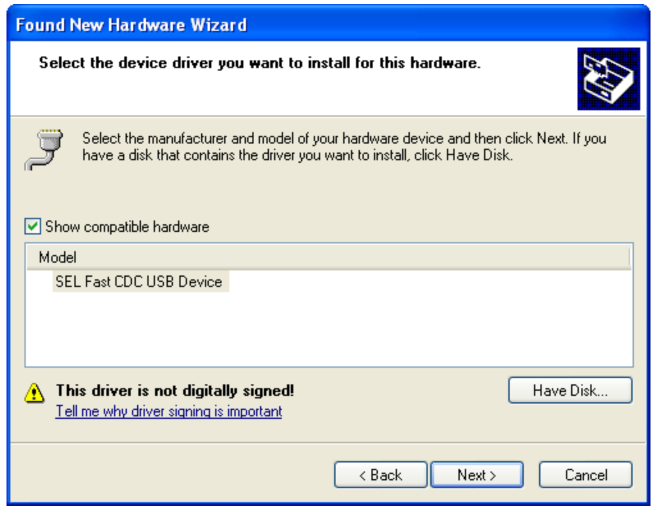
Step 4. Select **Don't search. I will choose the driver to install**. Click **Next**.



Step 5. If prompted for a hardware type select **Ports (COM & LPT)** and click **Next**. Some Windows XP systems will skip this screen and go to the next screen.



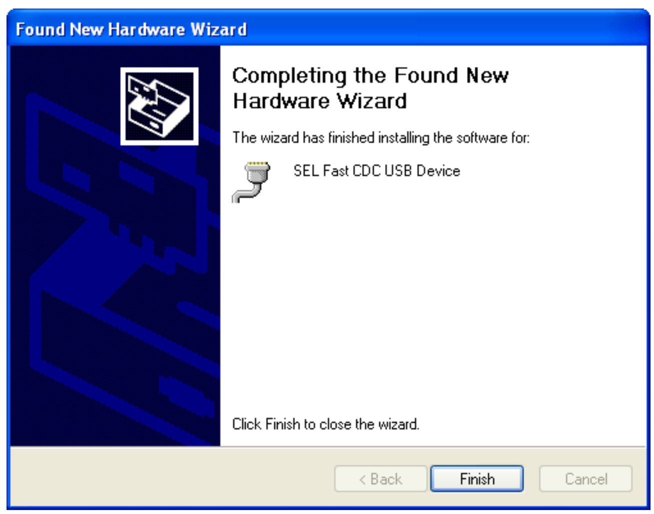
Step 6. If necessary, use the **Have Disk** button and direct the wizard to the folder containing the INF file you copied to your local drive in *Step 1*. After you locate the INF file, the **Found New Hardware Wizard** will return to the screen shown below. Verify the selected **Model** is **SEL Fast USB CDC Device**. Click **Next**.



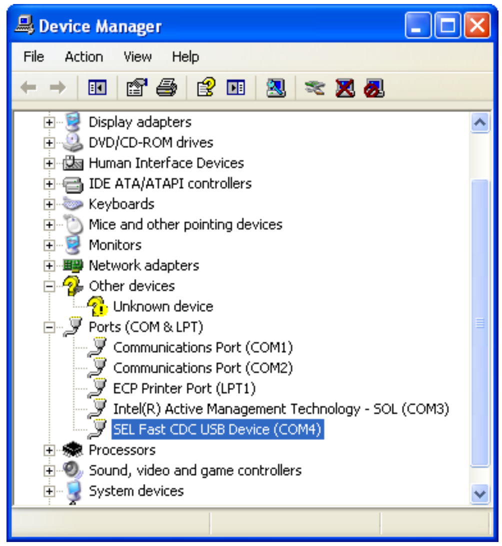
Step 7. If Windows warns that the driver has not passed Windows Logo testing, verify that the name **SEL Fast CDC USB Device** matches the Model selected in *Step 6*, and then click **Continue Anyway**.

Step 8. Wait while the wizard installs the driver software.

Step 9. Click **Finish** to finish the installation process.



The USB port driver is now installed, and a new virtual COM port (e.g., COM 4) is ready for use. To see what virtual COM port has been created, launch any communications program that allows selection of a COM port, and view the available ports, or go to the Windows Device Manager and inspect the available COM ports as shown below. Use Device Manager to verify which virtual COM port is associated with a particular physical USB port. Device Manager updates the available COM ports each time a cable is inserted or removed.



To test the USB port and the newly installed driver follow these steps:

Step 1. Launch QuickSet, and select **Communications > Parameters** from the menu, or click the **Communications Parameters** icon from the opening screen. See *Appendix C: PC Software* for more information on QuickSet. Select the new COM port created by the driver installation process, e.g., COM 4 in the screen capture. Ignore other settings like parity and baud rate. They have no effect on how the USB port operates, and are only presented to the operating system to retain compatibility with certain applications.

Step 2. Select **Communications > Terminal** from the menu, or click the terminal icon on the tool bar. Log in to the relay normally. The USB port should work similarly to an EIA-232 port, only much faster. See *Table 10.7* for a list of features available from the USB port.

Establishing Communications Using an Ethernet Port and Telnet or the Read-Only Web Server

Factory default settings for the Ethernet ports disable all Ethernet protocols except PING. Enable the Telnet and web server protocols with the **SET P 5** command using any of the serial ports or the USB port. Command **SET P 5** accesses settings for all Ethernet ports on the SEL-351: Port 5, Port 5A and Port 5B.

See ***SHO*** *(Show/View Settings)* on page 10.68 for a sample of the **SHO 5** command, with factory default settings. See *Port 5 Settings (for Ethernet Port 5, or 5A and 5B) (Serial Port SET P 5 Command)* on page SET.39 for the Port 5 settings sheets.

NOTE: The host portion of the IP address cannot be set to all 0s or 1s.

Make the following settings using the **SET P 5** command:

- IPADDR = IP Address assigned by network administrator
- SUBNETM = Subnet mask assigned by network administrator
- DEFRTR = Default router IP Address assigned by network administrator

NOTE: Telnet and the read-only web server work with other NETMODE settings also, but NETMODE = SWITCHED is easiest to begin communications. The relay hides setting NETMODE when equipped with a single Ethernet port.

- NETMODE = SWITCHED (available with dual Ethernet ports)
- ETELNET = Y
- EHTTP = Y

Leave all other settings at their default values.

Connect an Ethernet cable between your PC or a network switch and any Ethernet port on the relay. Verify that the amber **Link** LED illuminates on the connected relay port. Many computers and most Ethernet switches support auto-crossover, so nearly any CAT5 Ethernet cable with RJ45 connectors, such as SEL cable C627 will work. When the computer does not support auto-crossover, use a crossover cable, such as SEL cable C628. For fiber-optic Ethernet ports use SEL cable C808 62.5 µm fiber-optic cable with LC connectors. If your relay is equipped with dual Ethernet ports, connect to either port. Use a Telnet application or QuickSet on the host PC to communicate with the relay. To terminate a Telnet session, use the command **EXI <Enter>** from any access level.

Launch a web browser and browse address http://IPADDR, where IPADDR is the Port 5 IPADDR setting. To terminate the session, simply close the web browser.

Ethernet Port Speed

Change the speed of 10/100BASE-T copper Ethernet ports using Port setting NET5SPD for relays equipped with one 10/100BASE-T Ethernet port, and settings NET5ASPD and NET5BSPD for relays equipped with two 10/100BASE-T Ethernet ports. Port speed is fixed at 100 Mbps for all copper and fiber-optic ports in relays with one or more 100BASE-FX Ethernet ports.

Using Redundant Ethernet Ports

The SEL-351 is optionally equipped with two 10/100BASE-T copper Ethernet ports, two 100BASE-FX fiber-optic Ethernet ports, or one 10/100BASE-T port and one 100BASE-FX port. Use two Ethernet ports in redundant network architectures, or force the relay to use a single Ethernet port even though it is equipped with two ports.

Redundant Ethernet Network Using SWITCHED Mode

Make Port 5 setting NETMODE = SWITCHED to activate the internal Ethernet switch. The internal switch connects a single Ethernet stack inside the relay to the two external Ethernet ports. The combination of relay and internal switch operate the same as if a single Ethernet port on a relay were connected to an external unmanaged Ethernet switch. Use the internal switch to create “self-healing rings” as shown in *Figure 10.1*.

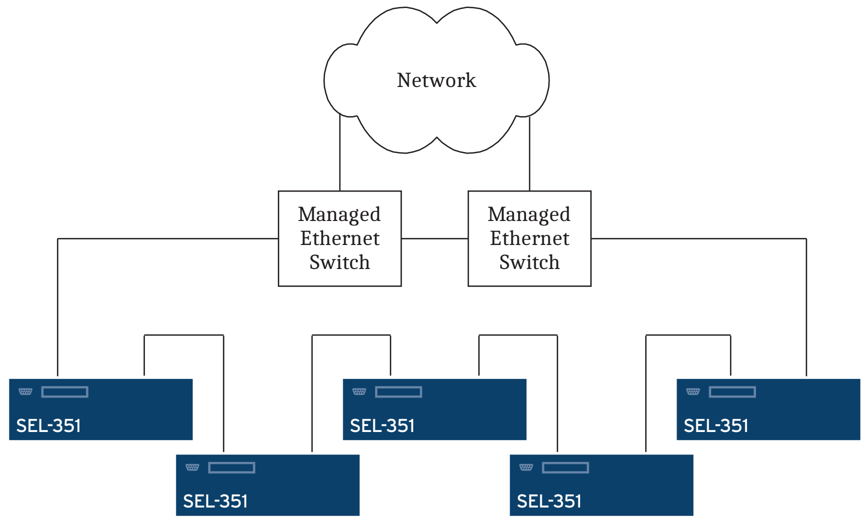


Figure 10.1 Self-Healing Ring Using Internal Ethernet Switch

Using this topology the network can still connect to any relay even if another relay, cable, or switch fails. The external managed network switches select which of the two relay Ethernet ports are used for what purpose. That selection is invisible to the relay, and does not require special relay configuration, other than making setting NETMODE = SWITCHED.

Redundant Ethernet Network Using FAILOVER Mode

Make the following settings in Port 5 to configure the relay for FAILOVER mode.

- NETMODE = FAILOVER
- FTIME = desired timeout for the active port before failover to the backup port (0.10–65.00 seconds and OFF)
- NETPORT = the preferred network interface (A for Port 5A, B for Port 5B)

Use the internal failover switch to connect the relay to redundant networks as shown in *Figure 10.2*.

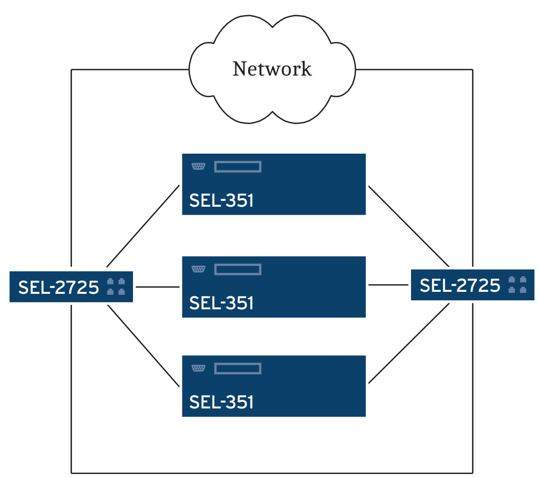


Figure 10.2 Failover Network Topology

On startup the relay communicates using the primary network interface selected by the NETPORT setting. If the relay detects a link failure on the primary interface, and the link status on the standby interface is healthy, the relay activates the standby network interface after time FTIME. If the link status on the primary interface returns to normal before time FTIME, the failover timer resets and operation continues on the primary network interface.

Setting FTIME = OFF allows fast port switching (with no intentional delay). Fast port switching can occur within one processing interval (typically 4 ms to 5 ms) and can help with IEC 61850 GOOSE performance.

After failover, while communicating via the standby interface, if the relay detects a link failure on the standby interface, and the link status on the primary interface is healthy, the relay activates the primary network interface after time FTIME. The choice of active port is reevaluated after settings change, and after relay restart.

Network Connection Using Fixed Connection Mode

Force the relay to use a single Ethernet port even when it is equipped with two Ethernet ports by making settings NETMODE = FIXED. When NETMODE = FIXED, only the interface selected by NETPORT is active. The other interface is disabled.

Network Connection Using PRP Connection Mode

Parallel Redundancy Protocol (PRP) is part of an IEC standard for high availability automation networks (IEC 62439-3). The purpose of the protocol is to provide seamless recovery from any single Ethernet network failure.

The basic concept is that the Ethernet network and all traffic are fully duplicated with the two copies operating in parallel.

Make the following settings in Port 5 to configure the relay for PRP mode.

- NETMODE = PRP
- PRPTOUT = desired timeout for PRP frame entry
- PRPADDR = PRP destination MAC address LSB (least significant byte of “01-15-4E-00-01-XX,” converted to decimal and entered as 0–255)
- PRPINTV = desired supervision frame transmit interval

When NETMODE is not set to PRP, the following settings are hidden.

Table 10.2 PRP Settings

Setting Name	Range	Units	Default Value	Setting Description
PRPTOUT	400–10000	ms	500	PRP Entry Timeout
PRPADDR	0–255		0	The multicast MAC address of PRP supervision frames is 01-15-4E-00-01-XX where XX is specified by this setting in decimal notation as 0–255.
PRPINTV	1–10	seconds	2	PRP Supervision TX Interval

Ethernet Status Relay Word Bits

The SEL-351 Ethernet status is available through the Relay Word bits shown in *Table 10.3*.

Table 10.3 Ethernet Status Indicators

Relay Word Bit	Available by Relay Model	Description	Valid When
LINK5	Single Ethernet	Asserts when a valid Ethernet link is detected on Port 5	Port 5 setting EPORT = Y
LINK5A	Dual Ethernet	Asserts when a valid Ethernet link is detected on Port 5A	Port 5 setting EPORT = Y
LINK5B	Dual Ethernet	Asserts when a valid Ethernet link is detected on Port 5B	Port 5 setting EPORT = Y
LNKFAIL	Single or Dual Ethernet	Asserts when the active port is down	Port 5 setting EPORT = Y
P5ASEL	Dual Ethernet	Asserts when Port 5A is selected	Port 5 setting NETMODE = FAILOVER
P5BSEL	Dual Ethernet	Asserts when Port 5B is selected	Port 5 setting NETMODE = FAILOVER

Port Connector and Communications Cables

Hardware Handshaking

All EIA-232 serial ports support RTS/CTS hardware handshaking. RTS/CTS handshaking is not supported on the optional Serial Port 1.

To enable hardware handshaking, use the **SET P** command (or front-panel SET pushbutton) to set RTSCTS = Y. Disable hardware handshaking by setting RTSCTS = N.

- ➤ If RTSCTS = N, the relay permanently asserts the RTS line.
- ➤ If RTSCTS = Y, the relay deasserts RTS when it is unable to receive characters.
- ➤ If RTSCTS = Y, the relay does not send characters until the CTS input is asserted.

Communications Port Pinouts

Figure 10.3 and *Table 10.4* through *Table 10.6* show the functions of the pins and terminals of the serial ports.

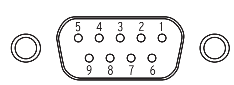


Figure 10.3 DB-9 Connector Pinout for EIA-232 Serial Ports

Table 10.4 Pinout Functions for EIA-232 Serial Ports 2, 3, and F (Sheet 1 of 2)

Pin	PORT 2	PORT 3	PORT F
1	N/C or +5 Vdc[a]	N/C or +5 Vdc[a]	N/C
2	RXD	RXD	RXD
3	TXD	TXD	TXD
4	+IRIG-B	N/C	N/C

Table 10.4 Pinout Functions for EIA-232 Serial Ports 2, 3, and F (Sheet 2 of 2)

Pin	PORT 2	PORT 3	PORT F
5, 9	GND	GND	GND
6	–IRIG-B	N/C	N/C
7	RTS	RTS	RTS
8	CTS	CTS	CTS

[a] See *EIA-232 Serial Port Voltage Jumpers* on page 2.41.

Table 10.5 Terminal Functions for EIA-485 Serial Port 1

Terminal	Function
1	+TX
2	–TX
3	+RX
4	–RX
5	SHIELD

Table 10.6 Serial Communications Port Pin/Terminal Function Definitions

Pin Function	Definition
N/C	No Connection
+5 Vdc (0.5 A combined limit)	5 Vdc Power Connection
RXD, RX	Receive Data
TXD, TX	Transmit Data
IRIG-B	IRIG-B Time-Code Input
GND	Ground
SHIELD	Shielded Ground
RTS	Request To Send
CTS	Clear To Send
DCD	Data Carrier Detect
DTR	Data Terminal Ready
DSR	Data Set Ready

IRIG-B

Demodulated IRIG-B time code can be input into the IRIG-B BNC connector at the rear of the relay (see *Figure 2.2* through *Figure 2.6*). Connect the IRIG-B BNC input to a high-quality time source such at the SEL-2407 Satellite-Synchronized Clock to enable microsecond accurate time synchronization, and to enable the SEL-351 to create C37.118 Synchrophasors (see *Appendix N: Synchrophasors*).

Demodulated IRIG-B time code can be input into Serial Port 2 (pin functions +IRIG-B and –IRIG-B, see *Table 10.1*). This is handled adeptly by connecting Serial Port 2 of the SEL-351 to an SEL-2032 with Cable C273A (see cable diagrams that follow in this section).

When paired with an SEL-2812MT or SEL-2812FT fiber-optic transceiver and SEL communications processor, automation controller, or satellite-synchronized clock, the fiber-optic serial port also operates as an IRIG-B input.

The relay uses IRIG-B signals from the three sources with the following priority:

➤ BNC input
➤ Serial Port 2 IRIG-B pins
➤ SEL-2812 compatible fiber-optic Port 1 (if present)

Simple Network Time Protocol (SNTP) can act as a reduced-accuracy backup to IRIG-B. See *Simple Network Time Protocol (SNTP)* on page 10.17 for more information on configuring SNTP.

Relay Word Bit TIRIG

TIRIG asserts when the relay time is based on an IRIG-B time source. If the relay is not synchronized to a connected IRIG-B time source, TIRIG deasserts. See *Configuring High-Accuracy Timekeeping* on page N.28 for more details on TIRIG.

Relay Word Bit TSOK

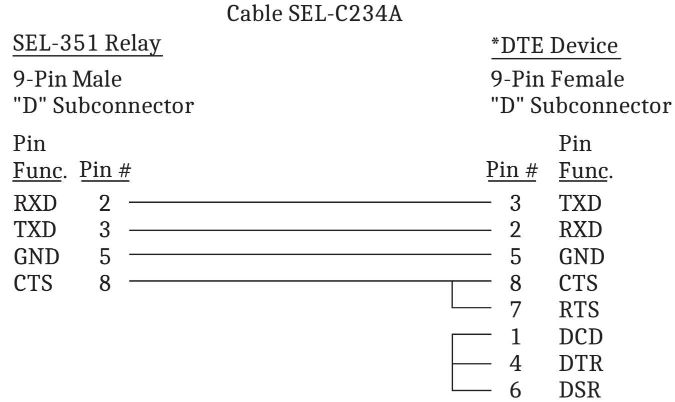
TSOK asserts to indicate that the IRIG-B time source is of a sufficient accuracy for synchrophasor measurement. See *Configuring High-Accuracy Timekeeping* on page N.28.

Communications Cables

The following cable diagrams show several types of EIA-232 serial communications cables that connect the SEL-351 to other devices. These and other cables are available from SEL. Contact the factory for more information.

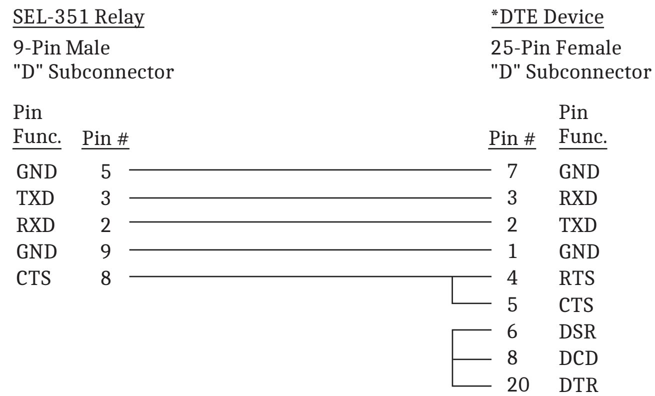
SEL-351 to Computer

Cable SEL-C234A



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

Cable SEL-C227A

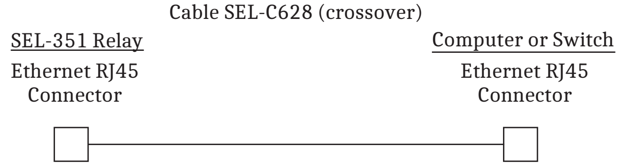


*DTE = Data Terminal Equipment (Computer, Terminal, Printer, etc.)

Cable SEL-C664

SEL-351 to Network

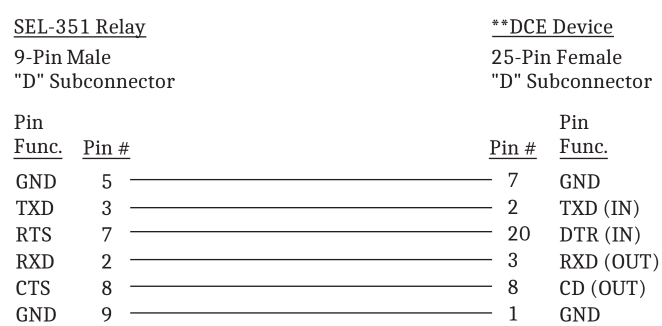
Cable SEL-C627 (straight-through)
Cable SEL-C628 (crossover)



Cable SEL-C808

SEL-351 to Modem

Cable SEL-C222



**DCE = Data Communications Equipment (Modem, etc.)

SEL-351 to SEL-PRTU

Cable SEL-C231

SEL-PRTU
9-Pin Male
Round Conxall

SEL-351 Relay
9-Pin Male
"D" Subconnector

Pin Func.	Pin #	Pin #	Pin Func.
GND	1	5	GND
TXD	2	2	RXD
RXD	4	3	TXD
CTS	5	7	RTS
+12	7	8	CTS
GND	9	9	GND

SEL-351 to SEL Communications Processor or to SEL-2100

Cable SEL-C273A

SEL Communications Processors and SEL-2100
9-Pin Male
"D" Subconnector

SEL-351 Relay
9-Pin Male
"D" Subconnector

Pin Func.	Pin #	Pin #	Pin Func.
RXD	2	3	TXD
TXD	3	2	RXD
IRIG+	4	4	IRIG+
GND	5	5	GND
IRIG–	6	6	IRIG–
RTS	7	8	CTS
CTS	8	7	RTS

SEL-351 to SEL-DTA2

Cable SEL-C272A

SEL-DTA2
9-Pin Male
"D" Subconnector

SEL-351 Relay
9-Pin Male
"D" Subconnector

Pin Func.	Pin #	Pin #	Pin Func.
RXD	2	3	TXD
TXD	3	2	RXD
GND	5	5	GND
RTS	7	7	RTS
CTS	8	8	CTS

For long-distance communications as far as 500 meters and for electrical isolation of communications ports, use the SEL-2800 family of Fiber-Optic Transceivers. For IRIG-B connections and cable details, refer to the instruction manuals for the SEL-2407 Satellite-Synchronized Clock, SEL-2401 Satellite-Synchronized Clock, and other clocks. Contact SEL for more details on these devices.

Communications Protocols

The SEL-351 supports many communications protocols, as shown in *Table 10.7*.

Table 10.7 Supported SEL-351 Communications Protocols

	Port 1 EIA-485 or Fiber-Optic	Port 2 EIA-232	Port 3 EIA-232	Port 4, F EIA-232	USB	5, 5A, 5B Ethernet	Section
DNP3 Level 2	X	X	X	X		X	*Appendix L*
IEC 61850						X[a]	*Appendix P*
Modbus	X	X	X			X	*Appendix O*
C37.118 Synchrophasors	X	X	X	X		X	*Appendix N*
SEL ASCII and Compressed ASCII	X	X	X	X	X	Telnet	*Section 10*, *Appendix K*
SEL Fast Synchrophasors	X	X	X	X			*Appendix J*, *Appendix N*
SEL Fast Operate	X	X	X	X		Telnet	*Appendix J*
Other SEL Fast Message (Meter, SER,...)	X	X	X	X	X	Telnet	*Appendix J*, *Appendix M*
SEL MIRRORED BITS	X	X	X	X			*Appendix H*
SEL LMD	X	X	X	X			*Appendix J*
SEL DTA	X	X	X	X			*Section 10*
SNTP						X	*Section 10*
FTP						X	*Section 10*
Telnet						X	*Section 10*
Ping						X	*Section 10*
Web Server (HTTP)						X	*Section 10*

[a] Not available with single copper Ethernet port.

SEL ASCII, Compressed ASCII, and Fast protocols are available when the serial port PROTO setting is either SEL or LMD, and when using Telnet.

Session Limits

The SEL-351 supports multiple simultaneous sessions of many of the protocols listed in *Table 10.7*. The number of allowed protocol sessions depends on what other protocols are enabled, as shown in *Table 10.8*.

Table 10.8 Protocol Session Limits (Sheet 1 of 2)

Protocol	Sessions Supported[a]
DNP3	The relay supports six total DNP sessions (combined serial and Ethernet sessions).
IEC 61850	The relay supports seven simultaneous sessions of IEC 61850.
Modbus	The relay supports three total Modbus sessions (combined serial and Ethernet). If the number of Ethernet DNP sessions is greater than three (EDNP > 3), no Ethernet Modbus sessions are supported.
FTP	The relay supports one session of File Transfer Protocol on Port 5.

Table 10.8 Protocol Session Limits (Sheet 2 of 2)

Protocol	Sessions Supported[a]
Telnet	The number of available simultaneous Telnet sessions depends on Port 5 relay settings E61850, EHTTP (read-only web server), EDNP (DNP over Ethernet), and EMODBUS (Modbus TCP) as follows: ➤ When Port 5 setting E61850 = N[b], the relay supports three simultaneous Telnet sessions. ➤ When Port 5 settings E61850 = Y, EHTTP = N, EDNP = 0, and EMODBUS = 0, the relay supports three simultaneous Telnet sessions. ➤ When Port 5 settings E61850 = Y, EHTTP = Y, EDNP = 0, and EMODBUS = 0, the relay supports two simultaneous Telnet sessions. ➤ When Port 5 settings E61850 = Y, EHTTP = N, and one or both of EDNP > 0, EMODBUS > 0, the relay supports two simultaneous Telnet sessions. ➤ When Port 5 settings E61850 = Y, EHTTP = Y, and one or both of EDNP > 0, EMODBUS > 0, the relay supports one Telnet session.
Web Server (HTTP)	The relay always supports three simultaneous web server sessions.
C37.118 Synchrophasors	The relay supports two C37.118 synchrophasor sessions on Port 5 if Port 5 setting E61850 = N[b]. When Port 5 setting E61850 = Y, the relay supports one C37.118 synchrophasor session on Port 5.
SNTP	The relay supports one session of SNTP on Port 5. Some operation modes of SNTP allow the relay to synchronize to one of multiple NTP servers.

[a] When properly configured (enable settings, IP addresses, etc.).
[b] Relays ordered without IEC 61850 are treated as if E61850 = N.

Distributed Network Protocol (DNP3)

The relay provides Distributed Network Protocol (DNP3) slave support. DNP is described in *Appendix L: DNP3 Communications*.

IEC 61850 Protocol

The relay supports IEC 61850 protocol, including GOOSE, as described in *Appendix P: IEC 61850*. The IEC 61850 protocol is only available on relays with two copper Ethernet ports, or with one or two fiber Ethernet ports.

Modbus Protocol

The relay provides Modbus protocol as described in *Appendix O: Modbus RTU and TCP Communications*.

IEEE C37.118 Synchrophasor Protocol

The relay supports the C37.118 protocol at as many as 60 messages per second as described in *Appendix N: Synchrophasors*.

SEL Compressed ASCII Protocol

SEL Compressed ASCII protocol provides compressed versions of some of the relay ASCII commands. The protocol is described in *Appendix K: Compressed ASCII Commands*.

Ping Server

Use a Ping client with the relay Ping server to verify that your network configuration is correct. Ping is an application based on ICMP over an IP network. A free Ping application is included with most computer operating systems.

SEL Fast Message Synchrophasor Protocol

SEL Fast Message Synchrophasor protocol has a maximum message rate of one per second, and is provided for compatibility with legacy installations. The protocol is described in *Appendix N: Synchrophasors*.

SEL Fast Meter Protocol

SEL Fast Meter protocol supports binary messages to transfer metering and control messages. The protocol is described in *Appendix J: Configuration, Fast Meter, and Fast Operate Commands*.

SEL Fast Sequential Events Recorder (SER) Protocol

SEL Fast Sequential Events Recorder (SER) Protocol, also known as SEL Unsolicited Sequential Events Recorder, provides SER events to an automated data collection system. SEL Fast SER Protocol is available on any serial or Ethernet port. The protocol is described in *Appendix M: Fast SER Protocol*.

MIRRORED BITS Communications

The SEL-351 supports MIRRORED BITS relay-to-relay communications on two ports simultaneously (available in firmware versions 6 and 7 only, see *Appendix H: MIRRORED BITS Communications (in Firmware Versions 6 and 7)*).

SEL Distributed Port Switch Protocol (LMD)

The SEL Distributed Port Switch Protocol (LMD) permits multiple SEL relays to share a common communications channel. The protocol is selected by setting the port setting PROTO = LMD. See *Appendix I: SEL Distributed Port Switch Protocol* for more information.

Simple Network Time Protocol (SNTP)

When Port 5 setting ESNTP is not OFF, the relay internal clock conditionally synchronizes to the time of day served by a Network Time Protocol (NTP) server. The relay uses a simplified version of NTP called the Simple Network Time Protocol (SNTP). SNTP is not as accurate as IRIG-B (see *Configuring High-Accuracy Timekeeping* on page N.28). The relay can use SNTP as a less accurate primary time source, or as a backup to the higher accuracy IRIG-B time source.

SNTP as Primary or Backup Time Source

If an IRIG-B time source is connected and either Relay Word bits TSOK or TIRIG assert, then the relay synchronizes the internal time-of-day clock to the incoming IRIB-G time-code signal, even if SNTP is configured in the relay and an NTP server is available. If the IRIG-B source is disconnected (if both TSOK and TIRIG deassert) then the relay synchronizes the internal time-of-day clock to the NTP server if available. In this way an NTP server acts as either the primary time source, or as a backup time source to the more accurate IRIG-B time source.

Creating an NTP Server

Three SEL application notes available from the SEL web site describe how to create an NTP server.

AN2009-10: Using an SEL-2401, SEL-2404, or SEL-2407 to Serve NTP Via the SEL-3530 RTAC

AN2009-38: Using SEL Satellite-Synchronized Clocks With the SEL-3332 or SEL-3351 to Output NTP

AN2010-03: Using an SEL-2401, SEL-2404, or SEL-2407 to Create a Stratum 1 Linux NTP Server

Configuring SNTP Client in the Relay

To enable SNTP in the relay make Port 5 setting ESNTP = UNICAST, MANY-CAST, or BROADCAST. *Table 10.9* shows each setting associated with SNTP.

Table 10.9 Settings Associated With SNTP

Setting	Range	Description
ESNTP	UNICAST, MANYCAST, BROADCAST	Selects the mode of operation of SNTP. See descriptions in *SNTP Operation Modes* on page 10.18.
SNTPPSIP	Valid IP Address	Selects primary NTP server when ENSTP = UNICAST, or broadcast address when ESNTP = MANYCAST or BROADCAST.
SNTPPSIB	Valid IP Address	Selects backup NTP server when ESNTP = UNICAST.
SNTPPORT	1–65534	Ethernet port used by SNTP. Leave at default value unless otherwise required.
SNTPRATE	15–3600 seconds	Determines the rate at which the relay asks for updated time from the NTP server when ESNTP = UNICAST or MANYCAST. Determines the time the relay will wait for an NTP broadcast when ENSTP = BROADCAST.
SNTPTO	5–20 seconds	Determines the time the relay will wait for the NTP master to respond when ENSTP = UNICAST or MANYCAST.

SNTP Operation Modes

The following sections explain the setting associated with each SNTP operation mode (UNICAST, MANYCAST, and BROADCAST).

ESNTP = UNICAST

In unicast mode of operation the SNTP client in the relay requests time updates from the primary (IP address setting SNTPPSIP) or backup (IP address setting SNTPBSIP) NTP server at a rate defined by setting SNTPRATE. If the NTP server does not respond within the period defined by setting SNTPTO then the relay tries the other SNTP server. When the relay successfully synchronizes to the primary NTP time server, Relay Word bit TSNTPP asserts. When the relay successfully synchronizes to the backup NTP time server, Relay Word bit TSNTPB asserts. The relay maintains synchronism to either the primary or backup NTP server until connection to that server is lost.

ESNTP = MANYCAST

In manycast mode of operation the relay initially sends an NTP request to the broadcast address contained in setting SNTPPSIP. The relay continues to broadcast requests at a rate defined by setting SNTPRATE. When a server replies, the relay considers that server to be the primary NTP server, and switches to UNICAST mode, asserts Relay Word bit TSNTPP, and thereafter requests updates from the primary server. If the NTP server stops responding for time SNTPTO, the relay deasserts TSNTPP and begins to broadcast requests again until that or another server responds.

ESNTP = BROADCAST

If setting SNTPPSIP = 0.0.0.0 while setting ESNTP = BROADCAST, the relay will listen for and synchronize to any broadcasting NTP server. If setting SNTPPSIP is set to a specific IP address while setting ESNTP = BROADCAST, then the relay will listen for and synchronize to only NTP server broadcasts from that address. When synchronized the relay asserts Relay Word bit TSNTPP. Relay Word bit TSNTPP deasserts if the relay does not receive a valid broadcast within five seconds after the period defined by setting SNTPRATE.

SNTP Accuracy Considerations

SNTP time synchronization accuracy is limited by the accuracy of the SNTP Server and by the networking environment. The highest degree of SNTP time synchronization can be achieved by minimizing the number of switches and routers between the SNTP Server and the SEL-351. Network monitoring software can also be used to ensure average and worst-case network bandwidth utilization is moderate.

When installed on a network configured with one Ethernet switch between the SEL-351 and the SNTP Server, and when using ESNTP = UNICAST or MANYCAST, the relay time synchronization error with the SNTP server is typically less than ±1 millisecond.

Using the Embedded Web Server (HTTP)

When Port 5 setting EHTTP = Y, the relay serves webpages displaying certain settings, metering, and status reports. The relay's embedded web server has been optimized and tested to work with the most popular web browsers, but should work with any standard web browser. As many as three users can access the embedded web server simultaneously.

Access Level 1 provides a read-only display of settings, reports, and meter values. Access Level 2 allows the user to upgrade firmware over the Web Server interface (see *Method Three: Using a Web Browser* on page B.21). Port 5 setting HTTPACC determines the maximum access level available to the web server, and its default is Level 2.

To begin using the embedded web server, launch your web browser, and browse to http://IPADDR, where IPADDR is the Port 5 setting IPADDR (e.g., http://192.168.1.2). The relay responds with a login screen, as shown in *Figure 10.4*.

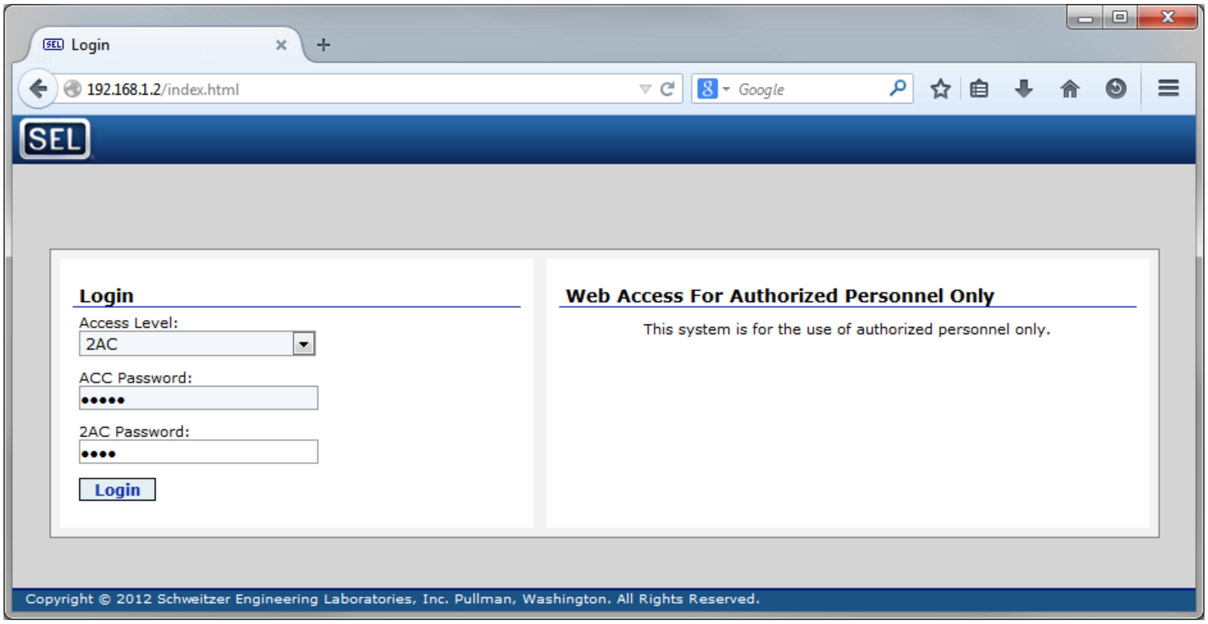


Figure 10.4 Web Server Login Screen

If HTTPACC is set to 2, Access Level 1 (ACC) or Access Level 2 (2AC) can be chosen from the Access Level drop down box. Enter the appropriate password(s) in the text box(es) below the Access Level drop down box. If 2AC is chosen, both the ACC and 2AC passwords must be entered to login, as shown in *Figure 10.4*. Note that access level passwords are not encrypted in any way by the web server when logging in.

Once you have entered the correct password(s), the relay responds with the meter display home page. While you remain logged into the relay, the webpage displays the approximate time as determined by the relay time-of-day clock, and increments the displayed time every few seconds based on the clock contained in your PC. *Figure 10.5* shows an example of the Device Features screen, equivalent to the relay version (**VER**) command.

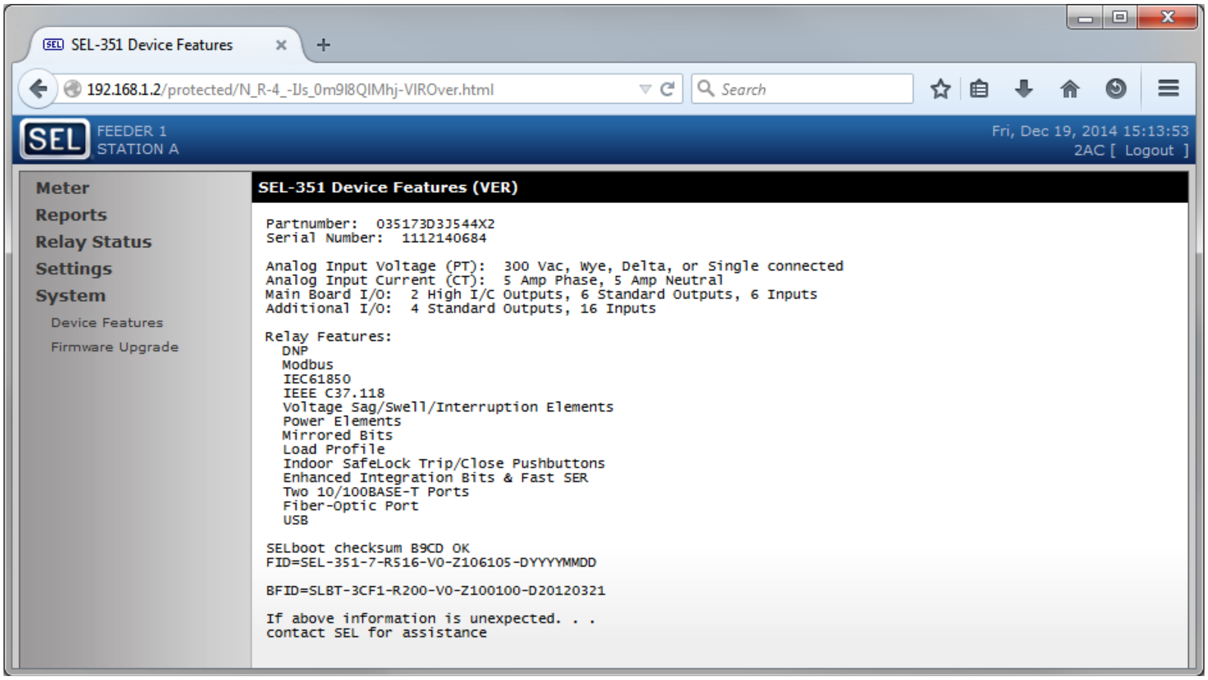


Figure 10.5 Web Server Response to System > Device Features Selection

Click on any menu selection from the left pane to retrieve various reports. Some menus expand to reveal more menus, such as the **Show Settings** menu shown in *Figure 10.6*.

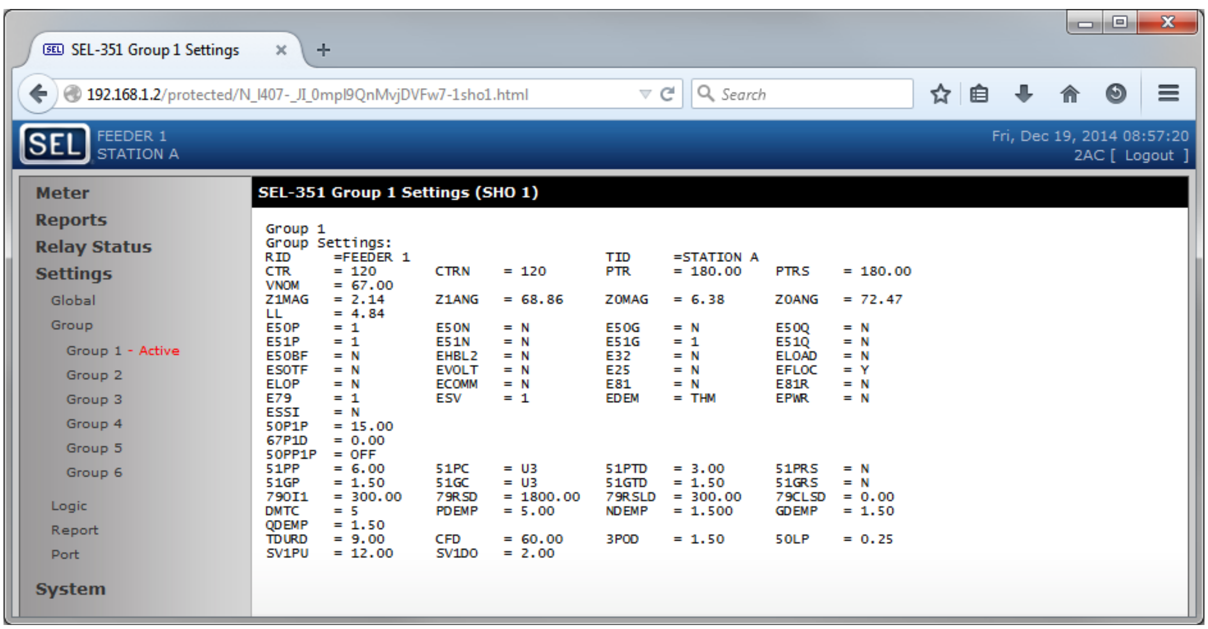


Figure 10.6 Web Server Show Settings Screen

The Meter Reports screens update automatically about every five seconds.

To log off, either close the web browser window or click on **[Logout]** in the banner bar near the top of the webpage.

File Transfer Protocol (FTP) and MMS File Transfer

File Transfer Protocol (FTP) is a standard protocol for exchanging files between computers over a TCP/IP network. The SEL-351 operates as an FTP server, presenting files to FTP clients. The relays supports one FTP session at a time. Requests to establish additional FTP sessions are denied.

Manufacturing Messaging Specification (MMS) is used in IEC 61850 applications and provides services for the transfer of real-time data, including files, within a substation LAN.

File Structure

The file structure is organized as a directory and subdirectory tree similar to that used by Windows and other common operating systems. See *Virtual File Interface* on page 10.26 for information on available files.

File dates within the last 12 months are displayed with month, day, hour, and minutes. Dates older than 12 months have the year, month, and day. The times are UTC.

Access Control

To log in to the FTP server, enter the value of the Port 5 setting FTPUSER as the user name in your FTP application. Enter the Level 2 password as the password in your FTP application. Note that FTP does not encrypt passwords before sending them to the server.

MMS is enabled when Port 5 setting E61850 is set to Y. MMS File Transfer is enabled when setting EMMSFS is set to Y. If MMS Authentication is enabled via the CID file, then an authenticated connection must be established via MMS for MMS file transfer to take place.

Using FTP and MMS

A free FTP application is included with most web browser software and PC operating systems. You can also obtain free or inexpensive FTP applications from the Internet. Once you have retrieved the necessary files, be sure to close the FTP connection using the disconnect function of your FTP application or completely closing the application. Failure to do so can cause the FTP connection to remain open, which blocks subsequent connection attempts until FTPIDLE time expires.

See *Appendix P: IEC 61850* for information about using MMS.

SEL ASCII Protocol

SEL ASCII protocol is designed for manual and automatic communications.

All commands received by the relay must be of the form:

<command><CR> or <command><CRLF>

NOTE: The **<Enter>** key on most keyboards is configured to send the ASCII character 13 (^M) for a carriage return. This manual instructs you to press the **<Enter>** key after commands, which should send the proper ASCII code to the relay.

A command transmitted to the relay should consist of the command followed by either a CR (carriage return) or a CRLF (carriage return and line feed). You may truncate commands to the first three characters. For example, **EVENT 1 <Enter>** would become **EVE 1 <Enter>**. Upper- and lowercase characters may be used without distinction, except in passwords.

Software Flow Control

The SEL-351 implements XON/XOFF flow control. You can use the XON/XOFF protocol to control the relay during data transmission. When the relay receives XOFF during transmission, it pauses until it receives an XON character. If there is no message in progress when the relay receives XOFF, it blocks transmission of any message presented to its buffer. Messages will be accepted after the relay receives XON.

The relay transmits XON (ASCII hex 11) and asserts the RTS output (if hardware handshaking is enabled) when the relay input buffer drops below 25 percent full.

The relay transmits XOFF (ASCII hex 13) when the buffer is more than 75 percent full. If hardware handshaking is enabled, the relay deasserts the RTS output when the buffer is approximately 95 percent full. Automatic transmission sources should monitor for the XOFF character to avoid overwriting the buffer. Transmission should terminate at the end of the message in progress when XOFF is received and can resume when the relay sends XON.

The CAN character (ASCII hex 18) aborts a pending transmission. This is useful for terminating an unwanted transmission.

Control characters can be sent from most keyboards with the following keystrokes:

- XOFF: **<Ctrl+S>** (hold down the **<Ctrl>** key and press **S**)
- XON: **<Ctrl+Q>** (hold down the **<Ctrl>** key and press **Q**)
- CAN: **<Ctrl+X>** (hold down the **<Ctrl>** key and press **X**)

Serial Port and Telnet Session Automatic Messages

When the Telnet or serial port AUTO setting is Y, the relay sends automatic messages to indicate specific conditions. The automatic messages are described in *Table 10.10*. The optional USB port does not support automatic messages.

When a serial port AUTO setting is DTA, the SEL-351 is compatible with the SEL-DTA2 on that port. The **MET** and **MET D** command responses are modified to comply with the DTA2 data format for that port.

Table 10.10 Serial Port Automatic Messages

Condition	Description
Power Up	The relay sends a message containing the present date and time, Relay and Terminal Identifiers, and the Access Level 0 prompt when the relay is turned on.
Event Trigger	The relay sends an event summary each time an event report is triggered. See *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*.
Group Switch	The relay displays the active settings group after a group switch occurs. See ***GRO*** *(Display Active Setting Group Number)* on page 10.51.
Self-Test Warning or Failure	The relay sends a status report each time a self-test warning or failure condition is detected. See ***STA*** *(Relay Self-Test Status)* on page 10.77.

Port Access Levels

Commands can be issued to the relay via the serial port, USB port, or Telnet session to view metering values, change relay settings, etc. The available serial port commands are listed in *Table 10.19*. The commands can be accessed only from the corresponding access level as shown in *Table 10.19*. The access levels are:

- Access Level 0 (the lowest access level)
- Access Level 1
- Access Level B
- Access Level 2 (the highest access level)
- Access Level C (restricted access level, should be used under direction of SEL only)

Limit Maximum Access Level or Disable Any Rear Port

Limit the maximum allowable access level on any enabled port configured for Telnet, SEL ASCII, or LMD protocols using the MAXACC setting. For example, if MAXACC = 1 on Port 5, then the maximum access level attainable from a Telnet session on Port 5, 5A, and 5B is limited to Access Level 1. The MAXACC setting on Port 5 does not limit FTP. FTP can always read and write settings files even if MAXACC = 1.

For serial port sessions and Ethernet port Telnet sessions, changing a port MAXACC setting to a lower access level will cause the relay to terminate any active session(s) on that port that exceed the new MAXACC level. The relay grants any new access level attempts on the port only to the level MAXACC allows.

For the optional USB port, changing the Port F MAXACC setting to a lower access level does not terminate a USB session in progress. After a **QUIT** command or timeout, the relay grants any new access level attempts on the USB port only granted to the level Port F MAXACC allows.

When MAXACC = 0, the port is available for SEL Fast Messaging, Fast Operate, and Fast Synchrophasors only.

Disable any port using the EPORT setting. For example, if EPORT = N on Port 5, then Port 5, 5A, and 5B will be nonresponsive.

See *Port Enable Settings* on page 9.27 for more information about these and other port settings.

Access Level 0

Once ASCII communications are established with the relay, the relay sends the following prompt:

```
=
```

This is referred to as Access Level 0. Enter the **ACC** command at the Access Level 0 prompt:

```
=ACC <Enter>
```

The **ACC** command takes the relay to Access Level 1 (see ***ACC*, *BAC*, *2AC*, *and CAL* *(Go to Access Level 1, B, 2, or C)*** on page 10.36 for more detail).

Access Level 1

When the relay is in Access Level 1, the relay sends the following prompt:

```
=>
```

Commands available from Access Level 1 are shown in *Table 10.19*. For example, enter the **MET** command at the Access Level 1 prompt to view metering data:

```
=>MET <Enter>
```

The **2AC** command allows the relay to go to Access Level 2 (see ***ACC**, **BAC**, **2AC**, and **CAL** (Go to Access Level 1, B, 2, or C)* for more detail). Enter the **2AC** command at the Access Level 1 prompt:

```
=>2AC <Enter>
```

The **BAC** command allows the relay to go to Access Level B (see ***ACC**, **BAC**, **2AC**, and **CAL** (Go to Access Level 1, B, 2, or C)* for more detail). Enter the **BAC** command at the Access Level 1 prompt:

```
=>BAC <Enter>
```

Access Level B

When the relay is in Access Level B, the relay sends the prompt:

```
==>
```

Commands available from Access Level B are shown in *Table 10.19*. For example, enter the **CLO** command at the Access Level B prompt to close the circuit breaker:

```
==>CLO <Enter>
```

While in Access Level B, any of the Access Level 1 commands are also available.

The **2AC** command allows the relay to go to Access Level 2 (see ***ACC**, **BAC**, **2AC**, and **CAL** (Go to Access Level 1, B, 2, or C)* on page 10.36 for more detail). Enter the **2AC** command at the Access Level B prompt:

```
==>2AC <Enter>
```

Access Level 2

When the relay is in Access Level 2, the relay sends the prompt:

```
=>>
```

Commands available from Access Level 2 are shown in *Table 10.19*. For example, enter the **SET** command at the Access Level 2 prompt to make relay settings:

```
=>>SET <Enter>
```

While in Access Level 2, any of the Access Level 1 and Access Level B commands are also available.

Access Level C

The Access Level C is intended for use by the SEL factory, and for use by SEL field service personnel to help diagnose troublesome installations. A list of commands available at the CAL level is available from SEL upon request. Do not enter the CAL access level except as directed by SEL.

The **CAL** command allows the relay to go to Access Level C (see *ACC, BAC, 2AC, and CAL (Go to Access Level 1, B, 2, or C)* on page 10.36 for more detail). Enter the **CAL** command at the Access Level 2 prompt:

```
=>>CAL <Enter>
```

Virtual File Interface

You can retrieve and send data as files through the relay virtual file interface. Devices with embedded computers can also use the virtual file interface. When using serial ports or virtual terminal links, use the **FILE DIR** command to access the file interface.

Send and receive files using the following three protocols:

1. File Transfer Protocol (FTP)
2. MMS File Transfer
3. Ymodem

FTP and MMS File Structure

FTP and MMS have a two-level file structure. Files are available at the root level and subdirectories. *Table 10.11* shows the directories and their contents.

Table 10.11 FTP and MMS Virtual File Structure

Directory	Contents
/	CFG.TXT[a] file, CFG.XML file, ERR.TXT file and SET_61850.CID and the SETTINGS, REPORTS, DIAGNOSTICS, EVENTS, and COMTRADE[b] directories
/SETTINGS[a]	Relay settings
/REPORTS	SER, target, metering, circuit breaker, and history reports
/DIAGNOSTICS	Relay status and vector reports
/EVENTS	CEV, COMTRADE, and history reports
/COMTRADE[b]	COMTRADE events

[a] Only available in FTP file structure.
[b] Only available in MMS file structure.

Root Directory

The root directory (/) contains files and subdirectories as shown in *Table 10.11*.

CFG.TXT File (Read-Only)

The CFG.TXT file contains general configuration information about the relay and each settings class. External support software retrieves the CFG.TXT file to interact automatically with the relay. The relay calculates a checksum, or hash code, for each settings class and lists the codes in the CFG.TXT file (see *Figure 10.7*). Improve system security by periodically reading the CFG.TXT file and comparing the current hash codes to those in a secured copy of the file. See *Appendix Q: Cybersecurity Features* for more information.

```
[INFO]
RELAYTYPE=0351
FID=SEL-351-7-R5xx-V0-Z106104-Dyyyymmdd
BFID=SLBT-3CF1-R200-V0-Z100100-D20120321
PARTNO=035172A3A54XX1
[CLASSES]
"1","Group 1","SET_1.TXT","30C0490A"
"2","Group 2","SET_2.TXT","30C0490A"
"3","Group 3","SET_3.TXT","30C0490A"
"4","Group 4","SET_4.TXT","30C0490A"
"5","Group 5","SET_5.TXT","30C0490A"
"6","Group 6","SET_6.TXT","30C0490A"
"D1","DNP Map 1","SET_D1.TXT","7DC463B8"
"D2","DNP Map 2","SET_D2.TXT","7DC463B8"
"D3","DNP Map 3","SET_D3.TXT","7DC463B8"
"G","Global","SET_G.TXT","C2B2FE98"
"L1","Logic 1","SET_L1.TXT","00340302"
"L2","Logic 2","SET_L2.TXT","00340302"
"L3","Logic 3","SET_L3.TXT","00340302"
"L4","Logic 4","SET_L4.TXT","00340302"
"L5","Logic 5","SET_L5.TXT","00340302"
"L6","Logic 6","SET_L6.TXT","00340302"
"M","Modbus","SET_M.TXT","E9CE3427"
"P1","Port 1","SET_P1.TXT","939DC3DD"
"P2","Port 2","SET_P2.TXT","55D70365"
"P3","Port 3","SET_P3.TXT","C47944EC"
"PF","Port F","SET_PF.TXT","8A4F4858"
"P5","Port 5","SET_P5.TXT","E665D08E"
"R","Report","SET_R.TXT","1C7ED04D"
"T","Text","SET_T.TXT","5F96E9BE"
[STORAGE]
```

Figure 10.7 Example CFG.TXT File

CFG.XML File (Read-Only)

Present only in units with the optional Ethernet card installed, the CFG.XML file is supplementary to the CFG.TXT file. The CFG.XML file describes the IED configuration, any options such as the Ethernet port, and includes firmware identification, settings class names, and configuration file information.

ERR.TXT (Read-Only) and SET_61850.CID File

Present if ordered with the IEC 61850 protocol option. The ERR.TXT file contents is based on the most recent SET_61850.CID file written to the relay. If there were no errors, the file is empty. If errors occurred, the relay logs these errors in the ERR.TXT file. The SET_61850.CID file contains the IEC 61850 configured IED description in XML. ACSELERATOR Architect SEL-5032 Software generates and then downloads this file to the relay. See *Appendix P: IEC 61850* for more information.

Settings Directory (Available Only for FTP)

You can access the relay settings through files in the SETTINGS directory. We recommend that you use support software to access the settings files, rather than directly accessing them via other means. External settings support software reads settings from all of these files to perform its functions. The relay only allows you to write to the individual SET_cn files, where c is the settings class code and n is the settings instance. Except for the SET_61850 CID file, changing settings with external support software involves the following steps:

Step 1. The PC software reads the CFG.TXT and SET_ALL.TXT files from the relay.

Step 2. You modify the settings at the PC. For each settings class that you modify, the software sends a SET_cn.TXT file to the relay.

Step 3. The PC software reads the ERR.TXT file. If the file is empty, the relay detected no errors in the SET_cn.TXT file. Otherwise, the ERR.TXT file contains a listing of the error(s) encountered in the SET_cn.TXT file.

Step 4. For any detected errors, modify the settings and send the settings until the relay accepts your settings.

Step 5. Repeat *Step 2–Step 4* for each settings class that you want to modify.

Step 6. Test and commission the relay.

SET_ALL.TXT File (Read-Only)

The SET_ALL.TXT file contains the settings for all of the settings classes in the relay.

SET_cn.TXT Files (Read and Write)

There is a file for each instance of each setting class. *Table 10.12* summarizes the settings files. The settings class is designated by *c*, and the settings instance number is designated by *n*.

ERR.TXT (Read-Only)

The ERR.TXT file contents are based on the most recent SET_*cn*.TXT file written to the relay. If there were no errors, the file is empty. If errors occurred, the relay logs these errors in the ERR.TXT file.

NOTE: Settings directory and files are not available in the MMS file structure.

Table 10.12 Settings Directory Files

Filename	Settings Description
SET_*n*.TXT	Group; *n* in range 1–6
SET_D*n*.TXT	DNP3 remapping; *n* in range 1–3
SET_G.TXT	Global
SET_L*n*.TXT	Logic; *n* in range 1–6
SET_M.TXT	Modbus remapping
SET_P*n*.TXT	Port; *n* in range 1, 2, 3, 5, F
SET_R.TXT	Report
SET_T.TXT	Text
SET_ALL.TXT	All instances of all settings classes
ERR.TXT	Error log for most recently written settings file

Reports Directory (Read-Only)

Use the REPORTS directory to retrieve files that contain the reports shown in *Table 10.13*. Note that the relay provides a report file that contains the latest information each time you request the file. In effect, when a report file read request is received the relay performs the following actions:

- ➤ Immediately executes the corresponding report command
- ➤ Captures the response in a text file with the requested name
- ➤ Transmits the text file

There is no need to manually enter any of the commands shown in *Table 10.13*.

Table 10.13 Reports Directory Files

Filename	Description	Equivalent Command Response
BRE.TXT	Breaker Report	**BRE**
BRE_H.TXT	Breaker History Report	**BRE H**
CHISTORY.TXT	Compressed ASCII History Report	**CHI**
HISTORY.TXT	History Report	**HIS**
LDP.TXT	Load Profile Report	**LDP**
MET.TXT	Instantaneous Metering	**MET**
MET_D.TXT	Demand Metering	**MET D**
MET_E.TXT	Energy Metering	**MET E**
MET_H.TXT	Harmonic Metering	**MET H**
MET_M.TXT	Max-Min Metering	**MET M**
MET_PM.TXT	Synchrophasor Metering	**MET PM**
SER. TXT	Sequence of Events	**SER**
SSI.TXT	Voltage Sag/Swell/Interruption Report	**SSI**
TAR.TXT	Status of all Relay Word bits	**TAR ROW LIST**

Events Directory (Read-Only)

The relay provides history, event reports, and oscillography files in the EVENTS directory as shown in the *Table 10.14*.

Event reports are available in the following formats:

- ➤ Compressed SEL ASCII
- ➤ Binary COMTRADE format (IEEE C37.111-1999)

The size of each event report file is determined by the LER setting in effect at the time the event is triggered.

Compressed SEL ASCII event report files are generated, when requested, by storing the appropriate command response shown in table *Table 10.14*. Oscillography files are generated at the time the event is triggered (see *Standard Event Report Triggering* on page 12.3). Higher resolution oscillography is available with SEL Compressed ASCII 128 sample/cycle raw event reports and binary COMTRADE files.

COMTRADE event files are available to read as a batch. See *Batch File Access* on page 10.32.

Table 10.14 Event Directory Files

Filename	Description	Equivalent Command Response
CHISTORY.TXT[a]	Compressed ASCII History Report	**CHI**
HISTORY. TXT[a]	History Report	**HIS**
C4_*nnnnn*.CEV	Compressed 4-samples/cycle ASCII filtered event report; event ID number = *nnnnn*[b]	**CEV *nnnnn***
CR_*nnnnn*.CEV	Compressed 128-samples/cycle ASCII raw event report; event ID number = *nnnnn*[b]	**CEV R S128 *nnnnn***
HR_*nnnnn*.CFG[c]	COMTRADE configuration file; event ID number = *nnnnn*[b]	N/A
HR_*nnnnn*.DAT[c]	COMTRADE binary data file; event ID number = *nnnnn*[b]	N/A
HR_*nnnnn*.HDR[c]	COMTRADE header file; event ID number = *nnnnn*[b]	N/A

[a] Also available in the Reports directory for convenience.
[b] nnnnn is the unique event identification number; see *HIS (Event Summaries/History)* on page 10.52 for additional details.
[c] Also available in the COMTRADE directory for MMS only.

HR_nnnnn.* (Read-Only)

The three files HR_*nnnnn*.CFG, HR_*nnnnn*.DAT, and HR_*nnnnn*.HDR shown in *Table 10.14* are used to create an event report that conforms to the COMTRADE standard. The event is an unfiltered (raw) 128 samples/cycle event. The field, *nnnnn*, corresponds to the unique event identification number displayed by the **HIS E** command. For details on event reports see *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*.

Diagnostics Directory (Read-Only)

Use the DIAGNOSTICS directory to retrieve files that contain the reports shown in *Table 10.15*. Each time a diagnostic report is requested the relay stores the following command response in the designated text file.

Table 10.15 Diagnostic Directory Files

Filename	Description	Equivalent Command Response
STATUS.TXT	Status report	**STA**
VEC_D.TXT	Standard vector report	**VEC D**
VEC_E.TXT	Extended vector report	**VEC E**

COMTRADE Directory (Available Only for MMS)

When using MMS file transfer, conveniently retrieve all of the COMTRADE files from the COMTRADE directory. Note that the COMTRADE files are also available in the Events directory. Refer to *Table 10.14* for all the files available in the COMTRADE directory.

Ymodem File Structure

All the files available (see *Table 10.16*) for Ymodem protocol are in the root directory. See ***FIL*** on page 10.46 for a response of the **FIL DIR** command.

Table 10.16 Files Available for Ymodem Protocol (Sheet 1 of 2)

Filename	Description	Read Access Level	Write Access Level
CFG.TXT	See *Root Directory* on page 10.26	1, B, 2, C	N/A
ERR.TXT	See *Settings Directory (Available Only for FTP)* on page 10.27	1, B, 2, C	N/A
SET_ALL.TXT[a]	See *Settings Directory (Available Only for FTP)* on page 10.27	1, B, 2, C	N/A
SET_*n*.TXT	See *Settings Directory (Available Only for FTP)* on page 10.27	1, B, 2, C	N/A
SET_C.TXT[a]	See *Settings Directory (Available Only for FTP)* on page 10.27	C	C
SET_D*n*.TXT	See *Settings Directory (Available Only for FTP)* on page 10.27	1, B, 2, C	2, C
SET_G.TXT	See *Settings Directory (Available Only for FTP)* on page 10.27	1, B, 2, C	2, C
SET_L*n*.TXT	See *Settings Directory (Available Only for FTP)* on page 10.27	1, B, 2, C	2, C
SET_M.TXT	See *Settings Directory (Available Only for FTP)* on page 10.27	1, B, 2, C	2, C
SET_P*n*.TXT	See *Settings Directory (Available Only for FTP)* on page 10.27	1, B, 2, C	2, C
SET_R.TXT	See *Settings Directory (Available Only for FTP)* on page 10.27	1, B, 2, C	2, C
SET_T.TXT	See *Settings Directory (Available Only for FTP)* on page 10.27	1, B, 2, C	2, C
SWCFG.ZIP	The SWCFG.ZIP file is a compressed file used to store external support software settings.	1, B, 2, C	2, C
C4_*nnnnn*.CEV[b]	See *Events Directory (Read-Only)* on page 10.29	1, B, 2, C	N/A
CR_*nnnnn*.CEV[b]	See *Events Directory (Read-Only)* on page 10.29	1, B, 2, C	N/A
HR_*nnnnn*.CFG[b]	See *Events Directory (Read-Only)* on page 10.29	1, B, 2, C	N/A
HR_*nnnnn*.DAT[b]	See *Events Directory (Read-Only)* on page 10.29	1, B, 2, C	N/A
HR_*nnnnn*.HDR[b]	See *Events Directory (Read-Only)* on page 10.29	1, B, 2, C	N/A
STATUS.TXT	See *Diagnostics Directory (Read-Only)* on page 10.30	1, B, 2, C	N/A
VEC_D.TXT	See *Diagnostics Directory (Read-Only)* on page 10.30	2, C	N/A
VEC_E.TXT	See *Diagnostics Directory (Read-Only)* on page 10.30	2, C	N/A
BRE.TXT	See *Reports Directory (Read-Only)* on page 10.28	1, B, 2, C	N/A

Table 10.16 Files Available for Ymodem Protocol (Sheet 2 of 2)

Filename	Description	Read Access Level	Write Access Level
BRE_H.TXT	See *Reports Directory (Read-Only)* on page 10.28	1, B, 2, C	N/A
CHISTORY.TXT	See *Reports Directory (Read-Only)* on page 10.28	1, B, 2, C	N/A
HISTORY.TXT	See *Reports Directory (Read-Only)* on page 10.28	1, B, 2, C	N/A
LDP.TXT	See *Reports Directory (Read-Only)* on page 10.28	1, B, 2, C	N/A
MET.TXT	See *Reports Directory (Read-Only)* on page 10.28	1, B, 2, C	N/A
MET_D.TXT	See *Reports Directory (Read-Only)* on page 10.28	1, B, 2, C	N/A
MET_E.TXT	See *Reports Directory (Read-Only)* on page 10.28	1, B, 2, C	N/A
MET_H.TXT	See *Reports Directory (Read-Only)* on page 10.28	1, B, 2, C	N/A
MET_M.TXT	See *Reports Directory (Read-Only)* on page 10.28	1, B, 2, C	N/A
MET_PM.TXT	See *Reports Directory (Read-Only)* on page 10.28	1, B, 2, C	N/A
SER.TXT	See *Reports Directory (Read-Only)* on page 10.28	1, B, 2, C	N/A
SSI.TXT	See *Reports Directory (Read-Only)* on page 10.28	1, B, 2, C	N/A
TAR.TXT	See *Reports Directory (Read-Only)* on page 10.28	1, B, 2, C	N/A

[a] Calibration settings are included only when accessed at Access Level C.

[b] nnnnn is the unique event identification number; see *HIS (Event Summaries/History)* on page 10.52 for additional details.

SWCFG.ZIP

SWCFG.ZIP file is only available for Ymodem protocol and is not available in the FTP and MMS file structure. The SWCFG.ZIP file is a fixed name, general purpose file that can be as large as 2 MB in length. Users may store any type of data or information file they choose in this file, even if it is not a zipped file, as long as it is named SWCFG.ZIP. QuickSet uses the SWCFG.ZIP file to store template files created by the licensed version of QuickSet. The SWCFG.ZIP file is only visible in the **FIL DIR** command when a user has loaded it onto the relay.

Batch File Access

FTP and MMS Wildcard Usage

Table 10.17 shows some examples using supported wildcards. Note that these wildcards may be appended to a directory path (e.g., /specified_directory/*.txt).

Table 10.17 FTP and MMS Wildcard Usage Examples

Usage	Description	Example	Note
Null String	Lists all files and/or subdirectories in a specified directory.	/SETTINGS/	Lists all files and/or subdirectories within the SETTINGS directory.
*	Lists all files and/or subdirectories in a specified directory.	/EVENTS/*	Lists all files and/or subdirectories within the EVENTS directory.
**xyz*	Lists all files and/or subdirectories in a specified directory whose name (including extension) ends with *xyz*.	/*.TXT	Lists all files with the *.TXT extension.
*abc**	Lists all files and/or subdirectories in a specified directory whose name begins with *abc*.	/SETTINGS/SET*	List all settings files that start with SET.
mno	Lists all files and/or subdirectories in a specified directory whose name contains *mno*.	/EVENTS/*_100*	List all events that contain _100 in the ID number.
filename	Lists only *filename* if it is a file and not a directory (i.e. it does not end with /).	/cfg.xml	

Ymodem Wildcard Usage

NOTE: Ymodem protocol does not support wildcards for settings files.

Event, report, and diagnostic files can also be accessed as batch using wildcards.

Table 10.18 Ymodem Wildcard Usage Examples

Usage	Description	Example	Note
**xyz*	Lists all files that end with *xyz*.	FILE DIR MET*.TXT	Lists all of the metering files (MET.TXT, MET_D.TXT, etc.)
*abc**	Lists all files whose name begins with *abc*.	FILE READ HR_10007*	Retrieves all of the three files for the COMTRADE event 10007 (HR_10007.CFG, HR_10007.DAT, and HR_10007.HDR)
mno	Lists all files whose name contains *mno*.	FILE READ *10007*	Retrieves all event files pertaining to the unique event number 10007 (including both the filtered and raw compressed event reports and all three COMTRADE files).
abc?.xyz	Lists all files whose name begins with *abc* and whose name (including extension) ends with *xyz* and has any one single character following the letter *c*.	FILE READ C?_10007.CEV	Retrieves both the filtered and raw compressed event reports pertaining to the unique event number 10007.

Command Summary

Table 10.19 alphabetically lists ASCII commands, the required access level, and the corresponding front-panel pushbuttons. See *Section 11: Front-Panel Interface* for more information on the front-panel pushbuttons. All commands available at lower access levels are also available from higher access levels.

Table 10.19 includes some commands not normally issued by operators. These commands are used during the firmware upgrade process or are used by SEL communications processors or PC software to communicate with intelligent electronic devices (IEDs), and are covered in *Appendix B: Firmware Upgrade Instructions for SEL-351 Relays With Ethernet*, *Appendix J: Configuration, Fast Meter, and Fast Operate Commands*, and *Appendix K: Compressed ASCII Commands*.

Table 10.19 ASCII Command Summary (Sheet 1 of 2)

Access Level	Prompt	ASCII Command	Command Description	Corresponding Front-Panel Pushbutton
1	=>	**2AC**	Go to Access Level 2.	
0	=	**ACC**	Go to Access Level 1.	
1	=>	**BAC**	Go to Access Level B.	
0	=	**BNA**	Displays information useful for autoconfiguration of data gathering equipment.	
1	=>	**BRE**	Breaker monitor data.	OTHER
1	=>	**BRE H**	View breaker history.	
B	==>	**BRE R**	Reset breaker wear.	OTHER
B	==>	**BRE W**	Preload/reset breaker wear.	
2	=>>	**CAL**	Go to Access Level C.	
0	=	**CAS**	Displays information useful for autoconfiguration of data gathering equipment.	
1	=>	**CEV**	Compressed event reports.	
1	=>	**CHI**	Compressed history reports.	
B	==>	**CLO**	Close breaker.	
1	=>	**COM**	MIRRORED BITS communications statistics.	
B	==>	**CON**	Control remote bit.	
2	=>>	**COP**	Copy setting group or DNP map.	
1	=>	**CST**	Compressed status report.	
1	=>	**CSU**	Compressed event summary.	
1	=>	**DAT**	View/change date.	OTHER
0	=>	**DNA X** or **T**	Displays information useful for autoconfiguration of data gathering equipment. Either X or T is mandatory and results are identical.	
1	=>	**ETH**	Displays information about Ethernet port(s).	
1	=>	**ETH C**	Clears Ethernet port statistics.	
1	=>	**EVE**	Event reports.	
0	=	**EXI**	Terminate Telnet session.	
1	=>	**FIL**	List or read available files.	
2	=>>	**FIL WRI**	Write file.	
1	=>	**GOO**	Display GOOSE transmit and receive information.	
1	=>	**GRO**	Display active setting group number.	GROUP
B	==>	**GRO** ***n***	Change active setting group.	GROUP
1	=>	**HIS**	Event history.	EVENTS
1	=>	**HIS E**	Event history with unique event number.	
0	=	**ID**	Display configuration information about the relay.	
2	=>>	**L_D**	Prepares the relay to receive new firmware.	
1	=>	**LDP**	Load profile report.	
2	=>>	**LOO**	Loopback.	
1	=>	**MAC**	Display Ethernet port MAC address.	
1	=>	**MET**	Metering data.	METER
B	==>	**OPE**	Open breaker.	
2	=>>	**PAS**	Change passwords.	SET

Table 10.19 ASCII Command Summary (Sheet 2 of 2)

Access Level	Prompt	ASCII Command	Command Description	Corresponding Front-Panel Pushbutton
2	=>>	**PAR**	Change the device part number. Use only under direction from SEL.	
1	=>	**PIN**	Ping command.	
B	==>	**PUL**	Pulse output contact.	CNTRL
2	=>>	**R_S**	Restore factory default settings. Only available under certain conditions.	
0	=>	**QUI**	Return to Access Level 0.	
1	=>	**SER**	Sequential Events Recorder report.	
2	=>>	**SET**	Change settings.	SET
1	=>	**SHO**	Show/view settings.	SET
0	=	**SNS**	Displays information useful for autoconfiguration of data gathering equipment.	
1	=>	**SSI**	Voltage Sag/Swell/Interruption Report.	
1	=>	**STA**	Relay self-test status.	STATUS
2	=>>	**STA C**	Clear self-test status and restart relay.	
1	=>	**SUM**	Display event summary.	
1	=>	**TAR**	Display relay element status.	OTHER
B	==>	**TES DB**	Force protocol binary and analog values. Used for protocol testing.	
2	=>>	**TDP**	Show the status of the SEL Livestream protocol. This feature is used for SEL testing and research. Contact SEL for more details.	
2	=>>	**TDP ON**	Enable the SEL Livestream protocol stream to the last used IP address and UDP port. **Note:** If the command has not been previously used, or a TDP reset has been performed, the default IP address and UDP port are used.	
2	=>>	**TDP ON *addr***	Enable the SEL Livestream protocol stream to the designated IP address and last used UDP port. **Note:** If the command has not been previously used, or a TDP reset has been performed, the default UDP port is used.	
2	=>>	**TDP ON *addr port***	Enable the SEL Livestream protocol stream to the designated IP address and UDP port.	
2	=>>	**TDP OFF**	Disable the SEL Livestream protocol stream.	
2	=>>	**TDP RESET**	Disable the SEL Livestream protocol and reset the IP address and UDP port to defaults.	
1	=>	**TIM**	View/change time.	OTHER
1	=>	**TRI**	Trigger an event report.	
2	=>>	**VEC**	Displays information useful to the factory in troubleshooting.	
1	=>	**VER**	Show relay configuration and firmware version.	

The relay responds with `Invalid Access Level` if a command is entered from an access level lower than the specified access level for the command. The relay responds with `Invalid Command` to commands not listed above or entered incorrectly.

Many of the command responses display the following header at the beginning:

```
FEEDER 1                          Date: 02/02/09    Time: 17:03:26.484
STATION A
```

The definitions are:

`FEEDER 1`: This is the RID setting (the relay is shipped with the default setting RID = FEEDER 1; see *Identifier Labels* on page 9.17).

`STATION A`: This is the TID setting (the relay is shipped with the default setting TID = STATION A; see *Identifier Labels* on page 9.17).

`Date`: This is the date the command response was given (except for relay response to the **EVE** command [Event], where it is the date the event occurred). You can modify the date display format (Month/Day/Year or Year/Month/Day) by changing the DATE_F relay setting.

`Time`: This is the time the command response was given (except for relay response to the **EVE** command, where it is the time the event occurred).

Command Explanations

ACC, BAC, 2AC, and CAL (Go to Access Level 1, B, 2, or C)

The **ACC**, **BAC**, **2AC**, and **CAL** commands provide entry to the multiple access levels. Different commands are available at the different access levels as shown in *Table 10.19*. Commands **ACC**, **BAC**, **2AC**, and **CAL** are explained together because they operate similarly.

Command	Description
ACC	Moves from Access Level 0 to Access Level 1
BAC	Moves from Access Level 1 to Access Level B
2AC	Moves from Access Level 1 or B to Access Level 2
CAL	Moves from Access Level 2 to Access Level C

Password Requirements

Passwords are required if the main board Access jumper is *not* in place (Access jumper = OFF). Passwords are not required if the main board Access jumper is in place (Access jumper = ON). Refer to *Figure 2.30* for Access jumper information. See ***PAS** (Change Passwords)* on page 10.64 for the list of default passwords and for more information on changing passwords.

Access Level Attempt (Password Required)

Assume the following conditions: Access jumper = OFF (not in place), Access Level = 0.

At the Access Level 0 prompt, enter the **ACC** command:

```
=ACC <Enter>
```

Because the Access jumper is not in place, the relay asks for the Access Level 1 password to be entered:

```
Password: ?
```

The relay is shipped with the default Access Level 1 password shown in the table under ***PAS*** *(Change Passwords)* on page 10.64. At the prompt above, enter the default password and press the **<Enter>** key. The relay responds:

```
FEEDER 1                            Date: 02/02/09    Time: 08:31:10.361
STATION A

Level 1
=>
```

The => prompt indicates the relay is now in Access Level 1.

If the entered password is incorrect, the relay asks for the password again (`Password: ?`). If the requested password is incorrectly entered for levels above Access Level 1, the relay asserts Relay Word bit PASNVAL for approximately one second. After three attempts, the relay displays an invalid access message, asserts Relay Word bit BADPASS for approximately one second, and prevents further access attempts for 30 seconds.

Access Level Attempt (Password Not Required)

Assume the following conditions: Access jumper = ON (in place), Access Level = 0.

At the Access Level 0 prompt, enter the **ACC** command:

```
=ACC <Enter>
```

Because the Access jumper is in place, the relay does not ask for a password; it goes directly to Access Level 1. The relay responds:

```
FEEDER 1                            Date: 02/02/09    Time: 08:31:10.361
STATION A

Level 1
=>
```

The => prompt indicates the relay is now in Access Level 1.

The relay closes the **ALARM** contact for one second after a successful Level B, Level 2, or Level C access. If access is denied, the **ALARM** contact closes for one second. The above two examples demonstrate how to go from Access Level 0 to Access Level 1. Refer to *Port Access Levels* on page 10.24 for more access level examples.

Access Level Indication

The relay asserts Relay Word bit ACCESSP for approximately one second after a successful Level B, Level 2, or Level C access. Relay Word bit ACCESS also asserts and remains asserted when an access level above Access Level 1 has been achieved on any port or on the front panel. These Relay Word bits can be used to create custom alarm schemes. See *Output Contacts* on page 7.33. Refer to *Port Access Levels* on page 10.24 for more access level examples.

BRE (Breaker Monitor Data)

Use the **BRE** command to view the breaker monitor report.

Command	Description	Access Level
BRE	Display the breaker monitor report.	1
BRE H	Display the 128 most recent breaker operations.	1
BRE W	Preload breaker/recloser contact wear monitor data.	B
BRE R	Reset breaker/recloser contact wear monitor.	B

```
=>BRE <Enter>
FEEDER 1                          Date: 08/17/11    Time: 04:45:23.181
STATION A

                                  A-phase     B-phase     C-phase
Accum Contact Wear (%)                 4           4           6

Rly Accum Pri Current (kA)          40.7        41.4        53.8
Ext Accum Pri Current (kA)           0.8         0.9         1.1

Rly Trip Count                         9
Ext Trip Count                         3

                                 Trip A  Trip B  Trip C   Cls A   Cls B   Cls C
Avg. Elect Op Time (ms)            35.4    35.2    33.8    50.5    51.2    51.3
Last Elect Op Time (ms)            75.5    75.1    75.9    51.8    51.6    52.1

Avg. Mech Op Time (ms)             43.7                    50.6
Last Mech Op Time (ms)            109.0+                   52.3

Last Op Minimum VDC (V)           124.4                   123.8

                                  Alarm  Total Count
Mechanical Operating Time         MSOAL         3
Electrical Operating Time         ESOAL         1

LAST RESET 08/17/11 04:42:29
=>
```

See ***BRE** n (Preload/Reset Breaker Wear)* and *Breaker Monitor* on page 8.1 for further details on the breaker monitor.

The **BRE** and **BRE H** command responses are also available via File Transfer Protocol (FTP) and MMS. See *File Transfer Protocol (FTP) and MMS File Transfer* on page 10.22.

BRE n (Preload/Reset Breaker Wear)

Use the **BRE W** command to preload breaker monitor data.

```
==>BRE W <Enter>
Breaker Wear Percent Preload
Relay/Internal Trip Counter (0-65353)         =  0          ? 14
Internal Current (0.0-999999 kA)      IA      = 0.0         ? 32.4
                                      IB      = 0.0         ? 18.6
                                      IC      = 0.0         ? 22.6
External Trip Counter (0-65353)               =   0         ? 2
External Current (0.0-999999 kA)      IA      = 0.0         ? 0.8
                                      IB      = 0.0         ? 0.6
                                      IC      = 0.0         ? 0.7
Percent Wear (0-100%)                 A-phase = 0           ? 22
                                      B-phase = 0           ? 28
                                      C-phase = 0           ? 25
Last Reset                            Date    = 08/17/11    ? 10/20/11
                                      Time    = 05:41:49    ? 06:18:00
```

```
Save Changes(Y/N)? Y <Enter>
FEEDER 1                          Date: 12/17/11    Time: 05:47:19.712
STATION A
                                  A-phase     B-phase     C-phase
Accum Contact Wear (%)                22          28          25
Rly Accum Pri Current (kA)          32.4        18.6        22.6
Ext Accum Pri Current (kA)           0.8         0.6         0.7
Rly Trip Count                        14
Ext Trip Count                         2
                                 Trip A  Trip B  Trip C   Cls A   Cls B   Cls C
Avg. Elect Op Time (ms)             0.0     0.0     0.0     0.0     0.0     0.0
Last Elect Op Time (ms)             0.0     0.0     0.0     0.0     0.0     0.0
Avg. Mech Op Time (ms)              0.0                     0.0
Last Mech Op Time (ms)              0.0                     0.0
Last Op Minimum VDC (V)             0.0                     0.0
                                  Alarm  Total Count
Mechanical Operating Time         MSOAL         0
Electrical Operating Time         ESOAL         0
LAST RESET 10/20/11 06:18:00
==>
```

The **BRE W** command only saves new settings after the `Save Changes (Y/N)?` message. If a data entry error is made using the **BRE W** command, the values echoed after the `Invalid format, changes not saved` message are the previous **BRE** values, unchanged by the aborted **BRE W** attempt.

```
==>BRE W <Enter>
Breaker Wear Percent Preload

Relay/Internal) Trip Counter (0-65353)        =   0          ? 14

Internal Current (0.0-999999 kA)      IA      = 0.0          ? 32.4
                                      IB      = 0.0          ? 18.6
                                      IC      = 0.0          ? 22.6

External Trip Counter (0-65353)               =   0          ? -22

Invalid format, changes not saved

FEEDER 1                          Date: 12/17/11    Time: 04:45:23.181
STATION A

                                  A-phase     B-phase     C-phase
Accum Contact Wear (%)                 0           0           0

Rly Accum Pri Current (kA)           0.0         0.0         0.0
Ext Accum Pri Current (kA)           0.0         0.0         0.0

Rly Trip Count                         0
Ext Trip Count                         0
                                 Trip A  Trip B  Trip C   Cls A   Cls B   Cls C
Avg. Elect Op Time (ms)             0.0     0.0     0.0     0.0     0.0     0.0
Last Elect Op Time (ms)             0.0     0.0     0.0     0.0     0.0     0.0

Avg. Mech Op Time (ms)              0.0                     0.0
Last Mech Op Time (ms)              0.0                     0.0

Last Op Minimum VDC (V)             0.0                     0.0

                                  Alarm  Total Count
Mechanical Operating Time         MSOAL         0
Electrical Operating Time         ESOAL         0

LAST RESET 10/20/11 06:18:00
==>
```

Use the **BRE H** command to view the most recent 128 breaker operations:

```
=>BRE H <Enter>

FEEDER 1                          Date: 08/17/11    Time: 05:38:47.063
STATION A
                                     Op Time(ms)   Current   VDC
No.    Date      Time       Bkr Op   Elec    Mech    (A)     (V)
1    08/17/11 05:38:42.741  CLS     254.2+  254.7+          118.7
2    08/17/11 05:37:01.118  TRIP     20.8    22.8     6649  115.3
3    08/17/11 05:38:08.243  CLS      29.2    29.2           117.5
.
.
.
128  08/17/11 05:35:13.117  TRIP     20.8    26.2     7379  122.0
=>
```

Use the **BRE R** command to reset the breaker monitor:

```
==>BRE R <Enter>
Reset Trip Counters and Accumulated Currents/Wear
Are you sure (Y/N)? Y <Enter>
FEEDER 1                          Date: 08/17/11    Time: 05:41:49.599
STATION A
                                  A-phase     B-phase     C-phase
Accum Contact Wear (%)                  0           0           0
Rly Accum Pri Current (kA)            0.0         0.0         0.0
Ext Accum Pri Current (kA)            0.0         0.0         0.0
Rly Trip Count                          0
Ext Trip Count                          0
                                 Trip A  Trip B  Trip C   Cls A   Cls B   Cls C
Avg. Elect Op Time (ms)             0.0     0.0     0.0     0.0     0.0     0.0
Last Elect Op Time (ms)             0.0     0.0     0.0     0.0     0.0     0.0
Avg. Mech Op Time (ms)              0.0                     0.0
Last Mech Op Time (ms)              0.0                     0.0
Last Op Minimum VDC (V)             0.0                     0.0
                                  Alarm  Total Count
Mechanical Operating Time         MSOAL         0
Electrical Operating Time         ESOAL         0
LAST RESET 08/17/11 05:41:49
==>
```

See *Breaker Monitor* on page 8.1 for further details on the breaker monitor.

CEV (Compressed Event Reports)

Use the **CEV** command to retrieve event reports in compressed format. See *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER* for details on retrieving event reports.

Command (Parameter n Is Optional)	Description	Access Level
CEV *n*	Return event report *n* in compressed format at full length with 4-samples/cycle data. Parameter *n* can correspond to the number from the **HIS** command or the unique event number from the **HIS E** command.	1

CLO (Close Breaker)

The **CLO** (**CLOSE**) command asserts Relay Word bit CC for 1/4 cycle when it is executed. Relay Word bit CC can then be programmed into the CL SELOGIC control equation to assert the CLOSE Relay Word bit, which in turn asserts an output contact (e.g., OUT102 = CLOSE) to close a circuit breaker. See *Figure 6.2*.

Command	Description	Access Level
CLO	This command asserts the close command Relay Word bit CC.	B

To issue the **CLO** command, enter the following:

```
==>CLO <Enter>
Close Breaker  (Y/N) ? Y <Enter>
Are you sure (Y/N) ? Y <Enter>
==>
```

Typing **N <Enter>** after either of the above prompts will abort the command.

The **CLO** command is supervised by the main board Breaker jumper (see *Figure 2.30*). If the Breaker jumper is not in place (Breaker jumper = OFF), the relay does not execute the **CLO** command and responds:

```
Aborted: No Breaker Jumper
```

COM (Communication Data—Available in Firmware Versions 6 and 7)

The **COM** command displays integral relay-to-relay (MIRRORED BITS) communications data. For more information on MIRRORED BITS communications, see *Appendix H: MIRRORED BITS Communications (in Firmware Versions 6 and 7).* To get a summary report, enter the command with the channel parameter (**A** or **B**).

Command	Description	Access Level
COM *n* **COM *n row1 row*2** **COM *n date1 date2***	Return a summary report of the records in the communications buffer.	1
COM *n* L	Display all available records. The most recent record is row 1 (at the top of the report) and the oldest record is at the bottom of the report.	1
COM *n* C	Clear/reset communications buffer data for MIRRORED BITS channel *n* (or both channels if *n* is not specified).	1

Parameter	Description
n	Parameter ***n*** is A for Channel A, and B for Channel B. If only one MIRRORED BITS port is enabled the channel specifier may be omitted.
row1 row2	Append *row1* to return a chronological progression of the first *row1* rows. Append *row1* and *row2* to return all rows between *row1* and *row2*, beginning with *row1* and ending with *row2*. Enter the smaller number first to display a numeric progression of rows through the report. Enter the larger number first to display a reverse numeric progression of rows.
date1 date2	Append *date1* to return all rows with this date. Append *date1* and *date2* to return all rows between *date1* and date beginning with *date1* and ending with *date2*. Enter the oldest date first to display a chronological progression through the report. Enter the newest date first to display a reverse chronological progression. Date entries are dependent on the date format setting DATE_F.

```
=>COM B <Enter>

FEEDER 1                          Date: 08/29/11    Time: 16:25:55.324
STATION A

FID=SEL-351-6-Rxxx-Vx-Z1xx1xx-Dxxxxxxxx       CID=xxxx
Summary for Mirrored Bits channel B

For 08/29/11 16:06:18.521 to 08/29/11 16:25:55.324

    Total failures      3                   Last error  Re-Sync
    Relay Disabled      1
    Data error          0                   Longest Failure     0.546 sec.
    Re-Sync             2
    Underrun            0                   Unavailability  0.000492
    Overrun             0
    Parity error        0
    Framing error       0                   Loop-back     0
    Bad Re-Sync         0

=>
```

If only one MIRRORED BITS port is enabled, the channel specifier may be omitted. Use the **L** parameter to get a summary report, followed by a listing of the COM records.

```
=>COM B L <Enter>

FEEDER 1                          Date: 08/29/11    Time: 16:25:55.488
STATION A

FID=SEL-351-6-Rxxx-Vx-Z1xx1xx-Dxxxxxxxx       CID=xxxx
Summary for Mirrored Bits channel B

For 08/29/11 16:06:18.521 to 08/29/11 16:25:55.487

    Total failures      3                   Last error  Re-Sync
    Relay Disabled      1
    Data error          0                   Longest Failure     0.546 sec.
    Re-Sync             2
    Underrun            0                   Unavailability  0.000492
    Overrun             0
    Parity error        0
    Framing error       0                   Loop-back     0
    Bad Re-Sync         0

    Failure                Recovery
#   Date     Time          Date     Time          Duration  Cause
1   08/29/11 16:09:17.4269 08/29/11 16:09:17.4603    0.033  Re-Sync
2   08/29/11 16:09:16.8186 08/29/11 16:09:17.3644    0.546  Re-Sync
3   08/29/11 16:06:18.5213 08/29/11 16:06:18.5213    0.000  Relay Disabled

=>
```

There may be as many as 255 records in the extended report.

If an error occurs before a previous error has cleared, the error counts in Summary and the communication history events in the Long report are not updated. Last error always displays the most recent error.

If communication with the other MIRRORED BITS device does not begin when the relay starts, such as when power is applied, the Last error is `Relay Disabled`.

CON (Control Remote Bit)

The **CON** command is a two-step command that allows you to control Relay Word bits RB1–RB32 (see Rows 27, 28, 68, and 69 in *Table D.1*).

Command	Description	Access Level
CON *n*[a]	First step of a two-command sequence. The SEL-351 will prompt for the second step (subcommand), shown below.	B

[a] Parameter n is a number from 1 to 32 representing RB1–RB32.

Step 1. At the Access Level B prompt, type:

a. **CON**

b. a space

c. the number of the remote bit you want to control (1–32)

Step 2. Press the **<Enter>** key on your computer.

The relay responds by repeating your command followed by a colon.

Step 3. At the colon, type the Control subcommand you want to perform (see *Table 10.20*).

The following example shows the steps necessary to pulse Remote Bit 5 (RB5):

```
==>CON 5 <Enter>
CONTROL RB5: PRB 5 <Enter>
==>
```

You must enter the same remote bit number in both steps in the command. If the bit numbers do not match, the relay responds:

```
Invalid Command
```

Table 10.20 SEL-351 Control Subcommand

Subcommand	Description
SRB *n*	Set Remote Bit *n* (“ON” position)
CRB *n*	Clear Remote Bit *n* (“OFF” position)
PRB *n*	Pulse Remote Bit *n* for 1/4 cycle (“MOMENTARY” position)

See *Remote Control Switches* on page 7.9 for more information.

COP (Copy Setting Group or DNP Map)

Copy relay and SELOGIC control equation settings from setting Group *m* to setting Group *n* with the **COP *m n*** command. Copy DNP map settings from Map *m* to Map *n* with the **COP D *m n*** command. Setting group numbers range from 1 to 6, and DNP maps range from 1 to 3. After entering settings into one setting group or map with the **SET** command, copy them to the other group(s) or map(s) with the **COP** command. Use the **SET** command to modify the copied settings. The relay disables for a few seconds and Relay Word bit SETCHG pulses for approximately one second.

Command	Description	Access Level
COPY *m n*	Copy settings from Group *m* to Group *n*.	2
COPY D *m n*	Copy DNP map *m* to map *n*.	2

Parameter	Description
m	Parameter *m* is a group number from 1 to 6 or a map number from 1 to 3.
n	Parameter *n* is a group number from 1 to 6 or a map number from 1 to 3.

For example, to copy settings from Group 1 to Group 3 issue the following command:

```
=>>COP 1 3 <Enter>

Copy 1 to 3
Are you sure (Y/N) ? Y <Enter>

Please wait...
Settings copied
=>>
```

DAT (View/Change Date)

DAT displays the date stored by the internal calendar/clock. If the Global setting DATE_F is set to MDY, the date is displayed as month/day/year. If the date format setting DATE_F is set to YMD, the date is displayed as year/month/day.

Command	Description	Access Level
DATE	Display the internal clock date.	1
DATE *date*	Set the internal clock date (DATE_F set to MDY, YMD, or DMY).	1

NOTE: After setting the date, allow at least 60 seconds before powering down the relay or the new setting may be lost.

To set the date:

Step 1. Type **DATE mm/dd/yy <Enter>** if the DATE_F setting is MDY.

Step 2. If the DATE_F is set to YMD, enter **DATE yy/mm/dd <Enter>**.

To set the date to June 1, 2009, enter:

```
=>DATE 6/1/09 <Enter>

06/01/09
=>
```

You can separate the month, day, and year parameters with spaces, commas, slashes, colons, and semicolons. The year can be entered with four digits (e.g., 2009), and the SEL-351 displays it in a two-digit format (e.g., 09).

If an IRIG-B or SNTP time synchronization signal is connected to the relay, the **DAT** command cannot alter the month or day portion of the date. If the IRIG-B or SNTP time source is IEEE C37.118 compliant and Global setting IRIGC = C37.118, or if an SNTP time source is connected, the **DAT** command cannot alter the year. See *Configuring High-Accuracy Timekeeping* on page N.28 for more details on IRIG time sources.

ETH (View Ethernet Port Information)

Use the **ETH** command when troubleshooting Ethernet connections. The report shown is for a relay with dual copper Ethernet ports and IEC 61850 Port 5 setting NETMODE = FAILOVER, E61850 = Y, and EGSE = Y. Different Ethernet configurations and different NETMODE settings result in slightly different information being displayed. See *Establishing Communications Using an Ethernet Port and Telnet or the Read-Only Web Server* on page 10.6 for a description of the settings and operating modes associated with the Ethernet port.

Command	Description	Access Level
ETH	Displays information about Ethernet port(s)	1
ETH C	Clears Ethernet port sent and received packets, bytes, and error statistics	1

```
=>ETH <Enter>

FEEDER 1                          Date: 10/25/11    Time: 05:40:00.603
STATION A

NETMODE: FAILOVER

PRIMARY PORT:  5A
ACTIVE PORT:   5A

             LINK   SPEED  DUPLEX MEDIA
PORT 5A      Up     100M   Full   TX
PORT 5B      Down   --     --     TX

IP Port:

MAC: 00-30-A7-01-09-2E
IP ADDRESS: 192.168.1.2
SUBNET MASK: 255.255.255.0
DEFAULT GATEWAY: 192.168.1.1

      PACKETS          BYTES          ERRORS
    SENT  RCVD      SENT    RCVD    SENT  RCVD
       2     2       128     172       0     0

GOOSE Port:

MAC: 00-30-A7-01-09-2F

      PACKETS          BYTES          ERRORS
    SENT  RCVD      SENT    RCVD    SENT  RCVD
      34     2      6932     184       0     0

=>
```

EVE (Event Reports)

Use the **EVE** command to view event reports. See *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER* for further details on retrieving event reports, including additional parameters.

Command (Parameter n Is Optional)	Description	Access Level
EVE [*n*]	Return event report *n* (including settings and summary) at full length with 4-samples/cycle data. Parameter *n* can correspond to the number from the **HIS** command or the unique event number from the **HIS E** command.	1

EXI

Use the **EXI** command to exit a Telnet session on any of the Ethernet ports.

Command	Description	Access Level
EXI	Exit active Telnet session	0

FIL

The **FILE** command provides an efficient means of transferring files between the relay and a PC. Software applications, such as QuickSet, use the **FILE** commands to send and receive settings files to and from the relay.

The **FILE** command uses Ymodem transfer protocol to transfer setting files and to retrieve event files (see *Retrieving COMTRADE Event Files* on page 12.15). Reports, event, and diagnostic files are available to read via Ymodem as a batch. See the *Ymodem Wildcard Usage* on page 10.33 for more information on using wildcards.

Command	Description	Access Level
FILE DIR	Return a list of files.	1
FILE READ *filename*	Transfer settings file *filename* from the relay to the PC.	1
FILE WRITE *filename*	Transfer settings file *filename* from the PC to the relay.	2
FILE SHOW *filename*	Displays contents of the file *filename*.	1

Below is a sample of the **FILE DIR** command response.

```
=>FILE DIR <Enter>

CFG.TXT                          R    15/01/29   15:24:55
ERR.TXT                          R    15/01/29   15:24:55
SET_ALL.TXT                      R    15/01/29   15:24:55
SET_1.TXT                        RW   15/01/29   15:23:45
SET_2.TXT                        RW   15/01/29   15:23:45
SET_3.TXT                        RW   15/01/29   15:23:45
SET_4.TXT                        RW   15/01/29   15:23:45
SET_5.TXT                        RW   15/01/29   15:23:45
SET_6.TXT                        RW   15/01/29   15:23:45
SET_D1.TXT                       RW   15/01/29   15:23:46
SET_D2.TXT                       RW   15/01/29   15:23:46
SET_D3.TXT                       RW   15/01/29   15:23:46
SET_G.TXT                        RW   15/01/29   15:23:45
SET_L1.TXT                       RW   15/01/29   15:23:45
SET_L2.TXT                       RW   15/01/29   15:23:45
SET_L3.TXT                       RW   15/01/29   15:23:45
SET_L4.TXT                       RW   15/01/29   15:23:46
SET_L5.TXT                       RW   15/01/29   15:23:46
SET_L6.TXT                       RW   15/01/29   15:23:46
SET_M.TXT                        RW   15/01/29   15:23:46
SET_P1.TXT                       RW   15/01/29   15:23:46
SET_P2.TXT                       RW   15/01/29   15:23:46
SET_P3.TXT                       RW   15/01/29   15:23:46
SET_PF.TXT                       RW   15/01/29   15:23:46
SET_P5.TXT                       RW   15/01/29   15:23:46
SET_R.TXT                        RW   15/01/29   15:23:46
SET_T.TXT                        RW   15/01/29   15:23:45
SWCFG.ZIP                        RW   15/01/29   15:24:51
STATUS.TXT                       R    15/01/29   15:24:55
VEC_D.TXT                        R    15/01/29   15:24:55
VEC_E.TXT                        R    15/01/29   15:24:55
BRE.TXT                          R    15/01/29   15:24:55
BRE_H.TXT                        R    15/01/29   15:24:55
CHISTORY.TXT                     R    15/01/29   15:24:55
HISTORY.TXT                      R    15/01/29   15:24:55
LDP.TXT                          R    15/01/29   15:24:55
MET.TXT                          R    15/01/29   15:24:55
MET_D.TXT                        R    15/01/29   15:24:55
MET_E.TXT                        R    15/01/29   15:24:55
MET_H.TXT                        R    15/01/29   15:24:55
MET_M.TXT                        R    15/01/29   15:24:55
MET_PM.TXT                       R    15/01/29   15:24:55
SER.TXT                          R    15/01/29   15:24:55
SSI.TXT                          R    15/01/29   15:24:55
TAR.TXT                          R    15/01/29   15:24:55
```

The file data and time are updated when settings are saved. Dates are displayed in yy/mm/dd format and are not affected by the Global setting DATE_F. Times are UTC.

SET_ALL.TXT File (Read-Only)

The SET_ALL.TXT file contains all of the settings for all of the settings classes in the relay.

CFG.TXT File (Read-Only)

The CFG.TXT file contains general configuration information about the relay and each settings class. External support software retrieves the CFG.TXT file to interact automatically with the relay. The relay calculates a checksum, or hash code, for each settings class and lists the codes in the CFG.TXT file (see *Figure 10.8*). Improve system security by periodically reading the CFG.TXT file and comparing the current hash codes to those in a secured copy of the file. See *Appendix Q: Cybersecurity Features* for more information.

```
[INFO]
RELAYTYPE=0351
FID=SEL-351-7-R5xx-V0-Zxxxxxx-Dxxxxxxx
BFID=SLBT-3CF1-Rxxx-V0-Zxxxxxx-Dxxxxxxx
PARTNO=035173D3J542X2
[CLASSES]
"1","Group 1","SET_1.TXT","30C0490A"
"2","Group 2","SET_2.TXT","30C0490A"
"3","Group 3","SET_3.TXT","30C0490A"
"4","Group 4","SET_4.TXT","30C0490A"
"5","Group 5","SET_5.TXT","30C0490A"
"6","Group 6","SET_6.TXT","30C0490A"
"D1","DNP Map 1","SET_D1.TXT","7DC463B8"
"D2","DNP Map 2","SET_D2.TXT","7DC463B8"
"D3","DNP Map 3","SET_D3.TXT","7DC463B8"
"G","Global","SET_G.TXT","C2B2FE98"
"L1","Logic 1","SET_L1.TXT","00340302"
"L2","Logic 2","SET_L2.TXT","00340302"
"L3","Logic 3","SET_L3.TXT","00340302"
"L4","Logic 4","SET_L4.TXT","00340302"
"L5","Logic 5","SET_L5.TXT","00340302"
"L6","Logic 6","SET_L6.TXT","00340302"
"M","Modbus","SET_M.TXT","E9CE3427"
"P1","Port 1","SET_P1.TXT","939DC3DD"
"P2","Port 2","SET_P2.TXT","55D70365"
"P3","Port 3","SET_P3.TXT","C47944EC"
"PF","Port F","SET_PF.TXT","8A4F4858"
"P5","Port 5","SET_P5.TXT","FBA33731"
"R","Report","SET_R.TXT","1C7ED04D"
"T","Text","SET_T.TXT","5F96E9BE"
[STORAGE]
"SWCFG.ZIP"
```

Figure 10.8 CFG.TXT File

ERR.TXT File (Read-Only)

The ERR.TXT file contents are based on the most recent SET_cn.TXT file you wrote to the relay. If there were no errors, the file is empty. If errors occurred, the relay logs these errors in the ERR.TXT file.

SWCFG.ZIP

File SWCFG.ZIP is a fixed name, general purpose file that can be as long as 768 KiB (768 kibibytes = 786432 bytes). You can store any type of data or information file you choose, even a file that is not zipped, as long as the file is named SWCFG.ZIP. QuickSet uses the SWCFG.ZIP file to store design template files created by QuickSet. The relay cannot read or modify the SWCFG.ZIP file and serves only as a storage location.

GOO

Use the **GOOSE** command to display transmit and receive GOOSE messaging and statistics information, which can be used for troubleshooting. The **GOOSE** command variants and options are shown below.

Command Variant	Description	Access Level
GOO	Display GOOSE information.	1
GOO *k*	Display GOOSE information *k* times.	1
GOO S	Display a list of GOOSE subscriptions with their ID.	1
GOO S *n*	Display GOOSE statistics for subscription ID *n*.	1
GOO S ALL	Display GOOSE statistics for all subscriptions.	1
GOO S *n* L	Display GOOSE statistics for subscription ID *n* including error history.	1

Command Variant	Description	Access Level
GOO S ALL L	Display GOOSE statistics for all subscriptions including error history.	1
GOO S *n* C	Clear GOOSE statistics for subscription ID *n*.	1
GOO S ALL C	Clear GOOSE statistics for all subscriptions.	1

The information displayed for each GOOSE IED is described in the following table.

Information Field	Description
Transmit GOOSE Control Reference	This field represents the GOOSE control reference information that includes the IED name, ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class), and GSEControl name (GSE Control Block Name) (e.g., SEL_351_1CFG/LLN0GOGooseDSet13).
Receive GOOSE Control Reference	This field represents the goCbRef (GOOSE Control Block Reference) information that includes the iedName (IED name), ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class), and cbName (GSE Control Block Name) (e.g., SEL_351_1CFG/LLN0GOGooseDSet13).
MultiCastAddr (Multicast Address)	This hexadecimal field represents the GOOSE multicast address.
Ptag	This three-bit decimal field represents the priority tag value, where spaces are used if the priority tag is unknown.
Vlan	This 12-bit decimal field represents the virtual LAN (Local Area Network) value, where spaces are used if the virtual LAN is unknown.
StNum (State Number)	This hexadecimal field represents the state number that increments with each state change.
SqNum (Sequence Number)	This hexadecimal field represents the sequence number that increments with each retransmitted GOOSE message sent.
TTL (Time to Live)	This field contains the time (in ms) before the next message is expected.
Code	When appropriate, this text field contains warning or error condition text that is abbreviated as follows: **Code Abbreviation** — **Explanation** OUT OF SEQUENC — Out of sequence error CONF REV MISMA — Configuration Revision mismatch NEED COMMISSIO — Needs Commissioning TEST MODE — Test Mode MSG CORRUPTED — Message Corrupted TTL EXPIRED — Time to live expired HOST DISABLED — Optional code for when the host is disabled or becomes unresponsive after the **GOOSE** command has been issued
Transmit Data Set Reference	This field represents the DataSetReference (Data Set Reference) that includes the IED name, LN0 lnClass (Logical Node Class), and GSEControl datSet (Data Set Name) (e.g., SEL_351_1CFG/LLN0$DSet13).
Receive Data Set Reference	This field represents the datSetRef (Data Set Reference) that includes the iedName (IED name), ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class), and datSet (Data Set Name) (e.g., SEL_351_1CFG/LLN0$DSet13).
Ctrl Ref/ ControlBlockReference	This is the GOOSE control block reference. It is a concatenation of the logical device name, LLN0 (logical node containing the control block), GO (functional constraint), and the GSEControl name. (e.g. SEL_351_1CFG/LLN0GOGooseDSet13)
AppID	This is the application identifier as a decimal number.
From	This is the date and time the current statistics collection started.
To	This is the date and time the GOOSE statistics command was executed.
Accumulated downtime duration	This represents the total amount of time a subscription was in an error state. The duration is displayed in the format: hhhh:mm:ss.zzz.

Information Field	**Description**
Maximum downtime duration	This represents the maximum amount of time a subscription was continuously in error state. The duration is displayed in the format: hhhh:mm:ss.zzz.
Date & time maximum downtime began	This is the date and time the recorded maximum downtime started.
Number of messages received out-of-sequence (OOS)	This represents the total number of messages received with either the state number and/or sequence number out-of-sequence. This includes cases where more than one instance of a message is received within a single relay processing interval. In this case, the most recent message is processed and the others are discarded.
Number of time-to-live (TTL) violations detected	This represents the total number of times a message was not received within the expected period/interval.
Number of messages incorrectly encoded or corrupted	This represents the total number of messages that were identified with this subscription but were either incorrectly encoded or encoded with a wrong data set.
Number of messages lost due to receive overflow	This represents the total number of messages that were not processed because memory resources were exhausted. This includes cases where more than one instance of a message is received within a single relay processing interval. In this case, the most recent message is processed and the others are discarded.
Calculated max. sequential messages lost due to OOS	This represents the maximum estimated number of messages that were missed after receiving a message with a higher state or sequence number than expected.
Calculated number of messages lost due to OOS	This represents the total of all estimated number of messages lost due to state or sequence number skip in received messages.

An example response to the **GOOSE** commands is shown in *Figure 10.9*.

```
#>GOOSE <Enter>

GOOSE Transmit Status

 MultiCastAddr   Ptag:Vlan AppID  StNum      SqNum      TTL    Code
-----------------------------------------------------------------------------
SEL_351_1CFG/LLN0$GO$GooseDSet13
 01-0C-CD-01-00-12 4:1     4114   1          11175      638
 Data Set: SEL_351_1CFG/LLN0$DSet13

GOOSE Receive Status

 MultiCastAddr   Ptag:Vlan AppID  StNum      SqNum      TTL    Code
-----------------------------------------------------------------------------
SEL_487E_1CFG/LLN0$GO$GOOSEMessage1
 01-0C-CD-01-00-10 4:1     4112   2          18248      2000
 Data Set: SEL_487E_1CFG/LLN0$DSet13

SEL_487E_1CFG/LLN0$GO$GOOSEMessage2
 01-0C-CD-01-00-05 4:3     5      3          18249      2000
 Data Set: SEL_487E_1CFG/LLN0$DSet03

SEL_487E_1CFG/LLN0$GO$GOOSEMessage3
 01-0C-CD-01-00-06 4:3     6      2          18250      2000
 Data Set: SEL_487E_1CFG/LLN0$DSet04

SEL_487E_1CFG/LLN0$GO$GOOSEMessage4
 01-0C-CD-01-00-07 4:3     7      2          18250      2000
 Data Set: SEL_487E_1CFG/LLN0$DSet10


=>GOOSE S 1 L <Enter>

 SubsID 1
-----------------------------------------------------------------------------
 Ctrl Ref: SEL_487E_1CFG/LLN0$GO$GOOSEMessage1
 AppID   : 4112
 From    : 03/14/2012 12:21:04.694  To: 03/14/2012 15:28:08.734
```

```
Accumulated downtime duration                      : 0000:00:00.029
 Maximum downtime duration                         : 0000:00:00.029
 Date & time maximum downtime began                : 03/14/2012 12:21:04.719
 Number of messages received out-of-sequence(OOS)   : 0
 Number of time-to-live(TTL) violations detected    : 1
 Number of messages incorrectly encoded or corrupted: 0
 Number of messages lost due to receive overflow    : 0
 Calculated max. sequential messages lost due to OOS: 0
 Calculated number of messages lost due to OOS      : 0

 #    Date        Time          Duration        Failure
 1    03/14/2012  12:21:04.719  0000:00:00.029  TTL EXPIRED

=>
```

Figure 10.9 GOOSE Command Response

GRO (Display Active Setting Group Number)

Use the **GRO** command to display the active settings group number. The **GRO *n*** command changes the active setting group to setting Group *n*.

Command	Description	Access Level
GRO	Display the presently active group	1
GRO *n*	Change the active group to Group *n*.	B

See *Multiple Setting Groups* on page 7.17 for further details on settings groups.

To change to settings Group 2, enter the following:

```
==>GRO 2 <Enter>

Change to Group 2
Are you sure (Y/N) ? Y <Enter>
Active Group = 2
==>
```

The relay switches to Group 2 and pulses Relay Word bit GRPSW for approximately one second. If the serial port AUTO setting = Y, the relay sends the group switch report:

```
==>

FEEDER 1                         Date: 02/02/09    Time: 09:40:34.611
STATION A

Active Group = 2
==>
```

If any of the SELOGIC control equations settings SS1 through SS6 are asserted to logical 1, the active setting group may not be changed with the **GRO** command—SELOGIC control equations settings SS1 through SS6 have priority over the **GRO** command in active setting group control.

For example, assume setting Group 1 is the active setting group and the SS1 setting is asserted to logical 1 (e.g., SS1 = IN101 and optoisolated input IN101 is asserted). An attempt to change to setting Group 2 with the **GRO 2** command will not be accepted:

```
==>GRO 2 <Enter>

No group change (see manual)
Active Group = 1
==>
```

For more information on setting group selection, see *Multiple Setting Groups* on page 7.17.

HIS (Event Summaries/History)

HIS *n* displays event summaries or allows you to clear event summaries (and corresponding event reports) from nonvolatile memory.

Command	Description	Access Level
HIS	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list.	1
HIS *n*	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list beginning at event *n*.	1
HIS E	Same as HIS. Events are identified with a unique number in the range 10000 to 65535	1
HIS C	Clear/reset the event history and all corresponding event reports from nonvolatile memory.	1

If no parameters are specified with the **HIS** command:

```
=>HIS <Enter>
```

the relay displays the most recent event summaries in reverse chronological order.

If ***n*** is a number:

```
=>HIS n <Enter>
```

the relay displays the ***n*** most recent event summaries. The maximum number of available event summaries is a function of the LER (length of event report) setting.

HIS E identifies each summary with a unique number in the range 10000 to 65535. Use the unique number with the **EVE** command to display the same event.

If ***n*** is "C" or "c", the relay clears the event summaries and all corresponding event reports from nonvolatile memory.

The event histories include the date and time the event was triggered, the type of event, the fault location, the maximum phase current in the event, the power system frequency, the number of the active setting group, the reclose shot count, and the front-panel targets.

To display the relay event history, enter the following command:

```
=>HIS <Enter>

FEEDER 1                          Date: 02/01/09    Time: 08:40:16.740
STATION A

#     DATE      TIME     EVENT   LOCAT  CURR  FREQ GRP SHOT TARGETS

1  02/01/09 08:33:00.365 TRIG  $$$$$$$     1 60.00  3    2
2  01/31/09 20:32:58.361 ER    $$$$$$$   231 60.00  2    2
3  01/29/09 07:30:11.055 AG T     9.65  2279 60.00  3    2   INST 50

=>
```

The fault locator has influence over information in the EVENT and LOCAT columns. If the fault locator is enabled (enable setting EFLOC = Y), the fault locator will attempt to run if the event report is generated by a trip (assertion of TRIP Relay Word bit) or other programmable event report trigger condition (SELOGIC control equation setting ER).

If the fault locator runs successfully, the location is listed in the LOCAT column, and the event type is listed in the EVENT column:

AG	for A-phase to ground faults
BG	for B-phase to ground faults
CG	for C-phase to ground faults
AB	for A–B phase-to-phase faults
BC	for B–C phase-to-phase faults
CA	for C–A phase-to-phase faults
ABG	for A–B phase-to-phase to ground faults
BCG	for B–C phase-to-phase to ground faults
CAG	for C–A phase-to-phase to ground faults
ABC	for three-phase faults
A	for A-phase faults (Petersen Coil or Ungrounded/High-Impedance Grounded Systems only)
B	for B-phase faults (Petersen Coil or Ungrounded/High-Impedance Grounded Systems only)
C	for C-phase faults (Petersen Coil or Ungrounded/High-Impedance Grounded Systems only)

If a trip occurs in the same event report, a T is appended to the event type (e.g., AG T).

If the fault locator does not run successfully, $$$$$$$ is listed in the LOCAT column. If the fault locator is disabled (enable setting EFLOC = N), the LOCAT column is left blank. If the phase involvement for the fault cannot be determined, the event type listed in the EVENT column is one of the following:

TRIP	event report generated by assertion of Relay Word bit TRIP
ER	event report generated by assertion of SELOGIC control equation event report trigger condition setting ER
PULSE	event report generated by execution of the **PUL** (Pulse) command
TRIG	event report generated by execution of the **TRI** (Trigger) command

The CURR displays the largest phase current from event summary currents. Event summary currents are determined based on Global setting FLTDISP as discussed in *Standard Event Report Summary* on page 12.6.

The TARGETS column displays the front-panel target LED status during the event.

For example, INST 50 under the TARGETS column is interpreted as follows:

INST → **INST** LED illuminated
50 → **50** LED illuminated

For more information on front-panel target LEDs, see *Section 5: Trip and Target Logic*. For more information on event reports, see *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*.

LDP (Load Profile Report—Available in Firmware Versions 6 and 7)

Use the **LDP** command to view the Load Profile report. For more information on Load Profile reports, see *Section 8: Breaker Monitor, Metering, and Load Profile Functions*.

Command	Description	Access Level
LDP	Use the **LDP** command to display a numeric progression of all load profile report rows.	1
LDP ***row1 row2*** **LDP** ***date1 date2***	Use the **LDP** command with parameters to display a chronological or reverse chronological subset of the load profile rows.	1
LDP D	Display the number of days of Load Profile memory capacity remaining before data overwrite occurs.	1
LDP C	Clear the Load Profile data from memory.	1

LOO (Loop Back—Available in Firmware Versions 6 and 7)

The **LOO** (LOOP) command is used for testing the MIRRORED BITS communications channel. For more information on MIRRORED BITS, see *Appendix H: MIRRORED BITS Communications (in Firmware Versions 6 and 7)*.

Command	Description	Access Level
LOOP ***c t***	Begin loopback of a single enabled MIRRORED BITS communications channel (either Channel A or Channel B); ignore input data and force receive bits (RMB) to defaults.	2
LOOP ***c t*** **DATA**	Begin loopback of a single MIRRORED BITS communications channel (either Channel A or Channel B): pass input data to receive data as in nonloopback mode.	2
LOOP ***c*** **R**	Cease loopback on MIRRORED BITS communications channel c. Reset the channel to normal use.	2

Parameter	Description
c	Append this parameter (*c* = A or B) to specify which channel to use if more than one MIRRORED BITS communications channel is enabled
t	Append this parameter to specify the timeout period in *t* minutes; *t* range is 1–5000 minutes. Defaults to 5 minutes if unspecified.

With the transmitter of the communications channel physically looped back to the receiver, the MIRRORED BITS addressing will be wrong and ROK will deassert. The **LOO** command tells the MIRRORED BITS software to temporarily expect to see its own data looped back as its input. In this mode, LBOK will assert if error-free data are received. The **LOO** command with just the channel specifier enables looped back mode on that channel for five minutes, while the inputs are forced to the default values.

MAC

The **MAC** command returns the Media Access Control (MAC) address of the Ethernet port.

Command	Description	Access Level
MAC	Display Ethernet port MAC address	1

```
=>MAC <Enter>

Port 5 MAC Address: 00-30-A7-00-00-00
```

MET (Metering Data)

NOTE: If the serial port AUTO setting is DTA, the SEL-351 response for **MET**, **MET X**, and **MET D** will be formatted differently on that serial port than shown below. Setting AUTO = DTA is not available on Ethernet or USB ports.

The **MET** commands provide access to the relay metering data. Metered quantities include phase voltages and currents, sequence component voltages and currents, power, frequency, substation battery voltage, energy, demand, harmonics, and maximum/minimum logging of selected quantities. To make the extensive amount of meter information manageable, the relay divides the displayed information into six reports: Instantaneous, Demand, Energy, Maximum/Minimum, Synchrophasors, and Harmonics.

See *Section 8: Breaker Monitor, Metering, and Load Profile Functions* for more information on metering.

Single-Phase Voltage Connection and Phantom Voltage Metering

The SEL-351 can be connected to a single-phase voltage source. With Global setting PTCONN = SINGLE, Global setting PHANTV = VA, VB, VC, VAB, VBC, or VCA instructs the relay to create a set of "phantom voltages" from the connected single-phase voltage (for metering purposes only). These derived voltages (visible in the **MET** and **MET X** command) are then used in power, demand, and energy calculations (**MET**, **MET X**, **MET D**, and **MET E** commands).

When the phantom voltage feature is active, the relay forces the voltage symmetric components (V_1, V_2, and $3V_0$) values to 0.00 in metering reports.

When Global setting PTCONN = SINGLE and the phantom voltage feature is not active (PHANTV = OFF), the relay forces the voltage symmetric components (V_1, V_2, and $3V_0$) and the power and energy quantities to 0.00 in metering reports.

The synchrophasor metering (**MET PM**) and harmonics metering reports are unaffected by the PHANTV setting.

See *Wye-, Delta-, and Single-Phase Voltage Connections for Metering* on page 8.22 and *Phantom Metering for Single-Phase Voltage Connections* on page 8.24 for full details.

MET k—Instantaneous Metering

Use the **MET *k*** command to display fundamental metering data.

Command	Description	Access Level
MET *k*	Display instantaneous metering data *k* times.	1

The **MET *k*** command displays instantaneous magnitudes (and angles if applicable) of the following quantities:

Type	Symbol	Description/Units
Currents	$I_{A,B,C,N}$	Input currents (A primary)
	I_G	Residual ground current (A primary; $I_G = 3I_0 = I_A + I_B + I_C$)
Voltages	$V_{A,B,C,S}$	Wye-connected[a] voltage inputs (kV primary)
	$V_{AB,BC,CA,S}$	Delta-connected voltage inputs (kV primary)
Power	$MW_{A,B,C}$	Single-phase megawatts (wye-connected[a] voltage inputs only)
	MW_{3P}	Three-phase megawatts
	$MVAR_{A,B,C}$	Single-phase megavars (wye-connected[a] voltage inputs only)
	$MVAR_{3P}$	Three-phase megavars
Power Factor	$PF_{A,B,C}$	Single-phase power factor; leading or lagging (wye-connected[a] voltage inputs only)
	PF_{3P}	Three-phase power factor; leading or lagging
Sequence	I_1, $3I_2$, $3I_0$	Positive-, negative-, and zero-sequence currents (A primary)
	V_1, V_2	Positive- and negative-sequence voltages (kV primary)
	$3V_0$	Zero-sequence voltage (kV primary, wye-connected voltage inputs only)
Frequency	FREQ	Instantaneous power system frequency (measured in Hz, from voltage channel **VA-N**, **VB-N**, or **VC-N**)[b]
Station DC	VDC	Voltage (V) at **POWER** terminals (input into station battery monitor)

[a] Or single-phase connected when the phantom voltage feature is being used.

[b] When PTCONN = SINGLE, the frequency measurement system ignores any signals on VB-N or VC-N.

The angles are referenced to voltage V_A (wye-connected) or V_{AB} (delta-connected) if the reference voltage is greater than 13 V secondary; otherwise, the angles are referenced to A-phase current. The angles range from –179.99 to 180.00 degrees.

To view instantaneous metering values, enter the command:

```
=>MET k <Enter>
```

NOTE: See *Small Signal Cutoff for Metering* on page 8.41 for metering behavior with small signals.

where *k* is an optional parameter to specify the number of times (1–32767) to repeat the meter display. If *k* is not specified, the meter report is displayed once. The output from an SEL-351 with wye-connected voltage inputs is shown:

```
=>MET <Enter>
FEEDER 1                          Date: 02/02/09    Time: 15:00:52.615
STATION A
                   A         B         C         N         G
I MAG (A)        195.146   192.614   198.090     0.302     4.880
I ANG (DEG)       -8.03   -128.02    111.89     52.98     81.22
                   A         B         C         S
V MAG (KV)        11.691    11.686    11.669    11.695
V ANG (DEG)        0.00   -119.79    120.15      0.05
                   A         B         C         3P
MW                 2.259     2.228     2.288     6.774
MVAR               0.319     0.322     0.332     0.973
PF                 0.990     0.990     0.990     0.990
                   LAG       LAG       LAG       LAG
                   I1        3I2       3I0       V1        V2        3V0
MAG              195.283     4.630     4.880    11.682     0.007     0.056
ANG   (DEG)       -8.06   -103.93     81.22      0.12    -80.25    -65.83
FREQ (Hz)        60.00               VDC (V)      129.5
=>
```

MET X k—Extended Instantaneous Metering

The **MET X *k*** command displays the same data as the **MET *k*** command with the addition of calculated phase-to-phase voltage quantities V_{AB}, V_{BC}, V_{CA}, and the Vbase quantity used by the Voltage Sag/Swell/Interruption Recorder.

Command	Description	Access Level
MET X *k*	Display instantaneous metering data and calculated phase-to-phase voltage quantities *k* times.	1

Type	Symbol	Description/Units
Currents	$I_{A,B,C,N}$	Input currents (A primary)
	I_G	Residual ground current (A primary; $I_G = 3I_0 = I_A + I_B + I_C$)
Voltages	$V_{A,B,C,S}$	Phase-to-neutral voltage inputs (kV primary) (wye-connected[a])
	$V_{AB,BC,CA,S}$	Phase-to-phase voltages (kV primary) (delta-connected)
	$V_{AB,BC,CA}$	Calculated phase-to-phase voltages (kV primary) (wye-connected[a])
	Vbase	Demand average value based on V1, subject to the operating logic of the SSI Elements (see *Section 3: Overcurrent, Harmonic Blocking, Voltage, Synchronism Check, Frequency, and Power Elements*) when setting ESSI=Y in the active setting group. Vbase only registers a value after valid three-phase voltage signals have been present since the last Vbase initializing. The Vbase quantity is used in the SEL-351-7 relay model. Vbase is always shown as 0.00 kV in SEL-351-5, -6 relay models.
Power	$MW_{A,B,C}$	Single-phase megawatts (wye-connected[a] voltage inputs only)
	MW_{3P}	Three-phase megawatts
	$MVAR_{A,B,C}$	Single-phase megavars (wye-connected[a] voltage inputs only)
	$MVAR_{3P}$	Three-phase megavars
Power Factor	$PF_{A,B,C}$	Single-phase power factor; leading or lagging (wye-connected[a] voltage inputs only)
	PF_{3P}	Three-phase power factor; leading or lagging

Type	Symbol	Description/Units
Sequence	I_1, $3I_2$, $3I_0$	Positive-, negative-, and zero-sequence currents (A primary)
	V_1, V_2	Positive- and negative-sequence voltages (kV primary)
	$3V_0$	Zero-sequence voltage (kV primary) (wye-connected voltage inputs only)
Frequency	FREQ (Hz)	Instantaneous power system frequency (measured in Hz, from voltage channel **VA-N**, **VB-N**, or **VC-N**)[b]
Station DC	VDC	Voltage (V) at **POWER** terminals (input into station battery monitor)

[a] Or single-phase connected when the phantom voltage feature is being used.

[b] When PTCONN = SINGLE, the frequency measurement system ignores any signals on VB-N or VC-N.

The angles are referenced to voltage V_A (wye-connected or single-phase connected) or V_{AB} (delta-connected) if the reference voltage is greater than 13 V secondary; otherwise, the angles are referenced to A-phase current. The angles range from –179.99 to 180.00 degrees.

To view instantaneous metering values, enter the command:

```
=>MET X k <Enter>
```

NOTE: See *Small Signal Cutoff for Metering* on page 8.41 for metering behavior with small signals.

where *k* is an optional parameter to specify the number of times (1–32767) to repeat the meter display. If *k* is not specified, the meter report is displayed once. The output from an SEL-351 with wye-connected voltage inputs is shown:

```
=>MET X <Enter>

FEEDER 12                         Date: 02/01/09    Time: 11:31:22.626
SUB B
                 A         B         C         N         G
I MAG (A)       30.302    36.558    29.254     7.454     7.526
I ANG (DEG)     -2.02   -121.88    119.60   -115.20   -117.52

                 A         B         C         S
V MAG (KV)      14.761    14.636    14.880    15.235
V ANG (DEG)      0.00   -119.95    120.94     29.93

                 AB        BC        CA        Vbase
V MAG (KV)      25.452    25.448    25.790    14.759
V ANG (DEG)     29.89    -89.23    150.34

                 A         B         C         3P
MW               0.447     0.535     0.435     1.417
MVAR             0.016     0.018     0.010     0.044
PF               0.999     0.999     1.000     1.000
                 LAG       LAG       LAG       LAG

                 I1       3I2       3I0        V1        V2       3V0
MAG             32.036     6.196     7.526    14.759     0.131     0.212
ANG   (DEG)     -1.47    106.38   -117.52      0.33    -59.08    157.40

FREQ (Hz)      60.00               VDC (V)      125.6

=>
```

MET D—Demand Metering

Use the following command to view or reset demand and peak demand metering values.

Command	Description	Access Level
MET D	Display demand metering data.	1

The **MET D** command displays the demand and peak demand values of the following quantities:

Type	Symbol	Description/Units
Currents	$I_{A,B,C,N}$	Input currents (A primary)
	I_G	Residual ground current (A primary; $I_G = 3I_0 = I_A + I_B + I_C$)
	$3I_2$	Negative-sequence current (A primary)
Power	$MW_{A,B,C}$	Single-phase megawatts (wye-connected[a] voltage inputs only)
	MW_{3P}	Three-phase megawatts
	$MVAR_{A,B,C}$	Single-phase megavars (wye-connected[a] voltage inputs only)
	$MVAR_{3P}$	Three-phase megavars
Reset Time	Demand, Peak	Last time the demands and peak demands were reset

[a] Or single-phase connected when the phantom voltage feature is being used.

To view demand metering values, enter the command:

```
=>MET D <Enter>
```

The output from an SEL-351 with wye-connected voltage inputs is shown:

NOTE: See *Small Signal Cutoff for Metering* on page 8.41 for metering behavior with small signals.

```
=>MET D <Enter>

FEEDER 1                        Date: 02/01/09    Time: 15:08:05.615
STATION A
            IA        IB        IC        IN        IG        3I2
DEMAND     188.6     186.6     191.8       0.2       4.5       4.7
PEAK       188.6     186.6     191.8       0.3       4.5       4.7
              MWA       MWB       MWC      MW3P     MVARA     MVARB     MVARC    MVAR3P
DEMAND IN      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
PEAK IN        0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
DEMAND OUT     2.2       2.2       2.2       6.6       0.3       0.3       0.3       0.9
PEAK OUT       3.1       3.1       3.1       9.3       0.4       0.4       0.4       1.2
LAST DEMAND RESET 01/27/09 15:31:51.238   LAST PEAK RESET 01/27/09 15:31:56.239

=>
```

Reset the accumulated demand values using the **MET RD** command. Reset the peak demand values using the **MET RP** command. For more information on demand metering, see *Demand Metering* on page 8.28.

MET E—Energy Metering

The **MET E** command displays the following quantities:

Command	Description	Access Level
MET E	Display energy metering data.	1
MET RE	Reset energy metering data.	1

Type	Symbol	Description/Units
Energy	$MWh_{A,B,C}$	Single-phase megawatt hours (in and out; wye-connected[a] voltage inputs only)
	MWh_{3P}	Three-phase megawatt hours (in and out)
	$MVARh_{A,B,C}$	Single-phase megavar hours (in and out; wye-connected[a] voltage inputs only)
	$MVARh_{3P}$	Three-phase megavar hours (in and out)
Reset Time		Last time the energy meter was reset

[a] Or single-phase connected when the phantom voltage feature is being used.

To view energy metering values, enter the command:

```
=>MET E <Enter>
```

The output from an SEL-351 with wye-connected voltage inputs is shown:

```
=>MET E <Enter>

FEEDER 1                          Date: 02/01/09    Time: 15:11:24.056
STATION A
        MWhA     MWhB     MWhC     MWh3P   MVARhA   MVARhB   MVARhC   MVARh3P
IN      0.00     0.00     0.00     0.00     0.00     0.00     0.00      0.00
OUT    36.05    36.62    36.71   109.28     5.13     5.26     5.39     15.68
LAST RESET 01/31/09 23:31:28.864

=>
```

NOTE: See *Small Signal Cutoff for Metering* on page 8.41 for metering behavior with small signals.

Reset the energy values using the **MET RE** command. For more information on energy metering, see *Energy Metering* on page 8.37.

Accumulated energy metering values function like those in an electromechanical energy meter. When the energy meter reaches 99999 MWh or 99999 MVARh, it starts over at zero.

MET H—Harmonic Metering

The **MET H** command displays harmonic, rms, and harmonic distortion metering values.

Command	Description	Access Level
MET H	Display harmonic, rms, and harmonic distortion.	1
MET H *k*	Display the harmonic metering data *k* times.	1

Type	Symbol	Description/Units
Total Harmonic Distortion	THD (%)	Total Harmonic Distortion of phase and neutral currents, phase voltage, and VS channel (percent of fundamental)
Root Mean Square Value	RMS	RMS value of phase and neutral currents, phase voltages, and VS channel (A primary and kV primary)
Fundamental	Fund.	Fundamental value of phase and neutral currents, phase voltages, and VS channel (A primary and kV primary)
Harmonic	2 (%), 3 (%), ... 16 (%)	Harmonic content of phase and neutral currents, phase voltages, and VS channel for 2nd through 16th harmonics (percent of fundamental)

To view the harmonics metering values, enter the command:

```
=>MET H <Enter>
```

```
=>MET H <Enter>

FEEDER 1                         Date: 11/13/09    Time: 13:19:22.102
STATION A

             Currents (A pri)                Voltages (kV pri)
             IA      IB      IC      IN      VA      VB      VC      VS
THD  (%)      19      22      11       0       2       4       2       2
RMS           35.40   41.79   38.60    0.00   21.61   21.54   21.50   21.50
Fund.         34.77   40.80   38.35    0.00   21.60   21.52   21.50   21.50

Harmonic
2    (%)       0       0       0       0       0       0       0       0
3    (%)       7      14       4       0       0       4       0       0
4    (%)       0       0       0       0       0       0       0       0
5    (%)       3      12       6       0       2       0       0       0
6    (%)       0       0       0       0       0       0       0       0
7    (%)      13       4       2       0       0       0       2       2
8    (%)       0       0       0       0       0       0       0       0
9    (%)       5       6       4       0       0       0       0       0
10   (%)       0       0       2       0       0       0       0       0
11   (%)       6       6       0       0       0       0       0       0
12   (%)       0       0       0       0       0       0       0       0
13   (%)       3       3       6       0       0       0       0       0
14   (%)       0       0       0       0       0       0       0       0
15   (%)       2       3       0       0       0       0       0       0
16   (%)       8       4       0       0       0       0       0       0

=>
```

For more information refer to *Harmonic Metering* on page 8.42, and *Harmonic Metering Small Signal Cutoff Thresholds* on page 8.43.

MET M—Maximum/Minimum Metering

Use the following commands to view or reset maximum and minimum metering values.

Command	Description	Access Level
MET M	Display maximum and minimum metering data.	1
MET RM	Reset maximum and minimum metering data. All values will display RESET until new maximum/minimum values are recorded.	1

The **MET M** command displays the maximum and minimum values of the following quantities:

Type	Symbol	Description/Units
Currents	$I_{A,B,C,N}$	Input currents (A primary)
	I_G	Residual ground current (A primary; $I_G = 3I_0 = I_A + I_B + I_C$)
Voltages	$V_{A,B,C,S}$	Wye-connected voltage inputs[a] (kV primary)
	$V_{AB,BC,CA,S}$	Delta-connected voltage inputs (kV primary)
Power	MW_{3P}	Three-phase megawatts
	$MVAR_{3P}$	Three-phase megavars
Reset Time		Last time the maximum/minimum meter was reset

[a] Or single-phase connected when the phantom voltage feature is being used.

To view maximum/minimum metering values, enter the command:

```
=>MET M <Enter>
```

The output from an SEL-351 with wye-connected voltage inputs is shown:

```
=>MET M <Enter>
FEEDER 1                          Date: 02/01/09    Time: 15:16:00.239

STATION A
              Max    Date      Time              Min    Date      Time
IA(A)       196.8  02/01/09  15:00:42.574       30.0  02/01/09  14:51:02.391
IB(A)       195.0  02/01/09  15:05:19.558       31.8  02/01/09  14:50:55.536
IC(A)       200.4  02/01/09  15:00:42.578       52.2  02/01/09  14:51:02.332
IN(A)        42.6  02/01/09  14:51:02.328       42.6  02/01/09  14:51:02.328
IG(A)        42.0  02/01/09  14:50:55.294       42.0  02/01/09  14:50:55.294
VA(kV)       11.7  02/01/09  15:01:01.576        3.4  02/01/09  15:00:42.545
VB(kV)       11.7  02/01/09  15:00:42.937        2.4  02/01/09  15:00:42.541
VC(kV)       11.7  02/01/09  15:00:42.578        3.1  02/01/09  15:00:42.545
VS(kV)       11.7  02/01/09  15:01:01.576        3.4  02/01/09  15:00:42.545
MW3P          6.9  02/01/09  15:00:44.095        0.4  02/01/09  15:00:42.545
MVAR3P        1.0  02/01/09  15:00:42.578        0.1  02/01/09  15:00:42.545
LAST RESET 01/27/09 15:31:41.237
=>
```

Reset the maximum/minimum values using the **MET RM** command. All values will display RESET until new maximum/minimum values are recorded. For more information on maximum/minimum metering, see *Maximum/Minimum Metering* on page 8.39.

MET PM—Synchrophasor Metering

The **MET PM** command (available when TSOK = logical 1 and EPMU = Y) displays the synchrophasor measurements. For more information, see *View Synchrophasors by Using the MET PM Command* on page N.18.

Command	Description	Access Level
MET PM	Display synchrophasor measurements.	1
MET PM *time*	Display synchrophasor measurements at specific time.	1
MET PM HIS	Display the most recent **MET PM** synchrophasor report.	1

Use the **MET PM** command to help with commissioning. The command:

```
=>MET PM time <Enter>
```

triggers a synchrophasor meter command at precisely the time specified. Parameter `time` must be in 24-hour format, e.g., 15:11:00.000. Compare magnitudes and phases of quantities displayed in response to the **MET PM** command to reports from other relays triggered at the same instant to verify correct phasing and polarity of current and voltage connections. To help facilitate comparing meter reports between several relays, the command:

```
=>MET PM HIS <Enter>
```

recalls the most recently triggered synchrophasor meter report. Values displayed reflect present relay settings, not settings in effect at the time of the original **MET PM** command. For exploratory testing, the command:

```
=>MET PM k <Enter>
```

repeats the **MET PM** command *k* times. The trigger times of the *k* reports are not carefully controlled, but the trigger times are still accurately displayed in the reports.

The output from an SEL-351 is shown:

```
=>MET PM <Enter>

FEEDER 1                         Date: 12/01/08    Time: 10:33:59.000
STATION A

                                                             PMDOK = 1
Time Quality   Maximum time synchronization error:     0.000 (ms)  TSOK = 1

Synchrophasors
                  Phase Voltages           Synch Voltage    Pos.-Seq. Voltage
               VA        VB        VC           VS                V1
MAG (kV)       12.045    12.037    12.038       12.042            12.040
ANG (DEG)     139.563    19.756  -100.109      140.066           139.737

                  Phase Currents          Neutral Current   Pos.-Seq. Current
               IA        IB        IC           IN                I1
MAG (A)       120.865   121.026   120.477        0.625           106.448
ANG (DEG)     140.109    20.452  -159.931      139.213           121.169

FREQ (Hz) 59.991
Rate-of-change of FREQ (Hz/s)    0.00

Digitals

SV1    SV2    SV3    SV4    SV5    SV6    SV7    SV8
 0      0      0      0      0      0      0      0
SV9    SV10   SV11   SV12   SV13   SV14   SV15   SV16
 0      0      0      0      0      0      0      0
=>
```

OPE (Open Breaker)

The **OPE** command asserts Relay Word bit OC for 1/4 cycle when it is executed. Relay Word bit OC can then be programmed into the TR SELOGIC control equation to assert the TRIP Relay Word bit, which in turn asserts an output contact (e.g., OUT101 = TRIP) to trip a circuit breaker.

Command	Description	Access Level
OPE	Assert the open command Relay Word bit OC.	B

The OC Relay Word bit appears in the factory-default SELOGIC settings for TR and 79DTL. See *Trip Logic* on page 5.1 and *Drive-to-Lockout and Drive-to-Last Shot Settings (79DTL and 79DLS, Respectively)* on page 6.22.

To issue the **OPE** command, enter the following:

```
==>OPE <Enter>

Open Breaker  (Y/N) ? Y <Enter>
Are you sure (Y/N) ? Y <Enter>
==>
```

Typing **N <Enter>** after either of the above prompts will abort the command.

The **OPE** command is supervised by the main board Breaker jumper (see *Figure 2.30*). If the Breaker jumper is not in place (Breaker jumper = OFF), the relay does not execute the **OPE** command and responds:

```
Aborted: No Breaker Jumper
```

PAS (Change Passwords)

The relay is shipped with factory default passwords for Access Levels 1, B, 2, and C. These passwords are shown in *Table 10.21*.

Command	Description	Access Level
PAS *level*	Set a password for Access Level *level*.	2

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

Table 10.21 Factory Default Passwords for Access Levels 1, B, 2, and C

Access Level	Factory Default Password
1	OTTER
B	EDITH
2	TAIL
C	CLARKE

The **PAS**sword command allows you to change existing Level 1, B, and 2 passwords at Access Level 2 and allows you to change the Level C password from Level C. To change passwords, enter **PAS *x***, where ***x*** is the access level whose password is being changed. The relay will prompt for the old password, new password, and a confirmation of the new password.

To change the password for Access Level 1, enter the following:

```
=>>PAS 1 <Enter>

Old Password: *********

New Password: ******
Confirm New Password: ******

Password Changed
=>>
```

The new password will not echo on the screen, and passwords cannot be viewed from the device. Record the new password in a safe place for future reference.

If the passwords are lost or you want to operate the relay without password protection, put the main board Access jumper in place (Access jumper = ON). Refer to *Figure 2.30* for Access jumper information. With the Access jumper in place, issue the **PAS *x*** command at Access Level 2. The relay will prompt for a new password and a confirmation of the new password.

Passwords may include as many as 12 characters. See *Table 10.22* for valid characters. Upper- and lowercase letters are treated as different characters. Strong passwords consist of 12 characters, with at least one special character or digit and mixed-case sensitivity, but do not form a name, date, acronym, or word. Passwords formed in this manner are less susceptible to password guessing and automated attacks. Examples of valid, distinct strong passwords include:

- Ot3579A24.68
- Ih2d&s4u-Iwg
- .351.Nt9g-t

Table 10.22 Valid Password Characters

Alpha	ABCDEFGHIJKLMNOPQRSTUVWXYZ abcdefghijklmnopqrstuvwxyz
Numeric	0123456789
Special	! " # $ % & ' ( ) * , - . / : ; < = > ? @ [\ ] ^ _ ` { | } ~

The relay issues a weak password warning if the new password does not include at least one special character, number, lowercase letter, and uppercase letter.

```
=>>PAS 1 <Enter>

Old Password: *********

New Password: ******
Confirm New Password: ******

Password Changed
=>>

CAUTION:  This password can be strengthened.  Strong passwords do not include a
    name, date, acronym, or word.  They consist of the maximum allowable
    characters, with at least one special character, number, lower-case letter, and
    upper-case letter.  A change in password is recommended.

=>>
```

PIN

The **PIN** command allows you to determine if a host is reachable across an IP network and/or if the Ethernet port is functioning or configured correctly. When you are setting up or testing substation networks, it is helpful to determine if the network is connected properly and if the other devices are powered up and configured properly.

Command	Description	Access Level
PIN *addr*	Use **PIN *addr*** without parameters to ping the specified address every 1 second until the command is canceled or 30 minutes elapse.	1
PIN *addr* [**I***i*]	Ping the specified address at the specified interval until the command is canceled or 30 minutes elapse.	1

Command	Description	Access Level
PIN *addr* **[T***t***]**	Ping the specified address every 1 second until the specified timeout elapses.	1
PIN *addr* **[I***i***] [T***t***]**	Ping the specified address at the specified interval until the specified timeout elapses.	1

After valid **PIN** command is issued, the relay sends out an ICMP echo request message at a 1-second interval (unless overridden by the I*i* parameter) until receiving a carriage return <CR>, the letter Q is typed, or the 30-minute duration elapses (unless overridden by the T*t* parameter). Use the optional I*i* parameter to specify the time in seconds (1–30) between successive ping commands. If I*i* is not specified, the interval between successive ping commands is 1 second. Use the optional T*t* parameter to specify the duration in minutes (1–60) of the **PIN** command. If T*t* is not specified, the ping duration is 30 minutes.

Command **PIN 10.201.7.52 I1** is executed in the following example.

```
=>PIN 10.201.7.52 I1 <Enter>
Pinging 10.201.7.52
Press <Enter> or Q to Terminate Ping Test
Reply from 10.201.7.52
Reply from 10.201.7.52
Reply from 10.201.7.52
Reply from 10.201.7.52
Reply from 10.201.7.52
Reply from 10.201.7.52
No response from host 10.201.7.52
Ping test stopped.

Ping Statistics for 10.201.7.52
Packets: Sent = 7, Received = 6, Lost = 1
Elapsed Time:    13 seconds

=>
```

Figure 10.10 PIN Command Response

PUL (Pulse Output Contact)

The **PUL** command allows you to pulse any of the output contacts for a specified length of time. The selected contact will close or open depending on the output contact type (a or b). See *Output Contacts* on page 7.33.

Command	Description	Access Level
PUL ***x y***	Pulse output *x* for *y* second. (*x* = output name; *y* = 1–30 seconds)	B

To pulse OUT101 for five seconds:

```
==>PUL OUT101 5 <Enter>

Are you sure (Y/N) ? Y <Enter>
==>
```

If the response to the `Are you sure (Y/N) ?` prompt is **N** or **n**, the command is aborted.

The **PUL** command is supervised by the main board Breaker jumper (see *Figure 2.30*). If the Breaker is not in place (Breaker jumper = OFF), the relay does not execute the **PUL** command and responds:

```
Aborted:  No Breaker Jumper
```

The relay generates an event report if any output contacts are pulsed. The **PUL** command is primarily used for testing purposes.

QUI (Quit Access Level)

The **QUI** command returns the relay to Access Level 0.

Command	Description	Access Level
QUI	Go to Access Level 0.	0

To return to Access Level 0, enter the command:

```
=>QUI <Enter>
```

The relay sets the port access level to 0 and responds:

```
FEEDER 1                          Date: 02/02/09    Time: 08:55:33.986
STATION A

=
```

The = prompt indicates the relay is back in Access Level 0.

The **QUI** command terminates the SEL Distributed Port Switch Protocol (LMD) connection if it is established (see *Appendix I: SEL Distributed Port Switch Protocol* for more information).

SER (Sequential Events Recorder Report)

Use the **SER** command to view the Sequential Events Recorder report. For more information on SER reports, see *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*.

Command	Description	Access Level
SER	Use the **SER** command to display a chronological progression of all available SER rows (as many as 1024 rows). Row 1 is the most recently triggered row and row 1024 is the oldest.	1
SER ***row1*** **SER** ***row1 row2*** **SER** ***date1*** **SER** ***date1 date2***	Use the **SER** command with parameters to display a chronological or reverse chronological subset of the SER rows.	1
SER C	Use this command to clear/reset the SER records.	1

SET (Change Settings)

The **SET** command allows the user to view or change the relay settings—see *Table 9.2*.

Command	Description	Access Level
SET *n*	Set the Group *n* settings, beginning at the first setting in each instance (*n* = 1–6); *n* defaults to the active setting group if not listed.	2
SET D	Set DNP settings.	2
SET G	Set Global settings.	2
SET L *n*	Set Logic settings for setting group *n* (*n* = 1, 2, 3, 4, 5, or 6); *n* defaults to the active setting group if not listed.	2
SET M	Set Modbus settings.	2
SET P *n*	Set Port settings. *n* specifies the port (1, 2, 3, F, or 5); *n* defaults to the active port if not listed.	2
SET R	Set Report settings.	2
SET T	Set Text Label settings.	2

SHO (Show/View Settings)

Use the **SHO** command to view relay settings, SELOGIC control equations, Global Settings, Serial Port settings, Sequential Events Recorder (SER) settings, and Text Label settings.

Command	Description	Access Level
SHO *n*	Show Group *n* settings. *n* specifies the setting group (1, 2, 3, 4, 5, or 6); *n* defaults to the active setting group if not listed.	1
SHO D	Show DNP settings.	1
SHO G	Show Global settings.	1
SHO L *n*	Show Logic settings for setting group *n* (*n* = 1, 2, 3, 4, 5, or 6); *n* defaults to the active setting group if not listed.	1
SHO M	Show Modbus settings.	1
SHO P *n*	Show Port settings. *n* specifies the port (1, 2, 3, F, or 5); *n* defaults to the active port if not listed.	1
SHO R	Show Report settings.	1
SHO T	Show Text Label settings.	1

You may append a setting name to each of the commands to specify the first setting to display (e.g., **SHO 1 E50P** displays the setting Group 1 relay settings starting with setting E50P). The default is the first setting.

The **SHO** commands display only the enabled settings. To display all settings, including disabled/hidden settings, append an **A** to the **SHO** command (e.g., **SHO 1 A**).

Below are sample **SHO** commands for the SEL-351, showing the *factory default settings* for a particular model. The factory default settings for the other SEL-351 models are similar.

```
=>SHO <Enter>
Group 1
Group Settings:
RID     =FEEDER 1                    TID     =STATION A
CTR     = 120      CTRN    = 120     PTR     = 180.00    PTRS    = 180.00
VNOM    = 67.00
Z1MAG   = 10.70    Z1ANG   = 68.86   Z0MAG   = 31.90     Z0ANG   = 72.47
LL      = 4.84
E50P    = 1        E50N    = N       E50G    = N         E50Q    = N
E51P    = 1        E51N    = N       E51G    = 1         E51Q    = N
E50BF   = N        EHBL2   = N       E32     = N         ELOAD   = N
ESOTF   = N        EVOLT   = N       E25     = N         EFLOC   = Y
ELOP    = N        ECOMM   = N       E81     = N         E81R    = N
E79     = 1        ESV     = 1       EDEM    = THM
EPWR    = N        ESSI    = N
50P1P   = 3.00
67P1D   = 0.00
50PP1P  = OFF
51PP    = 1.20     51PC    = U3      51PTD   = 3.00      51PRS   = N
51GP    = 0.30     51GC    = U3      51GTD   = 1.50      51GRS   = N
79OI1   = 300.00   79RSD   = 1800.00 79RSLD  = 300.00    79CLSD  = 0.00
DMTC    = 5        PDEMP   = 1.00    NDEMP   = 0.300     GDEMP   = 0.30
QDEMP   = 0.30
TDURD   = 9.00     CFD     = 60.00   3POD    = 1.50      50LP    = 0.05
SV1PU   = 12.00    SV1DO   = 2.00

=>
```

```
=>SHO L <Enter>
SELogic group 1

SELogic Control Equations:
TR      = OC + 51PT + 51GT + 81D1T + LB3 + 50P1 * SH0
TRQUAL  = 0
TRCOMM  = 0
TRSOTF  = 0
DTT     = 0
ULTR    = !(51P + 51G)
PT1     = 0
LOG1    = 0
PT2     = 0
LOG2    = 0
BT      = 0
52A     = IN101
CL      = CC + LB4
ULCL    = TRIP
79RI    = TRIP
79RIS   = 52A + 79CY
79DTL   = OC + !IN102 + LB3
79DLS   = 79LO
79SKP   = 0
79STL   = TRIP
79BRS   = TRIP
```

```
79SEQ    = 0
79CLS    = 1
SET1     = 0
RST1     = 0
SET2     = 0
RST2     = 0
SET3     = 0
RST3     = 0
SET4     = 0
RST4     = 0
SET5     = 0
RST5     = 0
SET6     = 0
RST6     = 0
SET7     = 0
RST7     = 0
SET8     = 0
RST8     = 0
SET9     = 0
RST9     = 0
SET10    = 0
RST10    = 0
SET11    = 0
RST11    = 0
SET12    = 0
RST12    = 0
SET13    = 0
RST13    = 0
SET14    = 0
RST14    = 0
SET15    = 0
RST15    = 0
SET16    = 0
RST16    = 0

67P1TC   = 1
67P2TC   = 1
67P3TC   = 1
67P4TC   = 1
67N1TC   = 1
67N2TC   = 1
67N3TC   = 1
67N4TC   = 1
67G1TC   = 1
67G2TC   = 1
67G3TC   = 1
67G4TC   = 1
67Q1TC   = 1
67Q2TC   = 1
67Q3TC   = 1
67Q4TC   = 1
51ATC    = 1
51BTC    = 1
51CTC    = 1
51PTC    = 1
51NTC    = 1
51GTC    = 1
51G2TC   = 1
51QTC    = 1
HBL2TC   = 1
81RTC    = !27B81
```

```
BFI     = 0
BFTR    = 0
BFULTR  = 0
LV1     = 0
LV2     = 0
LV3     = 0
LV4     = 0
LV5     = 0
LV6     = 0
LV7     = 0
LV8     = 0
LV9     = 0
LV10    = 0
LV11    = 0
LV12    = 0
LV13    = 0
LV14    = 0
LV15    = 0
LV16    = 0
LV17    = 0
LV18    = 0
LV19    = 0
LV20    = 0
LV21    = 0
LV22    = 0
LV23    = 0
LV24    = 0
LV25    = 0
LV26    = 0
LV27    = 0
LV28    = 0
LV29    = 0
LV30    = 0
LV31    = 0
LV32    = 0

SV1     = TRIP
SV2     = 0
SV3     = 0
SV4     = 0
SV5     = 0
SV6     = 0
SV7     = 0
SV8     = 0
SV9     = 0
SV10    = 0
SV11    = 0
SV12    = 0
SV13    = 0
SV14    = 0
SV15    = 0
SV16    = 0
OUT101  = TRIP
OUT102  = CLOSE
OUT103  = SV1T
OUT104  = 0
OUT105  = 0
OUT106  = 0
OUT107  = 0
ALRMOUT = !(SALARM + HALARM)
DP1     = IN102
DP2     = 52A

DP3     = 0
DP4     = 0
DP5     = 0
DP6     = 0
DP7     = 0
DP8     = 0
DP9     = 0
DP10    = 0
DP11    = 0
DP12    = 0
DP13    = 0
DP14    = 0
DP15    = 0
DP16    = 0
SS1     = 0
SS2     = 0
SS3     = 0
SS4     = 0
SS5     = 0
SS6     = 0
ER      = /51P + /51G + /OUT103
FAULT   = 51P + 51G
BSYNCH  = 52A
CLMON   = 0
BKMON   = TRIP
BKCLS   = CLOSE
```

```
E32IV   = 1
LOPBLK  = 0
SALARM  = BADPASS + CHGPASS + SETCHG + GRPSW + ACCESSP + PASNVAL
RSTTRGT = 0
RST_DEM = 0
RST_PDM = 0
RST_BK  = 0
RST_HIS = 0
RST_ENE = 0
RST_MML = 0
RST_HAL = 0
RSTDNPE = 0
PMTRIG  = 0
TREA1   = 0
TREA2   = 0
TREA3   = 0
TREA4   = 0
TMB1A   = 0
TMB2A   = 0
TMB3A   = 0
TMB4A   = 0
TMB5A   = 0
TMB6A   = 0
TMB7A   = 0
TMB8A   = 0
TMB1B   = 0
TMB2B   = 0
TMB3B   = 0
TMB4B   = 0
TMB5B   = 0
TMB6B   = 0
TMB7B   = 0
TMB8B   = 0
=>
```

```
=>SHO G <Enter>
Global Settings:
PTCONN  = WYE     VSCONN  = VS       TGR     = 0.00
NFREQ   = 60      PHROT   = ABC      DATE_F  = MDY
FP_TO   = 15      SCROLD  = 2        FPNGD   = IN
METHRES = Y       LER     = 15       PRE     = 4         FLTDISP = MAX
DCLOP   = OFF     DCHIP   = OFF
IN101D  = 0.50    IN102D  = 0.50     IN103D  = 0.50      IN104D  = 0.50
IN105D  = 0.50    IN106D  = 0.50
IN201D  = 0.50    IN202D  = 0.50     IN203D  = 0.50      IN204D  = 0.50
IN205D  = 0.50    IN206D  = 0.50     IN207D  = 0.50      IN208D  = 0.50
EBMON   = Y       COSP1   = 10000    COSP2   = 150       COSP3   = 12
KASP1   = 1.20    KASP2   = 8.00     KASP3   = 20.00     ESTRT   = 50
ESCLT   = 120     MSTRT   = 50       MSCLT   = 120
EPMU    = N       EVELOCK = 0        DNPSRC  = UTC       BOOPTCC = SET
BOOPPUL = SET     IRIGC   = NONE     UTC_OFF = 0.00
DST_BEGM= NA

=>
```

```
=>SHO P <Enter>
Port F

EPORT   = Y
PROTO   = SEL       MAXACC  = C
SPEED   = 9600      BITS    = 8         PARITY  = N         STOP    = 1
RTSCTS  = N         T_OUT   = 15
AUTO    = N         FASTOP  = N

=>
```

```
=>SHO P 5 <Enter>
Port 5
EPORT   = Y         IPADDR  = 192.168.1.2
SUBNETM = 255.255.255.0
DEFRTR  = 192.168.1.1
ETCPKA  = Y         KAIDLE  = 10        KAINTV  = 10        KACNT   = 5
NETMODE = FAILOVER  FTIME   = 1.00      NETPORT = A
NET5ASPD= AUTO      NET5BSPD= AUTO
ETELNET = N
EFTPSERV= N         EHTTP   = N
E61850  = Y         EGSE    = Y
EDNP    = 0
EMODBUS = 0
ESNTP   = OFF

=>
```

```
=>SHO R <Enter>
Sequential Events Recorder trigger lists:
SER1    = 51P,51G,50P1
SER2    = LB3,LB4,IN101,IN102,OUT101,OUT102,OUT103
SER3    = CF,79CY,79LO

Load Profile settings:
LDLIST  =
LDAR    = 15

=>
```

```
=>SHO T <Enter>

Text Labels:
NLB1    =               CLB1    =         SLB1    =         PLB1    =
NLB2    =               CLB2    =         SLB2    =         PLB2    =
NLB3    = MANUAL TRIP   CLB3    = RETURN  SLB3    =         PLB3    = TRIP
NLB4    = MANUAL CLOSE  CLB4    = RETURN  SLB4    =         PLB4    = CLOSE
NLB5    =               CLB5    =         SLB5    =         PLB5    =
NLB6    =               CLB6    =         SLB6    =         PLB6    =
NLB7    =               CLB7    =         SLB7    =         PLB7    =
NLB8    =               CLB8    =         SLB8    =         PLB8    =
NLB9    =               CLB9    =         SLB9    =         PLB9    =
NLB10   =               CLB10   =         SLB10   =         PLB10   =
NLB11   =               CLB11   =         SLB11   =         PLB11   =
NLB12   =               CLB12   =         SLB12   =         PLB12   =
NLB13   =               CLB13   =         SLB13   =         PLB13   =
NLB14   =               CLB14   =         SLB14   =         PLB14   =
NLB15   =               CLB15   =         SLB15   =         PLB15   =
NLB16   =               CLB16   =         SLB16   =         PLB16   =
DP1_1   = 79 ENABLED      DP1_0   = 79 DISABLED
DP2_1   = BREAKER CLOSED  DP2_0   = BREAKER OPEN
DP3_1   =                 DP3_0   =
DP4_1   =                 DP4_0   =
DP5_1   =                 DP5_0   =
DP6_1   =                 DP6_0   =
DP7_1   =                 DP7_0   =
DP8_1   =                 DP8_0   =
DP9_1   =                 DP9_0   =
DP10_1  =                 DP10_0  =
DP11_1  =                 DP11_0  =
DP12_1  =                 DP12_0  =
DP13_1  =                 DP13_0  =
DP14_1  =                 DP14_0  =
DP15_1  =                 DP15_0  =
DP16_1  =                 DP16_0  =
79LL    = SET RECLOSURES 79SL    = RECLOSE COUNT

=>
```

```
=>SHO M <Enter>

MOD_001 = IA       MOD_002 = IAFA     MOD_003 = IB       MOD_004 = IBFA
MOD_005 = IC       MOD_006 = ICFA     MOD_007 = IG       MOD_008 = IGFA
MOD_009 = IN       MOD_010 = INFA     MOD_011 = VA       MOD_013 = VAFA
MOD_014 = VB       MOD_016 = VBFA     MOD_017 = VC       MOD_019 = VCFA
MOD_020 = VS       MOD_022 = VSFA     MOD_023 = KW3      MOD_025 = KVAR3
MOD_027 = PF3      MOD_028 = LDPF3    MOD_029 = FREQ     MOD_030 = VDC
MOD_031 = MWH3I    MOD_033 = MWH3O    MOD_035 = MVRH3I   MOD_037 = MVRH3O
MOD_039 = ACTGRP   MOD_040 = ROW_0    MOD_041 = ROW_1    MOD_042 = ROW_35
MOD_043 = ROW_37   MOD_044 = NA       MOD_045 = NA       MOD_046 = NA
MOD_047 = NA       MOD_048 = NA       MOD_049 = NA       MOD_050 = NA
MOD_051 = NA       MOD_052 = NA       MOD_053 = NA       MOD_054 = NA
MOD_055 = NA       MOD_056 = NA       MOD_057 = NA       MOD_058 = NA
MOD_059 = NA       MOD_060 = NA       MOD_061 = NA       MOD_062 = NA
MOD_063 = NA       MOD_064 = NA       MOD_065 = NA       MOD_066 = NA
MOD_067 = NA       MOD_068 = NA       MOD_069 = NA       MOD_070 = NA
MOD_071 = NA       MOD_072 = NA       MOD_073 = NA       MOD_074 = NA
MOD_075 = NA       MOD_076 = NA       MOD_077 = NA       MOD_078 = NA
MOD_079 = NA       MOD_080 = NA       MOD_081 = NA       MOD_082 = NA
MOD_083 = NA       MOD_084 = NA       MOD_085 = NA       MOD_086 = NA
MOD_087 = NA       MOD_088 = NA       MOD_089 = NA       MOD_090 = NA
MOD_091 = NA       MOD_092 = NA       MOD_093 = NA       MOD_094 = NA
MOD_095 = NA       MOD_096 = NA       MOD_097 = NA       MOD_098 = NA
MOD_099 = NA       MOD_100 = NA       MOD_101 = NA       MOD_102 = NA
MOD_103 = NA       MOD_104 = NA       MOD_105 = NA       MOD_106 = NA
MOD_107 = NA       MOD_108 = NA       MOD_109 = NA       MOD_110 = NA
MOD_111 = NA       MOD_112 = NA       MOD_113 = NA       MOD_114 = NA
MOD_115 = NA       MOD_116 = NA       MOD_117 = NA       MOD_118 = NA
MOD_119 = NA       MOD_120 = NA       MOD_121 = NA       MOD_122 = NA
MOD_123 = NA       MOD_124 = NA       MOD_125 = NA

MOD_126 = NA       MOD_127 = NA       MOD_128 = NA       MOD_129 = NA
MOD_130 = NA       MOD_131 = NA       MOD_132 = NA       MOD_133 = NA
MOD_134 = NA       MOD_135 = NA       MOD_136 = NA       MOD_137 = NA
MOD_138 = NA       MOD_139 = NA       MOD_140 = NA       MOD_141 = NA
MOD_142 = NA       MOD_143 = NA       MOD_144 = NA       MOD_145 = NA
MOD_146 = NA       MOD_147 = NA       MOD_148 = NA       MOD_149 = NA
MOD_150 = NA       MOD_151 = NA       MOD_152 = NA       MOD_153 = NA
MOD_154 = NA       MOD_155 = NA       MOD_156 = NA       MOD_157 = NA
MOD_158 = NA       MOD_159 = NA       MOD_160 = NA       MOD_161 = NA
MOD_162 = NA       MOD_163 = NA       MOD_164 = NA       MOD_165 = NA
MOD_166 = NA       MOD_167 = NA       MOD_168 = NA       MOD_169 = NA
MOD_170 = NA       MOD_171 = NA       MOD_172 = NA       MOD_173 = NA
MOD_174 = NA       MOD_175 = NA       MOD_176 = NA       MOD_177 = NA
MOD_178 = NA       MOD_179 = NA       MOD_180 = NA       MOD_181 = NA
MOD_182 = NA       MOD_183 = NA       MOD_184 = NA       MOD_185 = NA
MOD_186 = NA       MOD_187 = NA       MOD_188 = NA       MOD_189 = NA
MOD_190 = NA       MOD_191 = NA       MOD_192 = NA       MOD_193 = NA
MOD_194 = NA       MOD_195 = NA       MOD_196 = NA       MOD_197 = NA
MOD_198 = NA       MOD_199 = NA       MOD_200 = NA       MOD_201 = NA
MOD_202 = NA       MOD_203 = NA       MOD_204 = NA       MOD_205 = NA
MOD_206 = NA       MOD_207 = NA       MOD_208 = NA       MOD_209 = NA
MOD_210 = NA       MOD_211 = NA       MOD_212 = NA       MOD_213 = NA
MOD_214 = NA       MOD_215 = NA       MOD_216 = NA       MOD_217 = NA
MOD_218 = NA       MOD_219 = NA       MOD_220 = NA       MOD_221 = NA
MOD_222 = NA       MOD_223 = NA       MOD_224 = NA       MOD_225 = NA
MOD_226 = NA       MOD_227 = NA       MOD_228 = NA       MOD_229 = NA
MOD_230 = NA       MOD_231 = NA       MOD_232 = NA       MOD_233 = NA
MOD_234 = NA       MOD_235 = NA       MOD_236 = NA       MOD_237 = NA
MOD_238 = NA       MOD_239 = NA       MOD_240 = NA       MOD_241 = NA
MOD_242 = NA       MOD_243 = NA       MOD_244 = NA       MOD_245 = NA
MOD_246 = NA       MOD_247 = NA       MOD_248 = NA       MOD_249 = NA
MOD_250 = NA

=>
```

```
=>SHO D <Enter>

DNP Map Settings 1
BI_000  = 52A      BI_001  = 79RS     BI_002  = 79LO     BI_003  = 81
BI_004  = 51       BI_005  = 50       BI_006  = SOTF     BI_007  = COMM
BI_008  = INST     BI_009  = TRIP_LED BI_010  = EN       BI_011  = LO
BI_012  = CY       BI_013  = RS       BI_014  = N        BI_015  = G
BI_016  = C        BI_017  = B        BI_018  = A        BI_019  = LDPF3
BI_020  = RLYDIS   BI_021  = STFAIL   BI_022  = STWARN   BI_023  = UNRDEV
BI_024  = NA       BI_025  = NA       BI_026  = NA       BI_027  = NA
BI_028  = NA       BI_029  = NA       BI_030  = NA       BI_031  = NA
BI_032  = NA       BI_033  = NA       BI_034  = NA       BI_035  = NA
BI_036  = NA       BI_037  = NA       BI_038  = NA       BI_039  = NA
BI_040  = NA       BI_041  = NA       BI_042  = NA       BI_043  = NA
BI_044  = NA       BI_045  = NA       BI_046  = NA       BI_047  = NA
BI_048  = NA       BI_049  = NA       BI_050  = NA       BI_051  = NA
BI_052  = NA       BI_053  = NA       BI_054  = NA       BI_055  = NA
BI_056  = NA       BI_057  = NA       BI_058  = NA       BI_059  = NA
BI_060  = NA       BI_061  = NA       BI_062  = NA       BI_063  = NA
BI_064  = NA       BI_065  = NA       BI_066  = NA       BI_067  = NA
BI_068  = NA       BI_069  = NA       BI_070  = NA       BI_071  = NA
BI_072  = NA       BI_073  = NA       BI_074  = NA       BI_075  = NA
BI_076  = NA       BI_077  = NA       BI_078  = NA       BI_079  = NA
BI_080  = NA       BI_081  = NA       BI_082  = NA       BI_083  = NA
BI_084  = NA       BI_085  = NA       BI_086  = NA       BI_087  = NA
BI_088  = NA       BI_089  = NA       BI_090  = NA       BI_091  = NA
BI_092  = NA       BI_093  = NA       BI_094  = NA       BI_095  = NA
BI_096  = NA       BI_097  = NA       BI_098  = NA       BI_099  = NA
BI_100  = NA       BI_101  = NA       BI_102  = NA       BI_103  = NA
BI_104  = NA       BI_105  = NA       BI_106  = NA       BI_107  = NA
BI_108  = NA       BI_109  = NA       BI_110  = NA       BI_111  = NA
BI_112  = NA       BI_113  = NA       BI_114  = NA       BI_115  = NA
BI_116  = NA       BI_117  = NA       BI_118  = NA       BI_119  = NA
BI_120  = NA       BI_121  = NA       BI_122  = NA       BI_123  = NA
BI_124  = NA       BI_125  = NA       BI_126  = NA       BI_127  = NA
BI_128  = NA       BI_129  = NA       BI_130  = NA       BI_131  = NA
BI_132  = NA       BI_133  = NA       BI_134  = NA       BI_135  = NA
BI_136  = NA       BI_137  = NA       BI_138  = NA       BI_139  = NA
BI_140  = NA       BI_141  = NA       BI_142  = NA       BI_143  = NA
BI_144  = NA       BI_145  = NA       BI_146  = NA       BI_147  = NA
BI_148  = NA       BI_149  = NA       BI_150  = NA       BI_151  = NA
BI_152  = NA       BI_153  = NA       BI_154  = NA       BI_155  = NA
BI_156  = NA       BI_157  = NA       BI_158  = NA       BI_159  = NA
BI_160  = NA       BI_161  = NA       BI_162  = NA       BI_163  = NA
BI_164  = NA       BI_165  = NA       BI_166  = NA       BI_167  = NA
BI_168  = NA       BI_169  = NA       BI_170  = NA       BI_171  = NA
BI_172  = NA       BI_173  = NA       BI_174  = NA       BI_175  = NA
BI_176  = NA       BI_177  = NA       BI_178  = NA       BI_179  = NA
BI_180  = NA       BI_181  = NA       BI_182  = NA       BI_183  = NA
BI_184  = NA       BI_185  = NA       BI_186  = NA       BI_187  = NA
BI_188  = NA       BI_189  = NA       BI_190  = NA       BI_191  = NA
BI_192  = NA       BI_193  = NA       BI_194  = NA       BI_195  = NA
BI_196  = NA       BI_197  = NA       BI_198  = NA       BI_199  = NA

BO_000  = RB1               BO_001  = RB2               BO_002  = RB3
BO_003  = RB4               BO_004  = RB5               BO_005  = RB6
BO_006  = RB7               BO_007  = RB8               BO_008  = RB9
BO_009  = RB10              BO_010  = RB11              BO_011  = RB12
BO_012  = RB13              BO_013  = RB14              BO_014  = RB15
BO_015  = RB16              BO_016  = OC                BO_017  = CC
BO_018  = DRST_TAR          BO_019  = NXTEVE            BO_020  = NA
BO_021  = NA                BO_022  = NA                BO_023  = NA
BO_024  = NA                BO_025  = NA                BO_026  = NA
BO_027  = NA                BO_028  = NA                BO_029  = NA
BO_030  = NA                BO_031  = NA                BO_032  = NA

AI_000  = IA                      AI_001  = IAFA::500
AI_002  = IB                      AI_003  = IBFA::500
AI_004  = IC                      AI_005  = ICFA::500
AI_006  = IN                      AI_007  = INFA::500
AI_008  = VA                      AI_009  = VAFA::500
AI_010  = VB                      AI_011  = VBFA::500
AI_012  = VC                      AI_013  = VCFA::500
AI_014  = VS                      AI_015  = VSFA::500
AI_016  = IG                      AI_017  = IGFA::500
AI_018  = MW3                     AI_019  = MVAR3
AI_020  = PF3                     AI_021  = FREQ
AI_022  = VDC                     AI_023  = MWH3I
AI_024  = MWH3O                   AI_025  = MVRH3I
AI_026  = MVRH3O                  AI_027  = WEARA
AI_028  = WEARB                   AI_029  = WEARC
AI_030  = FTYPE                   AI_031  = FLOC
AI_032  = FI                      AI_033  = FFREQ
AI_034  = FGRP                    AI_035  = FSHO
AI_036  = FTIMEH                  AI_037  = FTIMEM
AI_038  = FTIMEL                  AI_039  = FUNR
```

```
AI_040   = NA                    AI_041   = NA
AI_042   = NA                    AI_043   = NA
AI_044   = NA                    AI_045   = NA
AI_046   = NA                    AI_047   = NA
AI_048   = NA                    AI_049   = NA
AI_050   = NA                    AI_051   = NA
AI_052   = NA                    AI_053   = NA
AI_054   = NA                    AI_055   = NA
AI_056   = NA                    AI_057   = NA
AI_058   = NA                    AI_059   = NA
AI_060   = NA                    AI_061   = NA
AI_062   = NA                    AI_063   = NA
AI_064   = NA                    AI_065   = NA
AI_066   = NA                    AI_067   = NA
AI_068   = NA                    AI_069   = NA
AI_070   = NA                    AI_071   = NA
AI_072   = NA                    AI_073   = NA
AI_074   = NA                    AI_075   = NA
AI_076   = NA                    AI_077   = NA
AI_078   = NA                    AI_079   = NA
AI_080   = NA                    AI_081   = NA
AI_082   = NA                    AI_083   = NA
AI_084   = NA                    AI_085   = NA
AI_086   = NA                    AI_087   = NA
AI_088   = NA                    AI_089   = NA
AI_090   = NA                    AI_091   = NA
AI_092   = NA                    AI_093   = NA
AI_094   = NA                    AI_095   = NA
AI_096   = NA                    AI_097   = NA
AI_098   = NA                    AI_099   = NA
AI_100   = NA                    AI_101   = NA
AI_102   = NA                    AI_103   = NA
AI_104   = NA                    AI_105   = NA
AI_106   = NA                    AI_107   = NA

AI_108   = NA                    AI_109   = NA
AI_110   = NA                    AI_111   = NA
AI_112   = NA                    AI_113   = NA
AI_114   = NA                    AI_115   = NA
AI_116   = NA                    AI_117   = NA
AI_118   = NA                    AI_119   = NA
AI_120   = NA                    AI_121   = NA
AI_122   = NA                    AI_123   = NA
AI_124   = NA                    AI_125   = NA
AI_126   = NA                    AI_127   = NA
AI_128   = NA                    AI_129   = NA
AI_130   = NA                    AI_131   = NA
AI_132   = NA                    AI_133   = NA
AI_134   = NA                    AI_135   = NA
AI_136   = NA                    AI_137   = NA
AI_138   = NA                    AI_139   = NA
AI_140   = NA                    AI_141   = NA
AI_142   = NA                    AI_143   = NA
AI_144   = NA                    AI_145   = NA
AI_146   = NA                    AI_147   = NA
AI_148   = NA                    AI_149   = NA
AI_150   = NA                    AI_151   = NA
AI_152   = NA                    AI_153   = NA
AI_154   = NA                    AI_155   = NA
AI_156   = NA                    AI_157   = NA
AI_158   = NA                    AI_159   = NA
AI_160   = NA                    AI_161   = NA
AI_162   = NA                    AI_163   = NA
AI_164   = NA                    AI_165   = NA
AI_166   = NA                    AI_167   = NA
```

```
AI_168  = NA                    AI_169  = NA
AI_170  = NA                    AI_171  = NA
AI_172  = NA                    AI_173  = NA
AI_174  = NA                    AI_175  = NA
AI_176  = NA                    AI_177  = NA
AI_178  = NA                    AI_179  = NA
AI_180  = NA                    AI_181  = NA
AI_182  = NA                    AI_183  = NA
AI_184  = NA                    AI_185  = NA
AI_186  = NA                    AI_187  = NA
AI_188  = NA                    AI_189  = NA
AI_190  = NA                    AI_191  = NA
AI_192  = NA                    AI_193  = NA
AI_194  = NA                    AI_195  = NA
AI_196  = NA                    AI_197  = NA
AI_198  = NA                    AI_199  = NA

AO_000  = ACTGRP   AO_001  = NA       AO_002  = NA       AO_003  = NA
AO_004  = NA       AO_005  = NA       AO_006  = NA       AO_007  = NA

CO_000  = ACTGRP         CO_001  = INTTR          CO_002  = EXTTR
CO_003  = NA             CO_004  = NA             CO_005  = NA
CO_006  = NA             CO_007  = NA
=>
```

SSI (Voltage Sag/Swell/Interruption Report—Available in Firmware Version 7)

Use the **SSI** command to view the voltage Sag, Swell, and Interruption report. For more information on SSI reports, see *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*.

Command	Description	Access Level
SSI	Use the **SSI** command with parameters to display a chronological or reverse chronological subset of the SSI report rows.	1
SSI ***row1 row2*** **SSI** ***date1 date2***	Use the **SSI** command to display a chronological progression of all SSI report rows.	1
SSI C	Clear the SSI data from memory.	1
SSI R	Reset the SSI recorder logic. This command does not clear SSI records from memory.	1
SSI T	Trigger the SSI recorder.	1

STA (Relay Self-Test Status)

The **STA** command displays the status report, showing the relay self-test information.

Command	Description	Access Level
STA ***n***	Display the relay self-test information *n* times (*n* = 1–32767). Defaults to 1 if *n* is not specified.	1
STA C	Clear all relay self-test warnings and failures and restart the relay.	2

To view a status report, enter the command:

```
=>STA n <Enter>
```

where *n* is an optional parameter to specify the number of times (1–32767) to repeat the status display. If *n* is not specified, the status report is displayed once. A sample output of an SEL-351 is shown:

```
=>STA <Enter>
FEEDER 1                          Date: 02/02/09    Time: 23:19:50.339
STATION A

FID=SEL-351-7-R500-V0-Z100100-Dxxxxxxxx       CID=83ED

SELF TESTS

W=Warn    F=Fail

      IA      IB      IC      IN      VA      VB      VC      VS      MOF
OS    -1      1       1       1       2       0       1       2       0
OSH   -1      0       0       1

      15V_PS  5V_REG  3.3V_REG
PS    14.93   4.99    3.27

      RAM     ROM     FPGA    EEPROM  FLASH   A/D     USB_BRD COM_BRD IO_BRD
      OK      OK      OK      OK      OK      OK      OK      OK      OK

      TEMP    RTC     HMI
      32.2    OK      OK

Relay Enabled

=>
```

STA Row and Column Definitions

FID	FID is the firmware identifier string. It identifies the firmware revision.
CID	CID is the firmware checksum identifier.
OS	OS = Offset; displays measured dc offset voltages in millivolts for the current and voltage channels. The MOF (master) status is the dc offset in the A/D circuit when a grounded input is selected.
OSH	Similar to OS, but for high-gain current channels.
PS	PS = Power Supply; displays power supply voltages in Vdc for the power supply outputs.
RAM, ROM, EEPROM, FLASH	These tests verify the relay memory components.
FPGA	Displays health of FPGA.
A/D	Analog-to-digital convert status.
USB_BRD	USB port status, if supplied.
COM_BRD	Dual copper, and dual or single fiber-optic Ethernet ports status, if supplied.
IO_BRD	Extra I/O board status.
TEMP	Displays the internal relay temperature in degrees Celsius.
RTC	Battery backed time-of-day clock status.
HMI	Front-panel board status.
W or F	W (Warning) or F (Failure) is appended to the values to indicate an out-of-tolerance condition.

The relay latches all self-test warnings and failures in order to capture transient out-of-tolerance conditions. To reset the self-test statuses, use the **STA C** command from Access Level 2:

```
=>>STA C <Enter>
```

The relay responds:

```
Reboot the relay and clear status
Are you sure (Y/N) ?
```

If you select “N” or “n”, the relay displays:

```
Canceled
```

and aborts the command.

If you select “Y”, the relay displays:

```
Rebooting the relay
```

The relay then restarts (just like powering down, then powering up relay), and all diagnostics are rerun before the relay is enabled.

Refer to *Table 13.2* for self-test thresholds and corrective actions.

SUM (Long Summary Event Report)

The **SUM** command displays a long summary event report. The long summary contains more information than is available from the **HIS** command, but it is shorter than the full event report retrieved with the **EVE** or **CEV** commands.

Command	Description	Access Level
SUM *n*	Displays the summary event report for event *n*, where *n* is either the event number from the **HIS** report, or the unique event number in the range 10000 to 65535 from the **HIS E** report. **SUM** with no *n* displays the most recent summary event report.	1
SUM ACK *n*	Acknowledge the summary event report for event *n*, where *n* must be the unique event number in the range 10000 to 65535 from the **HIS E** report. **SUM ACK** with no *n* acknowledges the oldest unacknowledged event report. Each serial port remembers which reports have been acknowledged on that port. Reports acknowledged within a Telnet session are acknowledged for all Telnet sessions on the Ethernet port.	
SUM N	Displays the oldest unacknowledged summary event report.	

Issue the **SUM N** and **SUM ACK** command repeatedly to step through the available event summaries from oldest to newest. When all reports have been acknowledged, the next **SUM N** command returns:

```
No unacknowledged event summaries exist.
```

A sample report is shown below. MIRRORED BITS channel status is only displayed when MIRRORED BITS communications is enabled. *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER* describes the various fields of information available in the summary event report.

```
=>>SUM <Enter>

FEEDER 1                          Date: 07/02/10    Time: 20:32:44.519
STATION A

Event: ABC T      Location:   64.93           Trip Time: 20:32:44.531
#: 10022  Shot:    Freq:  60.00  Group: 1     Close Time: --:--:--.---
Targets: 51
Breaker: Open

PreFault:     IA     IB     IC     IN     IG    3I2       VA       VB       VC
MAG(A/kV)    501    501    501      1      3      2  120.150  120.090  120.140
ANG(DEG)  119.34  -0.44-120.37 -83.99  12.01  50.39     0.00  -119.84   120.29
Fault:
MAG(A/kV)   1811   1830   1819      1     22     12  112.910  112.900  112.910
ANG(DEG)   55.51 -64.40 175.70-176.77 -82.67-153.19   119.56    -0.27  -120.23

Mirrored Bits Channel Status:                       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


=>>
```

TAR (Display Relay Element Status)

The **TAR** command displays the status of front-panel target LEDs or relay elements, whether they are asserted or deasserted.

Command	Description	Access Level
TAR	Use **TARGET** without parameters to display Relay Word row 0 or last displayed target row.	1
TAR *name k*	Display the target row containing *name*. Repeat the display *k* times.	1
TAR *n k*	Display target row number *n*. Repeat the display *k* times.	1
TAR LIST	Display all target rows. If ROW is specified, the relay includes the target row number on each line.	1
TAR R	Clears front-panel tripping targets. Shows Relay Word Row 0.	1

NOTE: Elements in rows 0 and 1 cannot be used in SELOGIC control equations.

The target row elements are listed in rows of eight. The first two rows (0 and 1) correspond to the relay front-panel target LEDs shown in *Table 10.23*. The target row elements are asserted when the corresponding front-panel target LED is illuminated.

The remaining target rows correspond to the Relay Word as described in *Table D.1*. A Relay Word bit is either at a logical 1 (asserted) or a logical 0 (deasserted). Relay Word bits are used in SELOGIC control equations. See *Appendix F: Setting SELOGIC Control Equations*.

The **TAR** command does not remap the front-panel target LEDs, as is done in some previous SEL relays. But the execution of the equivalent **TAR** command via the front-panel display does remap the bottom row of the front-panel target LEDs (see *Figure 11.3*, pushbutton OTHER).

The **TAR** command options are:

TAR *n k* or **TAR ROW *n k***	Shows Relay Word row number *n* (where *n* is 0 through the maximum number of Relay Word rows—see *Table D.1*). *k* is an optional parameter to specify the number of times (1–32767) to repeat the Relay Word row display. If *k* is not specified, the Relay Word row is displayed once. Adding **ROW** to the command displays the Relay Word Row number at the start of each line.
TAR *name k* or **TAR ROW *name k***	Shows Relay Word row containing Relay Word bit name (e.g., TAR 50C displays Relay Word Row 5). Valid names are shown in *Table 10.23*, in *Table D.1*, and in *Table D.2*. *k* is an optional parameter to specify the number of times (1–32767) to repeat the Relay Word row display. If *k* is not specified, the Relay Word row is displayed once. Adding **ROW** to the command displays the Relay Word Row number at the start of each line.
TAR LIST or **TAR ROW LIST**	Shows all the Relay Word bits in all of the rows. Adding **ROW** to the command displays the Relay Word Row number at the start of each line.
TAR R	Clears front-panel tripping target LEDs **TRIP**, **INST**, **COMM**, **SOTF**, **50**, **51**, **81**, **A**, **B**, **C**, **G**, and **N**. Unlatches the trip logic for testing purposes (see *Figure 5.1*). Shows Relay Word Row 0.

NOTE: The **TAR R** command cannot reset the latched Targets if a TRIP condition is present.

Table 10.23 SEL-351 Relay Word and Its Correspondence to TAR Command

TAR 0 (Front-Panel LEDs)	EN	TRIP	INST	COMM	SOTF	50	51	81
TAR 1 (Front-Panel LEDs)	A	B	C	G	N	RS	CY 79	LO

Command **TAR SH1 10** is executed in the following example:

```
=>TAR SH1 10 <Enter>

79RS   79CY   79LO   SH0    SH1    SH2    SH3    SH4
0      0      1      0      1      0      0      0
0      0      1      0      1      0      0      0
0      0      1      0      1      0      0      0
0      0      1      0      1      0      0      0
0      0      1      0      1      0      0      0
0      0      1      0      1      0      0      0
0      0      1      0      1      0      0      0
0      0      1      0      1      0      0      0

79RS   79CY   79LO   SH0    SH1    SH2    SH3    SH4
0      0      1      0      1      0      0      0
0      0      1      0      1      0      0      0

=>
```

Note that Relay Word row containing the SH1 bit is repeated 10 times. In this example, the reclosing relay is in the Lockout State (79LO = logical 1), and the shot is at shot = 1 (SH1 = logical 1). Command **TAR 35** will report the same data because the SH1 bit is in Row 35 of the Relay Word.

Command **TAR ROW LIST** is executed in the following example (SEL-351 with dual Ethernet.

```
=>TAR ROW LIST <Enter>
Row   EN      TRIP    INST    COMM    SOTF    50      51      81
0     1       1       0       0       0       0       1       0

Row   A       B       C       G       N       RS      CY      LO
1     0       1       0       1       0       0       0       1

Row   50A1    50B1    50C1    50A2    50B2    50C2    50A3    50B3
2     0       0       0       0       0       0       0       0

Row   50C3    50A4    50B4    50C4    50AB1   50BC1   50CA1   50AB2
3     0       0       0       0       0       0       0       0

Row   50BC2   50CA2   50AB3   50BC3   50CA3   50AB4   50BC4   50CA4
4     0       0       0       0       0       0       0       0


(86 rows not shown)


Row   VB097   VB098   VB099   VB100   VB101   VB102   VB103   VB104
90    0       0       0       0       0       0       0       0

Row   VB105   VB106   VB107   VB108   VB109   VB110   VB111   VB112
91    0       0       0       0       0       0       0       0

Row   VB113   VB114   VB115   VB116   VB117   VB118   VB119   VB120
92    0       0       0       0       0       0       0       0

Row   VB121   VB122   VB123   VB124   VB125   VB126   VB127   VB128
93    0       0       0       0       0       0       0       0

Row   SALARM  ACCESS  ALRMOUT *       HALARMA HALARMP HALARML HALARM
94    0       0       1       0       0       0       0       0

Row   *       *       PASNVAL ACCESSP GRPSW   SETCHG  CHGPASS BADPASS
95    0       0       0       0       0       0       0       0

Row   DD      LOPRST  LOPBLK  LOP2    LOP3    *       *       *
96    0       0       0       0       0       0       0       0

Row   ESTRA   ESTRB   ESTRC   ESCLA   ESCLB   ESCLC   ESOAL   MSOAL
97    0       0       0       0       0       0       0       0

Row   *       *       HBL2T   HBL2AT  HBL2BT  HBL2CT  MSTR    MSCL
98    0       0       0       0       0       0       0       0

Row   *       *       *       81R4T   81R3T   81R2T   81R1T   81RT
99    0       0       0       0       0       0       0       0

Row   *       50BFA   50BFB   50BFC   50BFT   RT      BFT     BFTRIP
101   0       0       0       0       0       0       0       0

Row   *       *       *       *       *       *       *       RSTDNPE
102   0       0       0       0       0       0       0       0

=>
```

TDP Command

Use the **TDP** command to monitor the status of and configure the SEL Livestream protocol. The Livestream protocol is disabled by default. When enabled, this Ethernet-based protocol streams certain analog/digital quantities by using a continuous stream of UDP packets. The SEL Livestream function is used for HIF testing and research purposes. Contact SEL for additional details.

Command	Description	Access Level
TDP	Show the status of the SEL Livestream protocol. This feature is used for SEL testing and research. Contact SEL for more details.	2
TDP ON	Enable the SEL Livestream protocol stream to the last used IP address and UDP port. **Note:** If the command has not been previously used, or a TDP reset has been performed, the default IP address and UDP port are used.	2

Command	Description	Access Level
TDP ON ***addr***	Enable the SEL Livestream protocol stream to the designated IP address and last used UDP port. **Note:** If the command has not been previously used, or a TDP reset has been performed, the default UDP port is used.	2
TDP ON ***addr port***	Enable the SEL Livestream protocol stream to the designated IP address and UDP port.	2
TDP OFF	Disable the SEL Livestream protocol stream.	2
TDP RESET	Disable the SEL Livestream protocol and reset the IP address and UDP port to defaults.	2

TEST DB

Use the **TEST DB** command to temporarily force the relay to send fixed analog and/or digital values over communications interfaces for protocol testing.

Command	Description	Access Level
TEST DB	Display the present status of digital and analog overrides.	B
TEST DB A ***name value***	Force protocol analog element *name* to override *value*.	B
TEST DB A Row_*x* ***value***	Force protocol digital elements in an entire Relay Word row number *x* to override *value* (PSF-1841 and DE-490) (Modbus and SEL Fast Message only).	B
TEST DB D ***name value***	Force protocol digital element *name* to override *value* (PSF-1841 and DE-490) (DNP and IEC 61850 only).	B
TEST DB ***name*** **OFF**	Clear (analog or digital) override for element *name*.	B
TEST DB OFF	Clear all analog and digital overrides.	B

⚠WARNING
To reduce the chance of a false operating decision when using the **TEST DB** command, ensure that protocol master device(s) flag the data as "forced or test data". One possible method is to monitor the TESTDB Relay Word bit.

The **TEST DB** command provides a method to override Relay Word bits or analog values to aid testing of communications interfaces. The command overrides values in the communications interfaces (SEL Fast Message, DNP, Modbus, and IEC 61850) only. The actual values used by the relay for protection and control are not changed. However, remote devices may use these analog and digital signals to make control decisions. Ensure that remote devices are properly configured to receive the overridden data before using the **TEST DB** command.

To override analog data in a communications interface, enter the following from Access Level B or higher:

```
=>>TEST DB A name value <Enter>
```

NOTE: When using the **TEST DB** command to generate values for Fast Meter testing, you may need to override all current and voltage angles (IAFA, VAFA, etc.) to ensure the expected phase relationship.

where *value* is a numerical value and *name* is an analog label from *Table E.1*, Analog Quantities, with an "x" in the DNP, Modbus, Fast Meter, or IEC 61850 column.

For example, the **TEST DB** command can be used to force the value of Phase A current magnitude transmitted to a remote device to 100 A:

```
=>>TEST DB A IA 100 <Enter>
```

NOTE: When using the **TEST DB** command, specifying a negative value may yield an unexpected display in some instances.

To override digital data in a Modbus, DNP, or IEC 61850 communications interface, enter the following from Access Level B or higher:

```
=>>TEST DB D name value <Enter>
```

where *name* is a Relay Word bit (see *Table D.1*) and *value* is 1 or 0.

For example, if Relay Word bit 51PT = logical 0, the **TEST DB** command can be used to effectively force the communicated status of this Relay Word bit to logical 1 to test the communications interface:

```
=>>TEST DB D 51PT 1 <Enter>
```

Values listed in the SER triggers SER1, SER2, and SER3 cannot be overridden.

To override digital data in a Modbus, DNP, SEL Fast Messaging, or IEC 61850 communications interface, enter the following from Access Level B or higher:

```
=>>TEST DB A Row_x value <Enter>
```

where Row_*x* is a Relay Word row number (see *Table D.1*) and *value* is 1 to 255 (the integer sum of the individual Relay Word bits to be set).

For example, Relay Word bits 51PR and 51PT are bits 1 and 2, respectively, of Relay Word Row 6. The **TEST DB** command can be used to effectively force the communicated status of these Relay Word bits to logical 1 to test the communications interface:

```
=>>TEST DB A Row_6 6 <Enter>
```

where the value of 6 is the integer value to set bits 1 and 2 of the Relay Word row ($2^1 + 2^2 = 6$).

Values listed in the SER triggers SER1, SER2, and SER3 cannot be overridden.

When the relay is not in Test Mode, the relay responds to either the digital or analog override request with the following message:

```
WARNING:  TEST MODE is not a regular operation.
Communication outputs of the device will be overridden by simulated values.

Are you sure (Y/N)? Y <Enter>
```

The relay responds:

```
Test Mode Active.  Use Test DB OFF command to exit Test Mode.

Override Added
```

Relay Word bit TESTDB will also assert to indicate that Test Mode is active. If the relay is already in the test mode (overrides are already active), the relay responds:

```
Override Added
```

The **TEST DB** command alone displays the present status of digital and analog overrides. An example **TEST DB** response after two analogs follows:

```
==>TEST DB <Enter>

FEEDER 1                         Date: 02/02/09    Time: 16:24:38.764
STATION A

NAME          OVERRIDE VALUE
IA                 100.0000
FREQ                60.0000

==>
```

Individual overrides are cleared using the **TEST DB** command with the OFF parameter:

```
=>>TEST DB D or A name OFF <Enter>
```

Entering **TEST DB OFF** without name will clear all overrides. The relay will automatically exit the Test Mode and clear all overrides if there are no **TEST DB** commands entered for 30 minutes.

TIM (View/Change Time)

TIM displays the relay clock and allows the relay clock to be set manually. If a valid IRIG-B or SNTP time synchronization signal is connected to the relay, the **TIM** command cannot be used to set the relay time. See *Configuring High-Accuracy Timekeeping* on page N.28 for more details on IRIG time sources.

Command	Description	Access Level
TIME	Display the present internal clock time.	1
TIME *hh:mm*	Set the internal clock to *hh:mm*.	1
TIME *hh:mm:ss*	Set the internal clock to *hh:mm:ss*.	1
TIME Q	Display time statistics.	1
TIME DST	Display daylight-saving time information.	1

NOTE: After setting the time, allow at least 60 seconds before powering down the relay or the new setting may be lost.

Step 1. To set the clock, type **TIM**.

Step 2. Type the desired setting.

Step 3. Press **<Enter>**.

Step 4. Separate the hours, minutes, and seconds with colons, semicolons, spaces, commas, or slashes.

To set the clock to 23:30:00, enter:

```
=>TIM 23:30:00 <Enter>
23:30:00
=>
```

If **TIM** is entered with the Q parameter, time statistics are displayed.

```
FEEDER 1                    Date: 08/07/2011    Time: 07:13:01.005
STATION A

FID=SEL-351-7-R5xx-V0-Z100100-Dxxxxxxxx   CID=83ED

UTC: 12:13:01
UTC Offset: -5.00 hrs

Time Source: HIRIG
Last Update Source: HIRIG
Active Irig Port: BNC

Last Update Time: 07:13:01  08/07/11

IRIG Time Quality: 0.0 ms

Internal Clock Period: 20.000156 ns
```

Time Source is HIRIG when Relay Word bit TSOK is asserted. Otherwise, Time Source is OTHER. Last Update Source indicates the source of the last time or date update. Valid update sources are HIRIG, IRIG, DNP, MODBUS, SNTP, ASCII DATE, ASCII TIME, FRONT PANEL DATE, and FRONT PANEL TIME. If the relay time was last updated from the battery-backed clock, such as after a loss of power, Last Update Source is NONV CLK.

When at least one source of IRIG-B time signal is connected, Active IRIG Port displays which source is in use (BNC, Port 2, or Fiber).

If setting IRIGC = C37.118 and TIRIG or TSOK is asserted, IRIG Time Quality displays the time error calculated based on information contained in the control fields of the IRIG-B signal (see *Configuring High-Accuracy Timekeeping* on page N.28).

The internal clock period shows the time associated with the processor clock. This time may change slightly when an IRIG signal is connected.

If **TIM** is entered with the DST parameter and daylight-saving time is enabled (see *Automatic Daylight-Saving Time Settings* on page 9.24), daylight-saving time information is displayed.

```
=>TIME DST <Enter>

07:50:16

Daylight Saving Time Begin Rule: 2nd Sunday of March at 02:00
Daylight Saving Time End Rule:   1st Sunday of November at 02:00

Daylight Saving Time Active

Next Daylight Saving Time Beginning: 03/11/2012 02:00
Next Daylight Saving Time Ending:    11/06/2011 02:00
```

TRI (Trigger Event Report)

Command	Description	Access Level
TRI	Trigger event report data capture.	1
TRI *time*	Trigger an event report data capture at specified time.	1
TRI STA	Display the status of a previous **TRI *time*** command.	1

Issue the **TRI** command to generate an event report:

```
=>TRI <Enter>
Triggered
=>
```

Use the optional *time* parameter to specify the exact time to trigger an event. If *time* is not specified, the event is triggered at the current time. The *time* should be input in 24-hour format (i.e., 15:11:00). If fractional seconds are input, they will be ignored.

```
=>TRI 16:00:00 <Enter>

An event will trigger at 16:00:00
=>
```

One **TRI** ***time*** command may be pending on a single port at any one time. If a **TRI** ***time*** command is entered while another command is pending, the old request will be cancelled and the new request will be pending. **TRI** commands entered without the time parameter will not affect any pending **TRI** ***time*** commands.

A **TRI STA** command may be used if a **TRI** ***time*** command is pending.

The following shows the output from an SEL-351:

```
=>TRI STA <Enter>

An event will trigger at 16:00:00
=>
```

If the trigger has already been executed, or no trigger was set, the relay responds as follows:

```
=>TRI STA <Enter>

No trigger time set
=>
```

If the serial port AUTO setting = Y, the relay sends the summary event report:

```
FEEDER 1                          Date: 02/02/09    Time: 12:57:01.737
STATION A

Event: TRIG  Location: $$$$$$$  Shot: 2  Frequency:  60.00
Targets:
Currents (A Pri), ABCNGQ:    235   236   237     0     2     0
=>
```

See *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER* for more information on event reports.

VEC (Show Diagnostic Information)

Issue the **VEC** command under SEL's direction.

Command	Description	Access Level
VEC D	Display the standard Vector Report.	2
VEC E	Display the Extended Vector Report.	2

The information contained in a vector report is formatted for SEL in-house use only. Your SEL application engineer or the factory may request a **VEC** command capture to help diagnose a relay or system problem.

VER (Show Relay Configuration and Firmware Version)

The **VER** command provides relay configuration and information such as nominal current input ratings.

Command	Description	Access Level
VER	Display information about the configuration of the relay.	1

An example printout of the **VER** command for an SEL-351 follows:

```
=>>VER <Enter>
Partnumber:  035173C3E14XX2
Serial Number:  2009xxxxxx

Analog Input Voltage (PT):  300 Vac, Wye, Delta, or Single connected
Analog Input Current (CT):  1 Amp Phase, 1 Amp Neutral
Main Board I/O:  2 High I/C Outputs, 6 Standard Outputs, 6 Inputs

Relay Features:
  DNP
  Modbus
  IEC61850
  IEEE C37.118
  Voltage Sag/Swell/Interruption Elements
  Power Elements
  Mirrored Bits
  Load Profile
  Enhanced Integration Bits & Fast SER
  Two 10/100BASE-T Ports
  EIA-485
  USB

SELboot checksum 58FF OK
FID=SEL-351-7-R5xx-V0-Zxxxxxx-D2009xxxx

BFID=SLBT-3CF1-R1xx-V0-Zxxxxxx-D2009xxxx

If above information is unexpected. . .
contact SEL for assistance
=>>
```

SEL-351-5, -6, -7 Command Summary

Command	Description
2AC	Enter Access Level 2. If the main board Access jumper is not in place, the relay prompts for the entry of the Access Level 2 password.
ACC	Enter Access Level 1. If the main board Access jumper is not in place, the relay prompts for the entry of the Access Level 1 password.
BAC	Enter Breaker Access Level (Access Level B). If the main board Access jumper is not in place, the relay prompts the user for the Access Level B password.
BNA	Display names of status bits in the A5D1 Fast Meter Message.
BRE	Display breaker monitor data (trips, interrupted current, wear).
BRE H	Display breaker history.
BRE R	Reset breaker monitor.
BRE W	Preload breaker wear.
CAL	Enter Access Level C. If the main board Access jumper is not in place, the relay prompts for the entry of the Access Level C password. Access Level C is reserved for SEL use only.
CAS	Display compressed ASCII configuration message.
CEV *n*	Display event report *n* in compressed ASCII format.
CHI	Display history data in compressed ASCII format.
CLO	Close circuit breaker (assert Relay Word bit CC).
COM *n*[a]	Show communications summary report (COM report) on MIRRORED BITS channel *n* (where *n* = A or B) using all failure records in the channel calculations.
COM *n row1*[a]	Show a COM report for MIRRORED BITS channel *n* using the latest *row1* failure records (*row1* = 1–255, where 1 is the most recent entry).
COM *n row1 row2*[a]	Show COM report for MIRRORED BITS channel *n* using failure records *row1–row2* (*row1* = 1–255).
COM *n date1*[a]	Show COM report for MIRRORED BITS channel *n* using failures recorded on date *date1* (see **DAT** command for date format).
COM *n date1 date2*[a]	Show COM report for MIRRORED BITS channel *n* using failures recorded between dates *date1* and *date2* inclusive.
COM . . . L[a]	For all **COM** commands, L causes the specified COM report records to be listed after the summary.
COM *n* C[a]	Clears communications records for MIRRORED BITS channel *n* (or both channels if *n* is not specified, **COM C** command).
CON *n*	Control Relay Word bit RB*n* (Remote Bit *n*; *n* = 1–32). Execute **CON *n*** and the relay responds: CONTROL RB*n*. Then reply with one of the following: **SRB *n*** set Remote Bit *n* (assert RB*n*). **CRB *n*** clear Remote Bit *n* (deassert RB*n*). **PRB *n*** pulse Remote Bit *n* (assert RB*n* for 1/4 cycle).
COP *m n*	Copy relay and logic settings from group *m* to group *n* (*m* and *n* are numbers 1–6).
COP D *m n*	Copy DNP map *m* to map *n* (*m* and *n* are numbers 1–3).
CST	Display relay status in compressed ASCII format.
CSU	Display summary event report in compressed ASCII format.
DAT	Show date.
DAT mm/dd/yy	Enter date in this manner if Global Date Format setting, DATE_F, is set to MDY.
DAT yy/mm/dd	Enter date in this manner if Global Date Format setting, DATE_F, is set to YMD.
DNA X or T	Display names of Relay Word bits included in the A5D1 Fast Meter message. Either X or T is mandatory and both are identical.

Command	Description
ETH	Display the Ethernet port configuration and status.
ETH C	Clear Ethernet port statistics.
EVE *n*	Show event report *n* with 4 samples per cycle (*n* = 1 to highest numbered event report, where 1 is the most recent report: see **HIS** command). If *n* is omitted (**EVE** command), most recent report is displayed.
EVE *n* A	Show event report *n* with analog section only.
EVE *n* C	Show event report *n* in compressed ASCII format with 16 samples-per-cycle analog resolution and 4 samples-per-cycle digital resolution.
EVE *n* D	Show event report *n* with digital section only.
EVE *n* L	Show event report *n* with 32 samples per cycle (similar to **EVE *n* S32**).
EVE *n* L*y*	Show first *y* cycles of event report *n* (*y* = 1 to Global setting LER).
EVE *n* M[a]	Show event report *n* with communications section only.
EVE *n* P	Show event report *n* with synchrophasor-level accuracy time adjustment.
EVE *n* R	Show event report *n* in raw (unfiltered) format with 32 samples-per-cycle resolution.
EVE *n* S*x*	Show event report *n* with *x* samples per cycle (*x* = 4, 16, 32, or 128). Must append R parameter for S128 (**EVE S128 R**)
EVE *n* V	Show event report *n* with variable scaling for analog values.
EXI	Terminate Telnet session.
FIL DIR	Display a list of available files.
FIL READ *filename*	Transfer settings file *filename* from the relay to the PC.
FIL SHOW *filename*	Display contents of file *filename*.
FIL WRITE *filename*	Transfer settings file *filename* from the PC to the relay.
GOO	Display GOOSE transmit and receive information.
GOO *k*	Display GOOSE information *k* times.
GOO S	Display a list of GOOSE subscriptions with their ID.
GOO S *n*	Display GOOSE statistics for subscription ID *n*.
GOO S ALL	Display GOOSE statistics for all subscriptions.
GOO S *n* L	Display GOOSE statistics for subscription ID *n* including error history.
GOO S ALL L	Display GOOSE statistics for all subscriptions including error history.
GOO S *n* C	Clear GOOSE statistics for subscription ID *n*.
GOO S ALL C	Clear GOOSE statistics for all subscriptions.
GRO	Display active group number.
GRO *n*	Change active group to group *n* (*n* = 1–6).
HIS *n*	Show brief summary of *n* latest event reports, where 1 is the most recent entry. If *n* is not specified, (**HIS** command) all event summaries are displayed.
HIS C	Clear all event reports from nonvolatile memory.
HIS E	Same as **HIS** command except that reports have unique identification numbers in the range 10000 to 65535.
ID	Display relay configuration.
L_D	Prepares the relay to receive new firmware.
LDP[a]	Show entire Load Profile (LDP) report.
LDP[a] ***n***	Show latest *n* rows in the LDP report (*n* = 1 to several thousand, where 1 is the most recent entry).
LDP[a] ***m n***	Show rows *m*–*n* in the LDP report (*m* = 1 to several thousand).
LDP[a] ***date1***	Show all rows in the LDP report recorded on the specified date (see **DAT** command for date format).
LDP[a] ***date1 date2***	Show all rows in the LDP report recorded between dates *date1* and *date2*, inclusive.

Command	Description
LDP[a] C	Clears the LDP report from nonvolatile memory.
LDP[a] D	Display the number of days of LDP storage capacity before data overwrite will occur.
LOO[a] *n t*	Set MIRRORED BITS channel *n* to loopback (*n* = A or B). The received MIRRORED BITS elements are forced to default values during the loopback test; *t* specifies the loopback duration in minutes (*t* = 1–5000, default is 5).
LOO[a] *n* DATA	Set MIRRORED BITS channel *n* to loopback. DATA allows the received MIRRORED BITS elements to change during the loopback test.
LOO[a] *n* R	Cease loopback on MIRRORED BITS channel *n* and return the channel to normal operation.
MAC	Display Ethernet MAC address.
MET *k*	Display instantaneous metering data. Enter *k* for repeat count (*k* = 1–32767, if not specified, default is 1).
MET X *k*	Display same as **MET** command with phase-to-phase voltages and Vbase. Enter *k* for repeat count (*k* = 1–32767, if not specified, default is 1).
MET D	Display demand and peak demand data. Select **MET RD** or **MET RP** to reset.
MET E	Display energy metering data. Select **MET RE** to reset.
MET H	Display THD and harmonic metering data.
MET M	Display maximum/minimum metering data. Select **MET RM** to reset.
MET PM *time*	Display synchrophasor measurements (available when TSOK = logical 1). Enter *time* to display the synchrophasor for an exact specified time, in 24-hour format.
MET PM *k*	Display synchrophasor measurements (available when TSOK = logical 1). Enter *k* for repeat count.
MET PM HIS	Display the most recent **MET PM** synchrophasor report.
OPE	Assert the open command Relay Word bit OC.
PAR	Change the device part number. Use only under the direction of SEL.
PAS 1	Change Access Level 1 password.
PAS B	Change Access Level B password.
PAS 2	Change Access Level 2 password.
PAS C	Change the Access Level C password.
PIN	Ping command.
PUL *n k*	Pulse output contact *n* (where *n* is one of ALARM, ALRMOUT, OUT101–OUT107, OUT201–OUT212) for *k* seconds. *k* = 1–30 seconds; if not specified, default is 1.
QUI	Quit. Returns to Access Level 0.
R_S	Restore factory default settings. Use only under the direction of SEL. Only available under certain conditions.
SER	Show entire Sequential Events Recorder (SER) report.
SER *row1*	Show latest *row1* rows in the SER report (*row1* = 1–1024, where 1 is the most recent entry).
SER *row1 row2*	Show rows *row1–row2* in the SER report.
SER *date1*	Show all rows in the SER report recorded on the specified date (see **DAT** command for date format).
SER *date1 date2*	Show all rows in the SER report recorded between dates *date1* and *date2*, inclusive.
SER C	Clears SER report from nonvolatile memory.
SET *n*	Change relay settings (overcurrent, reclosing, timers, etc.) for Group *n* (*n* = 1–6, if not specified, default is active setting group).
SET *n* L	Change SELOGIC control equation settings for Group *n* (*n* = 1–6, if not specified, default is the SELOGIC control equations for the active setting group).
SET D	Change DNP settings.
SET G	Change Global settings.
SET M	Change Modbus settings.
SET P *p*	Change serial port *p* settings (*p* = 1, 2, 3, F, or 5; if not specified, default is active port).

Command	Description
SET R	Change SER and LDP Recorder[a] settings.
SET T	Change text label settings.
SET . . . *name*	For all **SET** commands, jump ahead to specific setting by entering setting name.
SET . . . TERSE	For all **SET** commands, TERSE disables the automatic **SHO** command after settings entry.
SHO *n*	Show relay settings (overcurrent, reclosing, timers, etc.) for Group *n* (*n* = 1–6, if not specified, default is active setting group).
SHO *n* L	Show SELOGIC control equation settings for Group *n* (*n* = 1–6, if not specified, default is the SELOGIC control equations for the active setting group).
SHO D	Show DNP settings.
SHO G	Show Global settings.
SHO M	Show Modbus settings.
SHO P *p*	Show serial port *p* settings (*p* = 1, 2, 3, or F; if not specified, default is active port).
SHO R	Show SER and LDP Recorder[a] settings.
SHO T	Show text label settings.
SHO . . . *name*	For all **SHO** commands, jump ahead to specific setting by entering setting name.
SNS	Display the Fast Message name string of the SER settings.
SSI[b]	Show entire Voltage Sag/Swell/Interruption (SSI) report.
SSI[b] *row1*	Show latest *row1* rows in SSI report (*row1* = 1 to several thousand, where 1 is the most recent entry).
SSI[b] *row1 row2*	Show rows *row1*–*row2* in SSI report.
SSI[b] *date1*	Show all rows in SSI report recorded on the specified date (see **DAT** command for date format).
SSI[b] *date1 date2*	Show all rows in SSI report recorded between dates *date1* and *date2*, inclusive.
SSI[b] C	Clears SSI report from nonvolatile memory.
SSI[b] R	Resets Vbase element. See Vbase initialization.
SSI[b] T	Trigger the SSI recorder.
STA	Show relay self-test status.
STA C	Resets self-test warnings/failures and reboots the relay.
SUM *n*	Shows event report summary for event *n*.
SUM ACK	Acknowledge oldest unacknowledged summary event report.
SUM N	Shows event report summary for oldest unacknowledged report.
TAR *n k*	Display Relay Word row. If *n* = 0–67, display row *n*. If *n* is an element name (e.g., 50A1), display row containing element *n*. Enter *k* for repeat count (*k* = 1–32767, if not specified, default is 1).
TAR LIST	Shows all the Relay Word bits in all of the rows.
TAR R	Reset front-panel tripping targets.
TAR ROW. . .	Shows the Relay Word row number at the start of each line, with other selected **TARGET** commands as described above, such as *n*, *name*, *k*, and LIST.
TDP	Show the status of the SEL Livestream protocol. This feature is used for SEL testing and research. Contact SEL for more details.
TDP ON	Enable the SEL Livestream protocol stream to the last used IP address and UDP port. **Note:** If the command has not been previously used, or a TDP reset has been performed, the default IP address and UDP port are used.
TDP ON *addr*	Enable the SEL Livestream protocol stream to the designated IP address and last used UDP port. **Note:** If the command has not been previously used, or a TDP reset has been performed, the default UDP port is used.
TDP ON *addr port*	Enable the SEL Livestream protocol stream to the designated IP address and UDP port.
TDP OFF	Disable the SEL Livestream protocol stream.

Command	Description
TDP RESET	Disable the SEL Livestream protocol and reset the IP address and UDP port to defaults.
TEST DB A ***name value***	Override analog label *name* with *value* in communications interface.
TEST DB D ***name value***	Override Relay Word bit *name* with *value* in communications interface, where *value* = 0 or 1.
TIM	Show or set time (24-hour time). Show current relay time by entering **TIM**. Set the current time by entering **TIM** followed by the time of day (e.g., set time 22:47:36 by entering **TIM 22:47:36**).
TIM DST	Display daylight-saving time information.
TIM Q	Display time statistics.
TRI ***time***	Trigger an event report. Enter *time* to trigger an event at an exact specified time, in 24-hour format.
VEC	Display standard vector troubleshooting report (useful to the factory in troubleshooting).
VER	Show relay configuration and firmware version.

[a] Available in firmware versions 6 and 7.
[b] Available in firmware version 7.

Key Stroke Commands

Key Stroke	Description	Key Stroke When Using SET Command	Description
Ctrl + Q	Send **XON** command to restart communications port output previously halted by XOFF.	**<Enter>**	Retains setting and moves on to next setting.
Ctrl + S	Send **XOFF** command to pause communications port output.	**^<Enter>**	Returns to previous setting.
Ctrl + X	Send **CANCEL** command to abort current command and return to current access level prompt.	**<<Enter>**	Returns to previous setting section.
		><Enter>	Skips to next setting section.
		END <Enter>	Exits setting editing session, then prompts user to save settings.
		Ctrl + X	Aborts setting editing session without saving changes.

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SECTION 11

Front-Panel Interface

Overview

This section describes how to get information, make settings, and execute control operations from the relay front panel. It also describes the default displays.

This section discusses the following functions in detail:

- ➤ *Front-Panel Pushbutton Operation* on page 11.1
- ➤ *Functions Unique to the Front-Panel Interface* on page 11.5
- ➤ *Rotating Display* on page 11.10

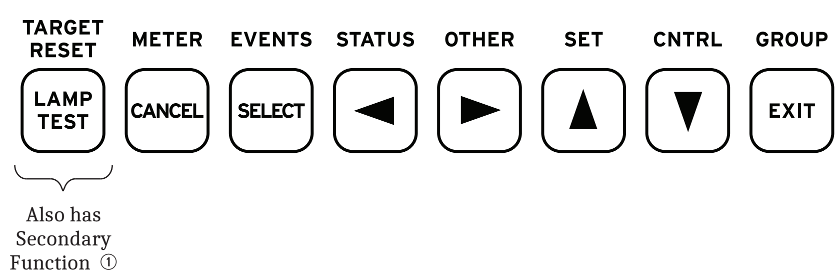
Front-Panel Pushbutton Operation

Overview

Note in *Figure 11.1* that most of the pushbuttons have dual functions (primary/ secondary).

The primary functions are shown above the buttons. A primary function is selected first (e.g., **METER** pushbutton).

After a primary function is selected, the pushbuttons operate on their secondary functions, which are shown on the face of the buttons (**CANCEL**, **SELECT**, left/right arrows, up/down arrows, **EXIT**). For example, after the **METER** pushbutton is pressed, the up/down arrows are used to scroll through the front-panel metering screens. The primary functions are active again when the selected function (metering) is exited by pressing the **EXIT** pushbutton. The front panel reverts to the default display and the primary functions are active after there is no front-panel activity for a time determined by Global setting FP_TO (see *Front-Panel Display Operation (see Section 11)* on page SET.1). The relay is shipped with FP_TO = 15 minutes.



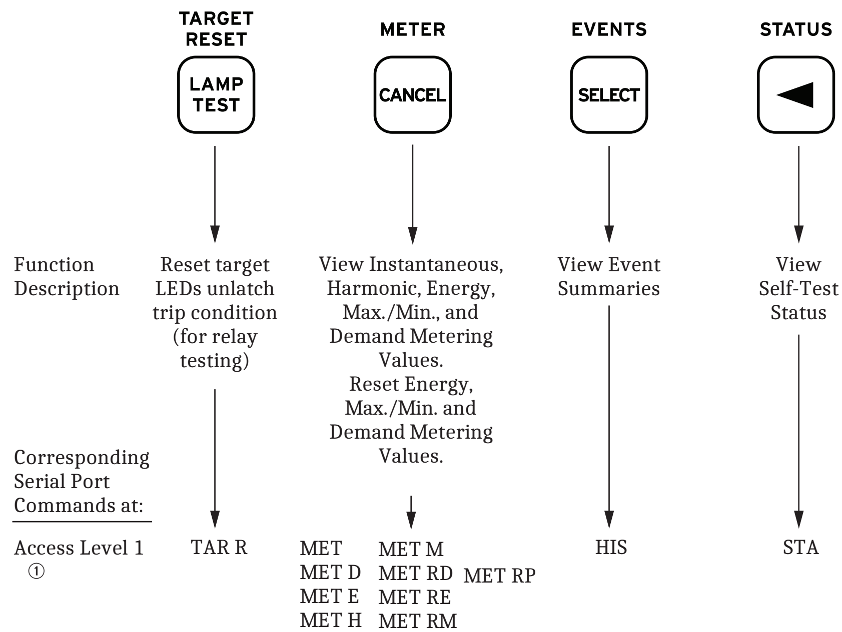
① See *Figure 11.4*.

Figure 11.1 Front-Panel Pushbuttons—Overview

Primary Functions

Note in *Figure 11.2* and *Figure 11.3* that the front-panel pushbutton primary functions correspond to serial port commands—both retrieve the same information or perform the same function. To get more detail on the information provided by the front-panel pushbutton primary functions, refer to the corresponding serial port commands in *Table 10.19*. For example, to get more information on the metering values available via the front-panel **METER** pushbutton, refer to ***MET*** *(Metering Data)* on page 10.55.

Some of the front-panel primary functions do *not* have serial port command equivalents. These are discussed in *Functions Unique to the Front-Panel Interface* on page 11.5.



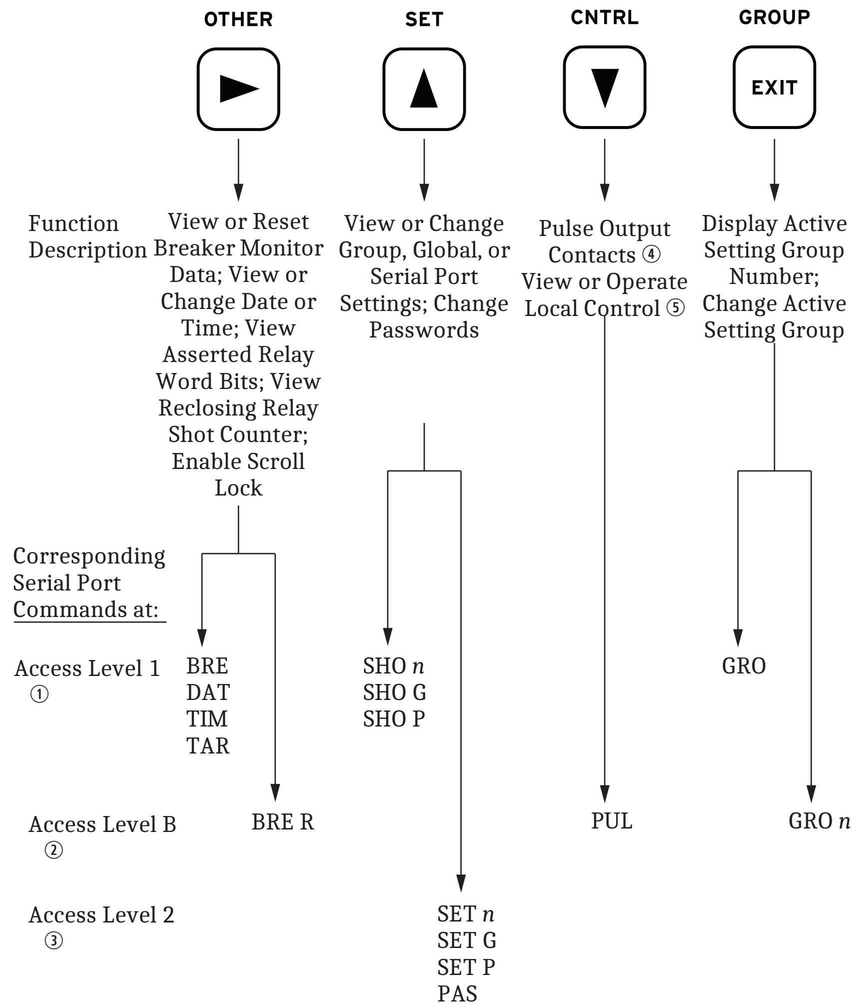
① Front-panel pushbutton functions that correspond to Access Level 1 serial port commands do **not** require the entry of the Access Level 1 password through the front panel.

Figure 11.2 Front-Panel Pushbuttons—Primary Functions

Front-Panel Password Security

Certain front-panel operations require a password. Refer to the comments at the bottom of *Figure 11.3* concerning Access Level B and Access Level 2 passwords. See ***PAS*** *(Change Passwords)* on page 10.64 for the list of default passwords and for more information on changing passwords.

The relay will prompt for the password when required. To enter the Access Level B and Access Level 2 passwords from the front panel, use the left/right arrow pushbuttons to underscore a password character position. Use the up/down arrow pushbuttons to change the character. Advance to the next character positions using the right arrow pushbutton. Once the last character has been selected, press the **SELECT** pushbutton to enter the password.



① Front-panel pushbutton functions that correspond to Access Level 1 serial port commands do **not** require the entry of the Access Level 1 password through the front panel.

② Front-panel pushbutton functions that correspond to Access Level B serial port commands **do** require the entry of the Access Level B or Access Level 2 passwords through the front panel **if** the main board Access jumper is not in place (see *Access and Breaker Jumpers* on page 2.40).

③ Front-panel pushbutton functions that correspond to Access Level 2 serial port commands **do** require the entry of the Access Level 2 password through the front panel **if** the main board Access jumper is not in place (see *Access and Breaker Jumpers* on page 2.40).

④ Output contacts are pulsed for only one second from the front panel.

⑤ Local control is **not** available through the serial port and does **not** require the entry of a password.

Figure 11.3 Front-Panel Pushbuttons—Primary Functions

Secondary Functions

After a primary function is selected (see *Figure 11.2* and *Figure 11.3*), the pushbuttons then revert to operating on their secondary functions (see *Figure 11.4*).

Use the left/right arrows to underscore a desired function, then press the **SELECT** pushbutton to select the function.

Use the left/right arrows to underscore a desired setting digit or underscore a desired function, then use the up/down arrows to change the setting digit or scroll up or down in the display. Press the **SELECT** pushbutton to enter the setting or select the displayed option.

Press the **CANCEL** pushbutton to abort a setting change procedure or escape to a higher menu level. Press the **EXIT** pushbutton to return to the default display and have the primary pushbutton functions activated again (see *Figure 11.2* and *Figure 11.3*).

NOTE: When viewing the harmonic metering data, the left, right, up, and down arrows allow navigation to adjacent columns or rows of the MET H report. See ***MET** (Metering Data)* on page 10.55.

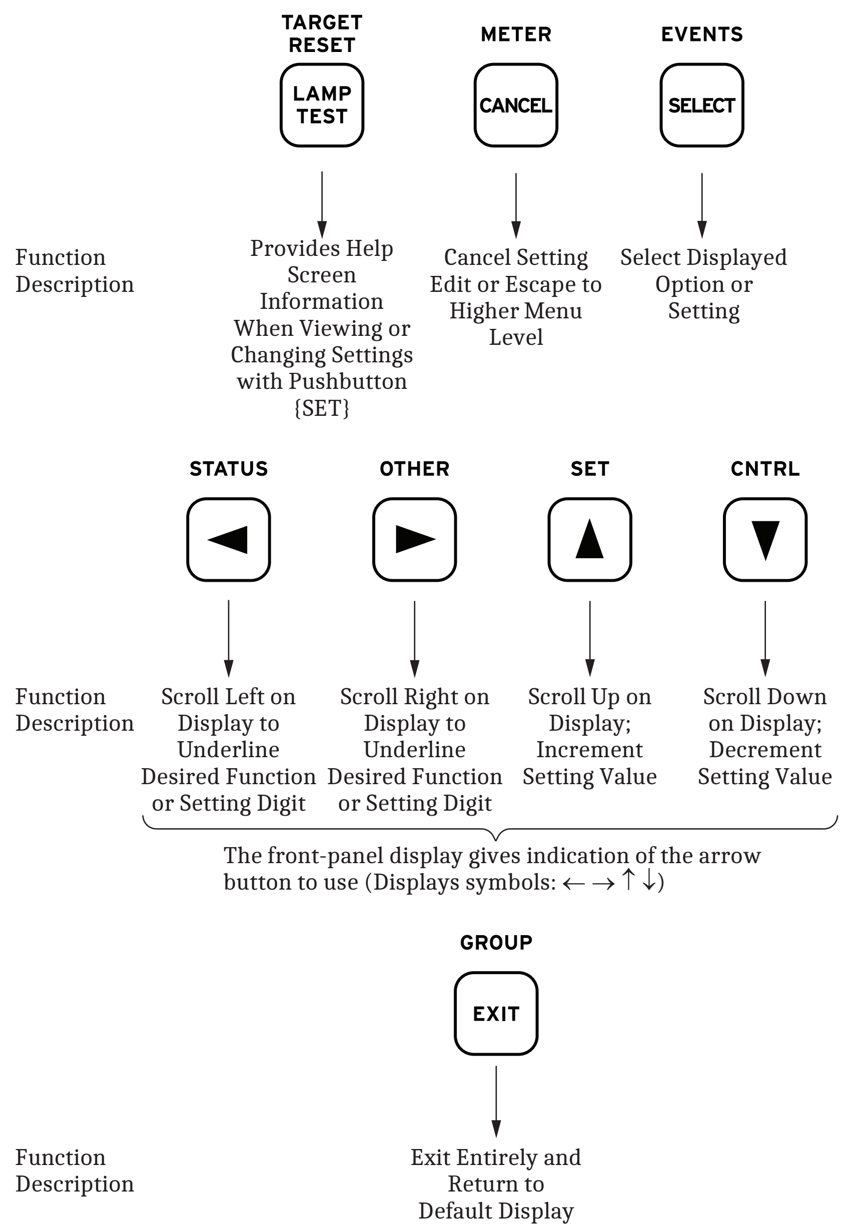


Figure 11.4 Front-Panel Pushbuttons—Secondary Functions

Functions Unique to the Front-Panel Interface

Three front-panel primary functions do *not* have serial port command equivalents. These are:

- ➤ Reclosing relay shot counter screen (accessed via the **OTHER** pushbutton)
- ➤ Local control (accessed via the **CNTRL** pushbutton)
- ➤ Modified rotating display with scroll lock control (accessed via the **OTHER** pushbutton)

Reclosing Relay Shot Counter Screen

Use this screen to see the progression of the shot counter during reclosing relay testing.

Access the reclosing relay shot counter screen via the **OTHER** pushbutton. The following screen appears:

```
DATE   TIME  79
TAR BRK_MON LCD
```

Scroll right with the right arrow pushbutton and select function `79` using the **SELECT** pushbutton. Upon selecting function `79`, the following screen appears (shown here with example settings):

```
SET RECLOSURES=2
RECLOSE COUNT =0
```

or

```
SET RECLOSURES=2
RECLOSE COUNT =2
```

If the reclosing relay does not exist (see *Reclosing Relay* on page 6.12), the following screen appears:

```
No Reclosing set
```

The corresponding text label settings (shown with factory default settings) are:

79LL = **SET RECLOSURES** (Last Shot Label—limited to 14 characters)

79SL = **RECLOSE COUNT** (Shot Counter Label—limited to 14 characters)

These text label settings are set with the **SET T** command or viewed with the **SHO T** command via the serial port (see *Section 9: Setting the Relay* and ***SHO** (Show/View Settings)* on page 10.68).

The top numeral in the above example screen (SET RECLOSURES=2) corresponds to the "last shot" value, which is a function of the number of set open intervals. There are two set open intervals in the factory default settings, thus two reclosures (shots) are possible in a reclose sequence.

The bottom numeral in the above example screen [RECLOSE COUNT = 0 (or = 2)] corresponds to the "present shot" value. If the breaker is closed and the reclosing relay is reset (**RS** LED on front panel is illuminated), RECLOSE COUNT = 0. If the breaker is open and the reclosing relay is locked out after a reclose sequence (**LO** LED on front panel is illuminated), RECLOSE COUNT = 2.

Reclosing Relay Shot Counter Screen Operation (With Example Settings)

The Group settings used for the following example are:

- E79 = 2
- 79OI1 = 30 cycles
- 79OI2 = 600 cycles

With the breaker closed and the reclosing relay in the reset state (front-panel **RS** LED illuminated), the reclosing relay shot counter screen appears as:

```
SET RECLOSURES=2
RECLOSE COUNT =0
```

The relay trips the breaker open, and the reclosing relay goes to the reclose cycle state (front-panel **CY** LED illuminates). The reclosing relay shot counter screen still appears as:

```
SET RECLOSURES=2
RECLOSE COUNT =0
```

The first open interval (e.g., 79OI1 = 30) times out, the shot counter increments from 0 to 1, and the relay recloses the breaker. The reclosing relay shot counter screen shows the incremented shot counter:

```
SET RECLOSURES=2
RECLOSE COUNT =1
```

The relay trips the breaker open again. The reclosing relay shot counter screen still appears as:

```
SET RECLOSURES=2
RECLOSE COUNT =1
```

The second open interval (e.g., 79OI2 = 600) times out, the shot counter increments from 1 to 2, and the relay recloses the breaker. The reclosing relay shot counter screen shows the incremented shot counter:

```
SET RECLOSURES=2
RECLOSE COUNT =2
```

If the relay trips the breaker open again, the reclosing relay goes to the lockout state (front-panel **LO** LED illuminates). The reclosing relay shot counter screen still appears as:

```
SET RECLOSURES=2
RECLOSE COUNT =2
```

If the breaker is closed, the reclosing relay reset timer times out (e.g., 79RSLD = 300), the relay goes to the reset state (front-panel **LO** LED extinguishes and **RS** LED illuminates), and the shot counter returns to 0. The reclosing relay shot counter screen appears as:

```
SET RECLOSURES=2
RECLOSE COUNT =0
```

Local Control

Use local control to enable/disable schemes, trip/close breakers, etc., via the front panel.

In more specific terms, local control asserts (sets to logical 1) or deasserts (sets to logical 0) what are called local bits LB1 through LB16. These local bits are available as Relay Word bits and are used in SELogic control equations (see Rows 25 and 26 in *Table D.1*).

Local control can emulate the following switch types in *Figure 11.5* through *Figure 11.7*.

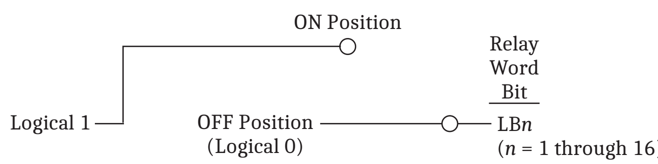


Figure 11.5 Local Control Switch Configured as an ON/OFF Switch

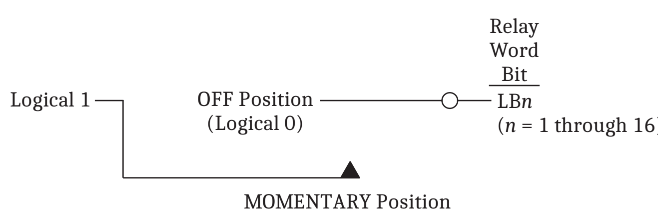


Figure 11.6 Local Control Switch Configured as an OFF/MOMENTARY Switch

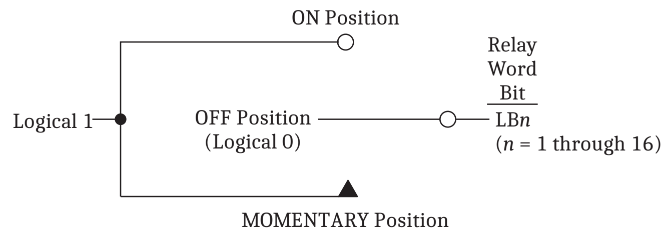


Figure 11.7 Local Control Switch Configured as an ON/OFF/MOMENTARY Switch

Local control switches are created by making corresponding switch position label settings. These text label settings are set with the **SET T** command or viewed with the **SHO T** command via the serial port (see *Section 9: Setting the Relay* and ***SHO** (Show/View Settings)* on page 10.68). See *Local Control Switches* on page 7.5 for more information on local control.

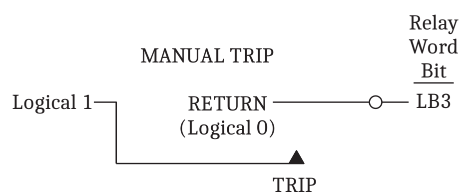
View Local Control (With Factory Settings)

Access local control via the **CNTRL** pushbutton. If local control switches exist (i.e., corresponding switch position label settings were made), the following message displays with the rotating default display messages.

```
Press CNTRL for
Local Control
```

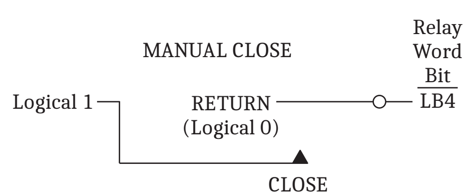
Press the **CNTRL** pushbutton, and the first set local control switch displays (shown here with factory default settings):

```
MANUAL TRIP ←→
Position: RETURN
```



Press the right arrow pushbutton, and scroll to the next example local control switch:

```
MANUAL CLOSE 1←→
Position: RETURN
```



The `MANUAL TRIP: RETURN/TRIP` and `MANUAL CLOSE: RETURN/CLOSE` switches are both OFF/MOMENTARY switches (see *Figure 11.6*).

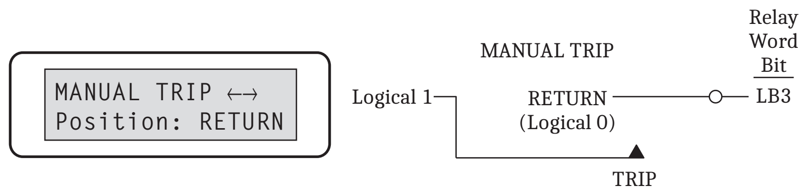
There are no more local control switches in the factory default settings. Press the right arrow pushbutton, and scroll to the `Output Contact Testing` function:

```
Output Contact←→
Testing
```

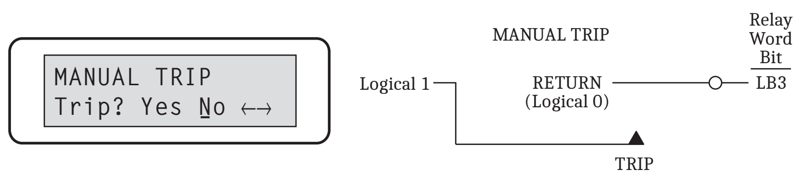
This front-panel function provides the same function as the serial port **PUL** command (see *Figure 11.3*).

Operate Local Control (With Factory Settings)

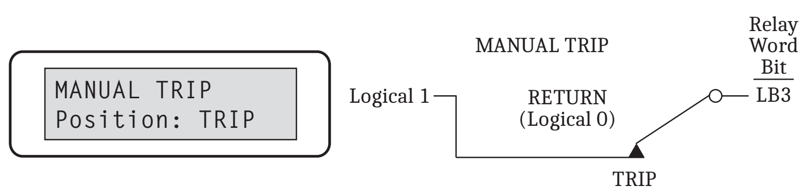
Press the right arrow pushbutton, and scroll back to the first set local control switch in the factory default settings:



Press the **SELECT** pushbutton, and the operate option for the displayed local control switch displays:



Scroll left with the left arrow pushbutton and then select `Yes`. The display then shows the new local control switch position:



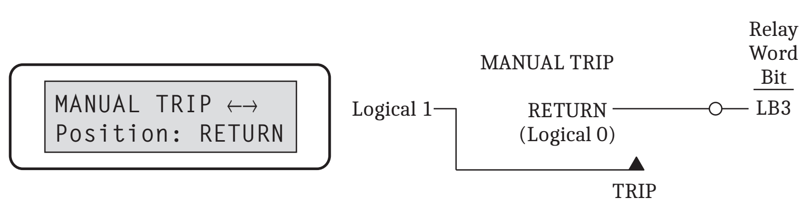
Because this is an OFF/MOMENTARY type switch, the `MANUAL TRIP` switch returns to the `RETURN` position after momentarily being in the `TRIP` position. Technically, the `MANUAL TRIP` switch (being an OFF/MOMENTARY type switch) is in the:

> `TRIP` position for one processing interval (1/4 cycle) which is long enough to assert the corresponding local bit LB3 to logical 1.

and then returns to the:

> `RETURN` position (local bit LB3 deasserts to logical 0 again).

On the display, the `MANUAL TRIP` switch is shown to be in the `TRIP` position for two seconds (long enough to be seen), and then it returns to the `RETURN` position:



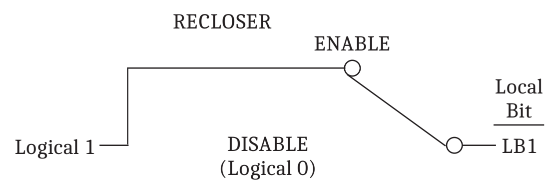
The `MANUAL CLOSE` switch is an OFF/MOMENTARY type switch, like the `MANUAL TRIP` switch, and operates similarly.

See *Local Control Switches* on page 7.5 for details on how local bit outputs LB3 and LB4 are set in SELOGIC control equation settings to respectively trip and close a circuit breaker.

Local Control State Retained When Relay De-Energized

Local bit states are stored in nonvolatile memory, so when power to the relay is turned off, the local bit states are retained.

For example, suppose the local control switch with local bit output LB1 is configured as an ON/OFF type switch (see *Figure 11.5*). Additionally, suppose it is used to enable/disable reclosing. If local bit LB1 is at logical 1, reclosing is enabled:



If power to the relay is turned off and then turned on again, local bit LB1 remains at logical 1, and reclosing is still enabled. This is akin to a traditional panel, where enabling/disabling of reclosing and other functions is accomplished by panel-mounted switches. If dc control voltage to the panel is lost and then restored again, the switch positions are still in place. If the reclosing switch is in the enable position (switch closed) before the power outage, it will be in the same position after the outage when power is restored.

In the factory default settings, the reclose enable/disable function is provided by optoisolated input **IN102** with the following SELOGIC control equation drive-to-lockout setting:

79DTL = **OC + !IN102 + LB3** =OC + NOT(IN102) + LB3

Local bit LB3 is the output of the previously discussed local control switch configured as a manual trip switch. The relay is driven to lockout for any manual trip via LB3.

Relay Word bit OC asserts when the serial port **OPEN** command is executed. Assuming that an **OPEN** command has not been executed and LB3 has not asserted, when input **IN102** is energized (IN102 = logical 1), reclosing is enabled (not driven-to-lockout):

79DTL = **OC + !IN102 + LB3** = logical 0 + !(logical 1) + logical 0 = logical 0

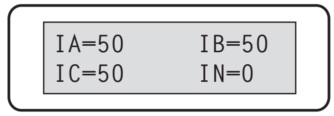
If local bit LB1 is substituted for input **IN102** to provide the reclose enable/disable function, the SELOGIC control equation drive-to-lockout setting is set as follows:

79DTL = **!LB1 + LB3** [=NOT(LB1) + LB3]

See *Drive-to-Lockout and Drive-to-Last Shot Settings (79DTL and 79DLS, Respectively)* on page 6.22 for more information on setting 79DTL.

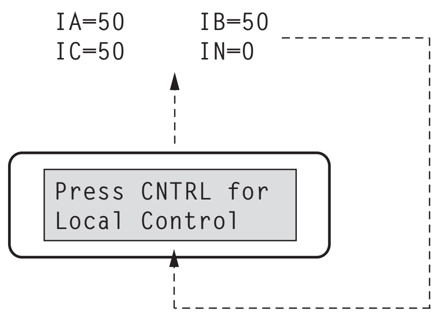
Rotating Display

With factory-default settings, the channel **IA**, **IB**, **IC**, and **IN** current values (in A primary) display continually if no local control is operational (i.e., no local control switches are enabled) and no display point labels are enabled for display.



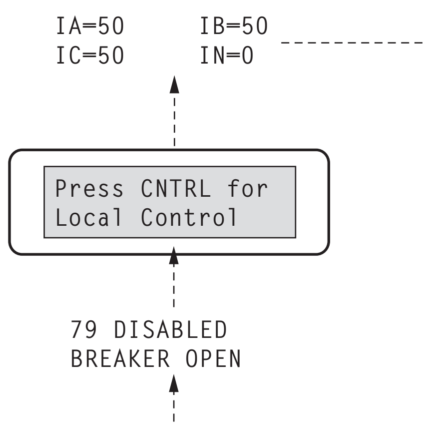
Global setting FPNGD determines whether **IN** (current channel IN) or **IG** (residual ground current) displays in the lower right-hand corner, or whether the lower right-hand corner is blank. See *Front-Panel Neutral/Ground Current Display* on page 11.14.

The `Press CNTRL for Local Control` message displays in rotation with the default metering screen if at least one local control switch is operational. It is a reminder of how to access the local control function. See the preceding discussion in this section and *Local Control Switches* on page 7.5 for more information on local control.



If display point labels (e.g., `79 DISABLED` and `BREAKER OPEN`) are enabled for display, they also enter into the display rotation.

Global setting SCROLD determines how long each message is displayed, settable from 1 to 60 seconds.



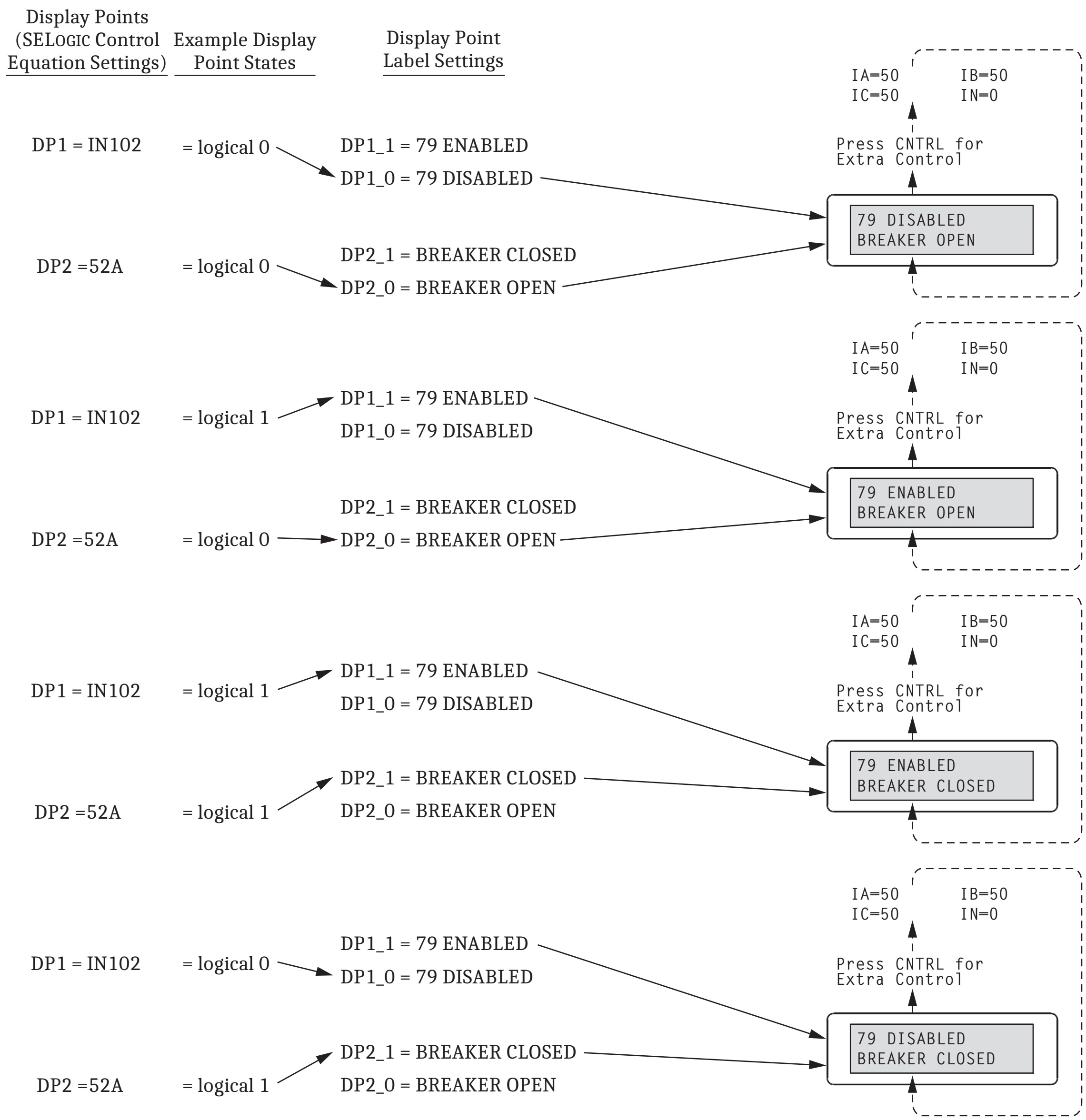
The following table and figures demonstrate the correspondence between display point logic equations (e.g., DP1 and DP2) and enabled display point labels (DP1_1/DP1_0 and DP2_1/DP2_0, respectively).

The display point example settings are:

DP1 = **IN102** (optoisolated input **IN102**)

DP2 = **52A** (breaker status, see *Figure 7.3*)

In this example, optoisolated input **IN102** is used to enable/disable the recloser. 52A is the circuit breaker status. See *Optoisolated Inputs* on page 7.1.



In the preceding example, only two display points (DP1 and DP2) and their corresponding display point labels are set. If additional display points and corresponding display point labels are set, the additional enabled display point labels join the rotation on the front-panel display. The display time is controlled with the SCROLD setting, which is made with the **SET G** command and can be viewed with the **SHO G** command. SCROLD can also be found in ACSELERATOR QuickSet SEL-5030 software Global, General settings.

Display point label settings are set with the **SET T** command or viewed with the **SHO T** command (see *Section 9: Setting the Relay* and ***SHO*** *(Show/View Settings)* on page 10.68). Display point label settings can also be found in QuickSet Text, Display Point Labels settings.

For more detailed information on the logic behind the rotating default display, see *Rotating Display* on page 7.37.

Scroll Lock Control of Front-Panel LCD

The rotating default display can be locked on a single screen. Access the scroll lock control with the **OTHER** pushbutton.

```
DATE   TIME  79
TAR BRK_MON LCD
```

Select LCD for Scroll Lock Control mode. The rotating display will then appear, and the scroll mode reminder screen will appear for one second every eight seconds as a reminder that the display is in Scroll Lock Control mode.

```
Scroll lock OFF
SELECT to Lock
```

Stop Scrolling (Lock)

When in the Scroll Lock Control mode, press the **SELECT** key to stop display rotation. Scrolling can be stopped on any of the display point screens, or on the current-meter display screen. While rotation is stopped, the active display is updated continuously so that current or display point changes can be seen. If no button is pressed for eight seconds, the reminder message will appear for one second, followed by the active screen.

```
Scroll lock ON
SELECT to Unlock
```

Restart Scrolling (Unlock)

The **SELECT** key unlocks the LCD and resumes the rotating display.

Single Step

From the Scroll Locked state, single-step through the display screens by pressing the **SELECT** key twice. After the first press wait for the next screen to display, then press the **SELECT** key a second time to freeze scrolling.

Exit

Press the **EXIT** key to leave Scroll Lock Control and return the rotating display to normal operation.

Cancel

Press the **CANCEL** key to return to the **OTHER** menu.

```
DATE   TIME  79
TAR BRK_MON LCD
```

Front-Panel Neutral/Ground Current Display

Global setting FPNGD (Front-Panel Neutral/Ground Display) selects whether IG (residual current), IN (channel IN current), or neither is displayed on the front-panel rotating display. Setting choices are:

FPNGD = **IN**

```
IA=   1  IB=   1
IC=   1  IN=   1
```

FPNGD = **IG**

```
IA=   1  IB=   1
IC=   1  IG=   1
```

FPNGD = **OFF**

```
IA=   1  IB=   1
IC=   1
```

Additional Rotating Default Display Example

See *Figure 5.20* and accompanying text in *Section 5: Trip and Target Logic* for an example of resetting a rotating default display with the **TARGET RESET** pushbutton.

SECTION 12

Standard Event Reports, Sag/Swell/ Interruption Report, and SER

Overview

This section covers the event reporting, voltage sag/swell/interruption (SSI) reporting, and sequential events recorder (SER) reporting functions of the SEL-351 Relay, in the following subsections:

Introduction

The SEL-351 offers five styles of event reports: Standard ASCII (EVE) reports, Compressed ASCII (CEV) reports, Binary COMTRADE event reports, Sequential Event Recorder (SER) reports, and Voltage Sag, Swell, and Interruption Reports (selected models).

Event (EVE) Reports and Compressed ASCII Event (CEV) Reports

Standard ASCII event reports capture highly detailed information over a specified time period (selectable as 15, 30, or 60 power system cycles) in an easy to read format. Compressed ASCII event reports are in a computer-readable format, suitable for SEL-5601-2 SYNCHROWAVE Event Software or ACSELERATOR QuickSet SEL-5030 Software.

Event reports are useful in commissioning tests, system disturbance analysis, and protective device or scheme performance analysis.

Event report data are stored to nonvolatile memory just after they are generated.

Event report information includes:

- Date and time of the event report trigger with a maximum of 1 µs resolution.
- Individual sample analog input oscillography (currents and voltages) at 4, 16, 32, or 128 samples per cycle
- System frequency

- ➤ EVE: Digital element states of selected Relay Word bits (listed in *Table 12.4*) at 4 samples per cycle
- ➤ CEV: Digital element states of all Relay Word bits at 4 samples per cycle
- ➤ Event summary, including the front-panel target states at the time of tripping, fault current, fault location, and fault type
- ➤ Group, Logic, and Global settings that were active at the time of the event trigger
- ➤ 10 µs precision trigger time stamps and relative sample times (accurate when a high-accuracy IRIG-B time source is connected to the relay)

An adjustable prefault recording period allows system conditions to be captured prior to the actual event report trigger. Event reports are stored to nonvolatile memory a short time after an event trigger is processed.

Use SYNCHROWAVE Event and QuickSet to analyze compressed ASCII and COMTRADE file format versions of the event report. With this software, you can easily do the following:

- ➤ View or print oscillographic traces and digital element traces
- ➤ Perform step-by-step phasor analysis of the prefault, fault, and post-fault intervals
- ➤ View power system harmonic data

Sequential Events Recorder (SER)

The SER report captures detailed digital element state changes over a long time period. Programmable trigger lists allow as many as 72 Relay Word bits to be monitored, in addition to the automatically generated triggers for relay power-up, settings changes, and active setting group changes. State changes are time-tagged to the nearest millisecond.

SER report data are useful in commissioning tests and during operation for system monitoring and control.

SER information is stored to nonvolatile memory when state changes occur.

Sag/Swell/Interruption (SSI) Report (SEL-351-7 only)

The SSI report captures power quality data related to voltage disturbances over a long period of time. Data captured includes the magnitude of currents, voltages, a reference voltage, and the status of the voltage sag/swell/interrupt (VSSI) Relay Word bits—see *Voltage Sag, Swell, and Interruption Elements* on page 3.66.

SSI report information is useful for analyzing power quality disturbances, or protective device actions that last longer than the time window of a conventional event report.

The SSI recording rate varies from fast to slow, depending on changes in the triggering elements.

SSI data are stored to nonvolatile memory just after they are generated.

Standard 15/30/60-Cycle Event Reports

NOTE: *Figure 12.7* is on multiple pages.

See *Figure 12.7* for an example event report.

Event Report Length (Settings LER and PRE)

The SEL-351 provides user-programmable event report length and prefault length. Event report length is either 15, 30, or 60 cycles. Prefault length ranges from 1 to 59 cycles. Prefault length is the first part of the event report that precedes the event report triggering point.

Set the event report length with the LER setting. Set the prefault length with the PRE setting. See the **SET G** command in *Table 9.2* and corresponding *Event Report Parameters (see Section 12)* on page SET.2 for instructions on setting the LER and PRE settings.

Changing the LER setting will erase all events stored in nonvolatile memory. Changing the PRE setting has no effect on the nonvolatile reports.

Event Report Capacity

The SEL-351 event report capacity depends on the selected event report length (LER setting), as shown in *Table 12.1*.

NOTE: During testing, be aware that once the relay event report memory is full, triggering a new event may displace one of the oldest events.

Table 12.1 Event Report Capacity

LER Setting	Number of Event Reports Stored
15 cycles (factory default)	44
30 cycles	23
60 cycles	11

The SEL-351 stores event reports in nonvolatile memory soon after the events are captured. If the power supply is interrupted during the saving of an event report, the relay will report `Invalid History Data` for the event that was not fully stored.

Standard Event Report Triggering

The relay triggers (generates) a standard event report when any of the following occur:

- Relay Word bit TRIP asserts
- Programmable SELOGIC control equation setting ER asserts to logical 1
- **TRI** (Trigger Event Reports) serial port command executed
- Output contacts pulsed via the serial port or front-panel **PUL** (Pulse Output Contact) command

Relay Word Bit TRIP

Refer to *Figure 5.1*. If Relay Word bit TRIP asserts to logical 1, an event report is automatically generated. Thus, any condition that causes a trip does not have to be entered in SELOGIC control equation setting ER.

For example, SELOGIC control equation trip settings TR and TRQUAL are unsupervised. Any trip condition that asserts in TR causes the TRIP Relay Word bit to assert immediately. Any trip element that asserts in TRQUAL causes the TRIP Relay Word bit to assert immediately if a system disturbance is detected (see *Figure 4.2*) or after a two-cycle delay (see *Figure 5.1*) if a system disturbance is not detected. For example, if TR and TRQUAL are:

TR = **OC + LB3**

TRQUAL = **51PT + 51GT + 81D1T + 50P1 * SH0**

If any of the individual conditions OC, 51PT, 51GT, 81D1T, LB3, or 50P1 * SH0 assert, Relay Word bit TRIP asserts, and an event report is automatically generated. Thus, these conditions do not have to be entered in SELOGIC control equation setting ER.

Relay Word bit TRIP (in *Figure 5.1*) is usually assigned to an output contact for tripping a circuit breaker (e.g., SELOGIC control equation setting OUT101 = TRIP).

Programmable SELOGIC Control Equation Setting ER

The programmable SELOGIC control equation event report trigger setting ER is set to trigger standard event reports for conditions other than trip conditions. When setting ER sees a logical 0 to logical 1 transition, it generates an event report (if the SEL-351 is not already generating a report that encompasses the new transition). The factory setting for most SEL-351 Relays is:

ER = **/51P + /51G + /OUT103**

The elements in this example setting are:

51P	Maximum phase current above pickup setting 51PP for phase time-overcurrent element 51PT (see *Figure 3.14*).
51G	Residual ground current above pickup setting 51GP for residual ground time-overcurrent element 51GT (see *Figure 3.19*).
OUT103	Output contact **OUT103** is set as a breaker failure trip output (see *Figure 7.28*).

Note the rising-edge operator / in front of each of these elements. See *Appendix F: Setting SELOGIC Control Equations* for more information on rising-edge operators and SELOGIC control equations in general.

Rising-edge operators are especially useful in generating an event report at fault inception and then generating another later if a breaker failure condition occurs. For example, at the inception of a ground fault, pickup indicator 51G asserts and an event report is generated:

ER = **... + /51G + ... = logical 1** (for one processing interval)

Even though the 51G pickup indicator will remain asserted for the duration of the ground fault, the rising-edge operator / in front of 51G (/51G) causes setting ER to be asserted for only one processing interval. In this example, if there was no rising-edge operator on 51G, the ER equation would remain at logical 1 while a fault is present. This would prevent the relay from seeing a subsequent logical 0 to logical 1 transition for a new trigger condition, such as 51P asserting.

Falling-edge operators \ are also used to generate event reports. See *Figure F.2* for more information on falling-edge operators.

TRI (Trigger Event Report) and PUL (Pulse Output Contact) Commands

The sole function of the **TRI** serial port command is to generate standard event reports, primarily for testing purposes.

NOTE: The Modbus "pulse output" contact function also triggers an event report.

The **PUL** command asserts the output contacts for testing purposes or for remote control. If an output contact asserts via the **PUL** command, the relay triggers a standard event report. The **PUL** command is available at the serial port and the relay front-panel CNTRL pushbutton.

See *Section 10: Communications* and *Figure 11.3* for more information on the **TRI** (Trigger Event Report) and **PUL** (Pulse Output Contact) commands.

Back-to-Back Event Report Capability

The SEL-351 is capable of recording successive "back-to-back" event reports for as many as 300 cycles. When back-to-back events are triggered, the relay shortens the prefault portion of the latter event report(s).

Figure 12.1 shows an example of back-to-back event report behavior with factory default Global settings LER = 15 cycles and PRE = 4 cycles. When the first event report is triggered, the relay records data from 4 cycles before the trigger to 11 cycles after the trigger. An additional event report trigger received during the 15-cycle event report time is ignored. The next event report trigger received after the end of the 11-cycle post-trigger recording period is processed in one of two ways:

- If the next trigger processed is within the 4-cycle (PRE) period from the end of the previous event report, the second event report contains less than 4 cycles of pretrigger data, and the second event report analog data are a continuation of the first event report.
- If the next trigger is processed beyond the 4-cycle (PRE) period from the end of the previous event report, the second event report contains the usual 4 cycles of PRE data, and there will be an unrecorded period between the event reports.

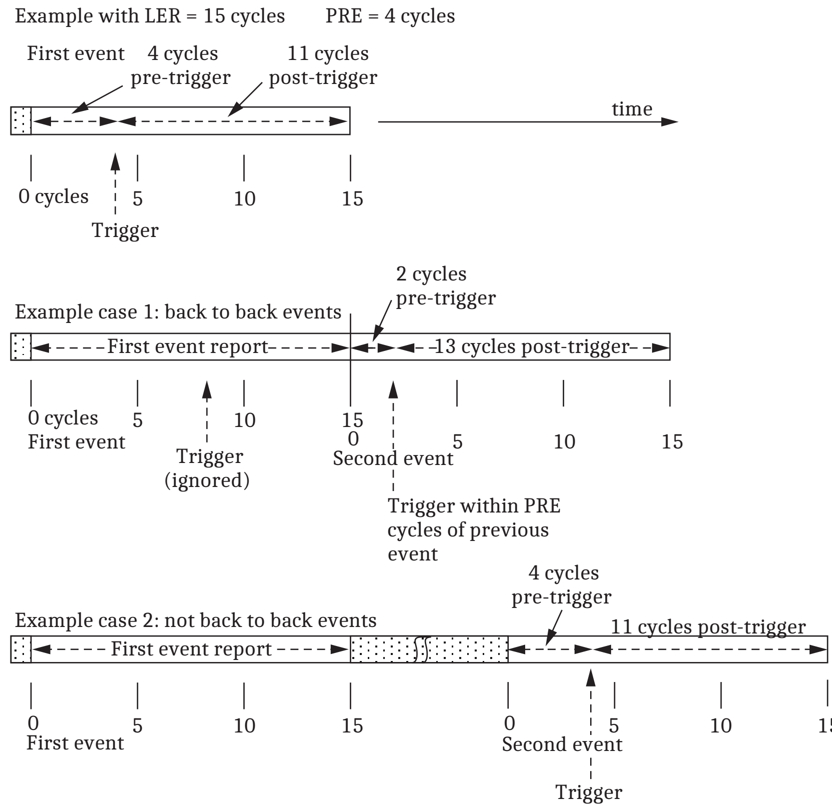


Figure 12.1 Example Behavior for Back-to-Back Event Reports

Standard Event Report Summary

Each time the relay generates a standard event report, it also generates a corresponding event summary (see *Figure 12.2*). Event summaries contain the following information:

- ➤ Relay and terminal identifiers (settings RID and TID)
- ➤ Date and time when the event was triggered
- ➤ Unique event identification number
- ➤ Event type
- ➤ Fault location
- ➤ Recloser shot count at the trigger time
- ➤ System frequency at the front of the event report
- ➤ Front-panel fault type targets at the time of trip
- ➤ Phase (IA, IB, IC), neutral ground (IN), calculated residual ground ($I_G = 3I_0$), and negative-sequence ($3I_2$) current magnitudes in amperes primary. The event summary currents are determined based on Global setting FLTDISP. See *Currents* on page 12.9.

NOTE: *Figure 12.7* is on multiple pages.

The relay includes the event summary in the standard event report. The identifiers, date, time, and unique event identification number are at the top of the standard event report, and the other information follows at the end. See *Figure 12.7*.

The example event summary in *Figure 12.2* corresponds to the full-length standard 15-cycle event report in *Figure 12.7*.

```
FEEDER 1                         Date: 07/12/09    Time: 09:28:31.721
STATION A
FID=SEL-351-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx       CID=xxxx
Event Number = 10522

.
.
.

Event: AG T  Location:    2.36  Shot: 0  Frequency:  60.01
Targets: INST 50
Currents (A Pri), ABCNGQ:   2752 pk   209   209     0  2689  2689
```

Figure 12.2 Example Event Summary

The relay sends event summaries to all serial ports with setting AUTO = Y each time an event triggers. The latest event summaries are stored in nonvolatile memory and are accessed by the **HIS** (Event Summaries/History) command.

Event Number

The `Event Number` field shows the unique event identification number of the event. The unique event identification number of any event can be found by issuing the **HIS E** command (see ***HIS*** *(Event Summaries/History)* on page 10.52 for details).

Event Type

The `Event:` field shows the event type. The possible event types and their descriptions are shown in the table below. Note the correspondence to the preceding event report triggering conditions (see *Standard Event Report Triggering* on page 12.3).

Table 12.2 Event Types

Event Type	Description
AG, BG, CG	Single phase-to-ground faults. Appends T if TRIP asserted.
A, B, C	Single phase-to-ground faults (Petersen Coil- and ungrounded/ high-impedance grounded systems only). Appends T if TRIP asserted.
ABC	Three-phase faults. Appends T if TRIP asserted.
AB, BC, CA	Phase-to-phase faults. Appends T if TRIP asserted.
ABG, BCG, CAG	Phase-to-phase-to-ground faults. Appends T if TRIP asserted.
TRIP	Assertion of Relay Word bit TRIP (fault locator could not operate successfully to determine the phase involvement, so just TRIP is displayed).
ER	SELOGIC control equation setting ER. Phase involvement is indeterminate.
TRIG	Execution of **TRIGGER** command.
PULSE	Execution of **PULSE** command.

The event type designations `AG` through `CAG` in *Table 12.2* are only entered in the `Event:` field if the fault locator operates successfully. If the fault locator does not operate successfully, just TRIP or ER is displayed.

The event type logic uses the front-panel target logic Relay Word bits FSA, FSB, FSC, NSA, NSB, and NSC to help determine the fault type, and to select the appropriate fault location method. See *Front-Panel Target LEDs* on page 5.34 for a description of LEDs **A**, **B**, and **C**, and for more information on the target logic function.

Fault Location

NOTE: The fault locator will not operate properly unless three-phase voltages are connected.

NOTE: The fault locator is most accurate when the fault currents last longer than two cycles.

NOTE: The fault locator will not operate for phase-to-ground faults on Petersen Coil- or ungrounded/high-impedance grounded systems.

The relay reports the fault location if the EFLOC setting = Y and the fault locator operates successfully after an event report is generated. If the fault locator does not operate successfully, $$$$$$ is listed in the field. If EFLOC = N, the field is blank. Fault location is based upon the line impedance settings Z1MAG, Z1ANG, Z0MAG, and Z0ANG; source impedance settings Z0SMAG and Z0ANG; and corresponding line length setting LL. See the **SET** command in *Table 9.2* and corresponding *Line Settings (see Line Settings on page 9.25)* on page SET.6 for information on the line parameter settings.

Because the fault locating function requires three-phase voltages, the Group setting EFLOC cannot be set to Y when Group setting VNOM = OFF. Similarly, the Group setting EFLOC is hidden and set to N internally when Group setting PTCONN = SINGLE. See *Appendix R: Fault Location and Supplemental Fault Location and Impedance Data* for additional details on fault location.

Fault Detector Elements

The fault locator algorithm uses the overcurrent elements 50P1–50P4, 50AB1–50AB4, 50BC1–50BC4, 50CA1–50CA4, 50N1–50N4, 50G1–50G4, 67Q1–67Q4, 51P, 51A, 51B, 51C, 51N, 51G, 51G2, and 51Q as fault detectors. If any of these elements are set to low pickup values for use as load indicators, they may be asserted during non-fault conditions. In this situation, even though these elements are not being used for tripping the relay, they may still affect the operation of the fault locator, because the start of the disturbance may be unclear. If load detectors are required in your application, use the highest-numbered instantaneous overcurrent elements 50P5, 50P6, 50N5, 50N6, 50G5, 50G6, 50Q5, or 50Q6, because these are not used by the fault locator algorithm.

Fault Locator Operating Window

The SEL-351 uses a 15-cycle subset of the event report data to calculate the event type and fault location. For Global setting LER = 30 and LER = 60, the relay processes the portion of stored data that includes the event report trigger. For LER = 15, the entire event report is available for calculation of the event type and fault location. The relay calculates fault location using a number of event report rows from the 15-cycle subset. When the fault evolves, the fault location is calculated using rows that represent the predominant fault type.

It is possible for the event type or fault location to be calculated from a different portion of the event report than expected. For example (with default settings), when the event report is first triggered by overcurrent element pickup (ER = /51P + /51G + /OUT103), but the trip occurs more than 12 cycles later, the conditions at the time of trip are not considered (unless covered by a new event report). If the fault type changed between pickup and tripping, the event type may not match the front-panel target LEDs. See *Front-Panel Target LEDs* on page 5.34 for details on the target LED operation.

Targets

The relay displays the front-panel targets that are asserted at the end of the event report if a trip occurred during the event. The targets include: `INST`, `COMM`, `SOTF`, `50`, `51`, and `81`. If there is no rising edge of TRIP in the report, the `Targets` field is blank. See *Front-Panel Target LEDs* on page 5.34.

Currents

The `Currents (A pri), ABCNGQ:` field shows event report summary currents. The listed currents are:

NOTE: When Global setting FLTDISP is set to MAX, the event summary currents are determined in the same manner as in firmware R510 and earlier. This is the default setting.

- Phase (A = channel IA, B = channel IB, C = channel IC)
- Neutral ground (N = channel IN)
- Calculated residual (G = I_G = $3I_0$; calculated from channels IA, IB, and IC)
- Negative-sequence (Q = $3I_2$; calculated from channels IA, IB, and IC)

The event summary currents come from one of two locations within the event report. When Global setting FLTDISP is set to MAX, the summary shows currents from the event report row containing the maximum phase current. The phase currents are calculated by the cosine filter or peak detector. When the relay uses the peak detector value, the relay displays pk as shown in the Event summary portion of *Figure 12.7*. For more information on the cosine filter and bipolar peak detector, see *CT Saturation Protection* on page 3.7.

When FLTDISP is set to FL, the summary shows currents from the event report row used to calculate fault location.

If FLTDISP is changed, the event summary currents change for all events stored in the relay.

Event History (HIS)

The event history gives you a quick look at recent relay activity. The SEL-351 labels each new event in reverse chronological order with 1 as the most recent event. If the E parameter is used with the **HIS** command, the event number is replaced by a unique event identification number from 10000 to 65535 (see ***HIS** (Event Summaries/History)* on page 10.52 for details). The unique identifier increments by 1 for each new event. See *Figure 12.3* for a sample event history.

The event history contains the following:

- Standard report header
  - Relay and terminal identification
  - Date and time of report
- Event history data for each stored event report. Column heading text is shown in (parenthesis).
  - Event number (#) or unique event identification (#)
  - Event date and time (`DATE`, `TIME`)
  - Event type (`EVENT`)
  - Location of fault (`LOCAT`) (if applicable)

- Largest phase current from event summary currents (CURR). Event summary currents are determined based on Global setting FLTDISP as discussed in *Standard Event Report Summary* on page 12.6.
- Power system frequency at start of event report (FREQ)
- Active group at the trigger instant (GRP)
- Reclosing relay shot count (SHOT)
- Targets (TARGETS)

Figure 12.3 is a sample event history.

```
=>HIS <Enter>

FEEDER 1                          Date: 12/03/10    Time: 09:01:10.354
STATION A

#     DATE      TIME     EVENT   LOCAT  CURR  FREQ GRP SHOT TARGETS
1  11/07/10 05:32:24.062 ABG T   94.95 10000 60.00  1    0  INST SOTF 50 51 81
2  Invalid History Data
3  10/17/10 19:01:38.302 TRIP  $$$$$$$  8455 60.00  1    0  TRIP
4  09/28/10 11:10:49.220 PULSE   26.92  2144 60.00  1    0

=>HIS E<Enter>

FEEDER 1                     Date: 12/03/10    Time: 09:01:11.001
STATION A

#     DATE      TIME     EVENT   LOCAT  CURR  FREQ GRP SHOT TARGETS
10381 11/07 05:32:24.062 ABG T   94.95 10000 60.00  1    0  INST SOTF 50 51 81
      Invalid History Data
10379 10/17 19:01:38.302 TRIP  $$$$$$$  8455 60.00  1    0  TRIP
10378 09/28 11:10:49.220 PULSE   26.92  2144 60.00  1    0

=>
```

Figure 12.3 Sample Event History

The event number (#) or the unique identification number is used in the **EVE**, **CEV**, and **SUM** commands to select the desired event report. The event types in the event history are the same as the event types in the event summary. See *Table 12.2* for event types.

Viewing the Event History

Access the history report from the communications ports or the front-panel. 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. Clear/reset history data at any communications port.

Use the **HIS** command from a terminal to obtain the event history. See ***HIS*** *(Event Summaries/History)* on page 10.52 for information on the **HIS** command.

Use the front-panel EVENTS menu to display event history data on the SEL-351 LCD. See *Front-Panel Pushbutton Operation* on page 11.1 for information on the front-panel interface.

Use the QuickSet software to retrieve the relay event history via the **Tool > Event > Get Event Files**... menu. *Appendix C: PC Software* provides more details.

SUM Command (Long Summary Event Report)

The **SUM** command displays a long summary event report (see ***SUM** (Long Summary Event Report)* on page 10.79 for command details). The long event report contains more information than is available from the **HIS** command, but it is shorter than the full event report retrieved with the **EVE** or **CEV** commands. The long summary event report contains the following information:

- Standard report header
  - Relay and terminal identifiers (settings RID and TID)
  - Date and time the event was triggered
- Event Information
  - Event type
  - Fault location
  - Breaker trip time
  - Unique event identification number from the **HIS E** command
  - Recloser shot count at the trigger time
  - System frequency at trigger time
  - Active settings group
  - Breaker close time
  - Targets
  - Breaker status (open or closed)
  - Phase currents (IA, IB, IC), phase voltages (VA, VB, VC), calculated residual ground (IG = 3I0), current IN, and negative-sequence (3I2) currents, along with phase angles for prefault and fault quantities.
  - MIRRORED BITS communications status if MIRRORED BITS communications is enabled

Event Type

The `Event:` field shows the event type (see *Event Type* on page 12.7 for details).

Fault Location

The `Location:` field displays the fault location determined by the relay. If EFLOC = Y and the fault locator operates successfully after an event report is generated, the relay displays the event location. If the fault locator does not operate successfully, the relay displays $$$$$$$ (see *Fault Location* on page 12.8 for details. See *Appendix R: Fault Location and Supplemental Fault Location and Impedance Data* for additional details on fault location.

Breaker Trip Time

The `Trip Time:` field displays the breaker trip time. If Relay Word bit TRIP is asserted when the event is triggered, the trip time is the trigger time. If TRIP asserts after the event is triggered, the assertion time of TRIP is displayed as the trip time. If TRIP does not assert during an event, the trip time is displayed as `--:--:--.---`.

Unique Event Identification Number

The event summary field displays the unique event identification number.

Recloser Shot Count

The `Shot:` field displays the shot count at the time of the event trigger. If reclosing is not enabled or is not active, this field is blank.

System Frequency

The `Freq:` field displays the system frequency at the beginning of the event report.

Active Settings Group

The `Group:` field displays the number of the active settings group at the time of the event trigger.

Breaker Close Time

The `Close Time:` field displays the breaker close time. If Relay Word bit CLOSE is asserted when the event is triggered, the close time is equivalent to the trigger time. If CLOSE asserts after the event is triggered, the assertion time of CLOSE is reported as the close time. If CLOSE does not assert during an event, the close time is reported as `--:--:--.---`.

Targets

The `Targets:` field displays the front-panel targets that are asserted at the end of the event report if a trip occurred during the event.

Breaker Status

The `Breaker:` field displays the status of the breaker at the end of the event. If Relay Word bit 52A is asserted, the relay reports the breaker Closed. If Relay Word bit 52A is not asserted, the relay reports the breaker Open.

Analog Phase Quantities

The `Prefault:` field displays the IA, IB, IC, IN, IG, 3I2, VA, VB, and VC from the first row of the event report.

The `Fault:` field displays currents and voltages from the event report rows used for fault location, or, if the fault locator does not operate successfully, from the event report rows 1.25 cycles after the event report trigger. All angles are referenced to the prefault A-phase voltage if it is greater than 13 V secondary. Otherwise, angles are referenced to the prefault A-phase current. The fault currents displayed in the Long Summary are not affected by Global Setting FLTDISP.

MIRRORED BITS Status

The status of MIRRORED BITS channels are displayed by the **SUM** command. The MIRRORED BITS display includes channel A and B transmit/receive bits at the time the event was triggered, channel A and B transmit/receive bits at the time the relay tripped (if a trip occurred during the event), and channel A and B MIRRORED BITS channel indicators (LBOKA, LBOKB, CBADA, CBADB, RBADA, RBADB, ROKA, and ROKB). If MIRRORED BITS communications is not enabled, this section is omitted from the **SUM** command response. If only one MIRRORED BITS channel is enabled, MIRRORED BITS information for both channels, A and B, is displayed (see *Appendix H: MIRRORED BITS Communications (in Firmware Versions 6 and 7)* for details on MIRRORED BITS communications.

COMTRADE File Format Event Reports

The SEL-351 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

NOTE: COMTRADE event reports are sampled at 128 samples per cycle, which are equivalent to CEV R S128 event reports.

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 event summary and relay settings information that appears in the event report for the data capture. The settings portion is in a comma-delimited format as illustrated in *Figure 12.4*.

Event Summary Information

```
FEEDER 1                          Date: 07/02/10    Time: 20:32:44.519
STATION A

Event: ABC T      Location: 64.93             Trip Time: 20:32:44.531
#: 10022  Shot: 1  Freq: 60.00 Group: 1       Close Time: --:--:--.---
Targets: 10000000 00100000
Breaker: Open
PreFault:     IA     IB     IC     IN     IG    3I2      VA      VB      VC
MAG(A/kV)    501    501    501      1      3      2 120.150 120.090 120.140
ANG(DEG)  119.34  -0.44-120.37 -83.99  12.01  50.39    0.00 -119.84  120.29
Fault:
MAG(A/kV)   1811   1830   1819      1     22     12 112.910 112.900 112.910
ANG(DEG)   55.51 -64.40 175.70-176.77 -82.67-153.19  119.56   -0.27 -120.23
```

Relay Settings

```
[1]
RID,"FEEDER 1"
TID,"STATION A"
CTR,"120"
CTRN,"120"
PTR,"180.00"
PTRS,"180.00"
.
.
.
```

Analong, digital, and input samples per cycle data

```
SAM/CYC_A = 128
SAM/CYC_D = 4
SAM/CYC_INPUTS = 16
```

Figure 12.4 Sample COMTRADE .HDR Header File

.CFG File

The .CFG file contains data that are used to reconstruct the input signals to the relay and status of Relay Word bits during the event report (see *Figure 12.5*). 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.

<RID setting>,FID=SEL-351-7-Rxxx-V0-Zxxxxxx-Dyyyymmdd,1999	COMTRADE Standard
#T,#A,#D	Total Channels, Analog, Digital
1,IA,A,,A,scale_factor[a],0.0,0,-32767,32767,[CTR],1.0,P 2,IB,B,,A,scale_factor[a],0.0,0,-32767,32767,[CTR],1.0,P 3,IC,C,,A,scale_factor[a],0.0,0,-32767,32767,[CTR],1.0,P 4,IN,,,A,scale_factor[a],0.0,0,-32767,32767,[CTRN],1.0,P 5,IG,,,A,scale_factor[a],0.0,0,-32767,32767,[CTR],1.0,P 6,VA,A,,kV,scale_factor[a],0.0,0,-32767,32767,[PTR],1.0,P 7,VB,B,,kV,scale_factor[a],0.0,0,-32767,32767,[PTR],1.0,P 8,VC,C,,kV,scale_factor[a],0.0,0,-32767,32767,[PTR],1.0,P 9,VS,C,,kV,scale_factor[a],0.0,0,-32767,32767,[PTRS],1.0,P 10,FREQ,,,Hz,0.01,0.0,0,0,12000,1.0,1.0,P 11,VDC,C,,V,scale_factor[a],0.0,0,-32767,32767,-0.0,1.0,P	Analog Channel Data
1,rwb_label[b,c],,,0 2,rwb_label[b,c],,,0 . . . nnnn[d],rwb_label[b,c],,,0	Digital (Status) Channel Data
<NFREQ> 0 0,<# of samples>	
dd/mm/yyyy,hh:mm:ss.ssssss	First Data Point
dd/mm/yyyy,hh:mm:ss.ssssss	Trigger Point
BINARY <time stamp multiplication factor>	

Figure 12.5 Sample COMTRADE .CFG Configuration File Data

[a] Scale_factor is the value used to convert the equivalent channel analog data in the DAT file to primary units (A or kV peak-to-peak).

[b] rwb_label will be replaced with Relay Word bit labels as seen in *Table D.1*.

[c] Place holders denoted by asterisk (*), will be labeled as UNUSEDxxx (where xxx is the number of the associated label).

[d] nnnn = number of the last Relay Word bit.

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
- Digital Relay Word bit names
- System 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 digital channel status 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 SYNCHROWAVE Event and QuickSet.

Retrieving COMTRADE Event Files

COMTRADE files are available as read-only files that can be retrieved using QuickSet, the **FILE** command and Ymodem file transfer, Ethernet File Transfer Protocol (FTP), or Manufacturing Messaging Specification (MMS). MMS is only available in models that support IEC 61850 and only when IEC 61850 is enabled (E61850 = Y). See ***FIL*** on page 10.46, *File Transfer Protocol (FTP) and MMS File Transfer* on page 10.22, and *FTP and MMS File Structure* on page 10.26 for additional information.

Retrieving Full-Length Standard Event Reports

The latest event reports are stored in nonvolatile memory. Each event report includes four sections:

- Current, voltage, station battery, frequency, contact outputs, optoisolated inputs
- Protection and control elements
- Event summary
- Group, SELOGIC control equations, and Global settings

NOTE: Compressed ASCII Event Reports contain all of the Relay Word bits and automatic variable analog scaling, and are easily analyzed using no-charge software. Regular, uncompressed event reports only contain a subset of the Relay Word bits, do not have automatic variable scaling, and are not fully supported by software. SEL recommends that you use compressed event reports for all event analysis. See *Compressed ASCII Event Reports* on page 12.18.

Use the **EVE** command to retrieve the reports. There are several options to customize the report format. The general command format is:

EVE [*n* S*x* L*y* L R A D V C M P] (parameters in [ ] are optional)

where:

n Event number (*n* = 1, 2, 3... to number of events stored) or unique event identifier (*n* = 10000–65535). Defaults to 1 if not listed, where 1 is the most recent event.

S*x* Display *x* samples per cycle (4, 16, 32, or 128); defaults to 4 if not listed. S128 is only available for unfiltered (raw) event reports and must be accompanied by the R parameter (**EVE S128 R**).

L*y* Display *y* cycles of data (1–LER). Defaults to LER value if not listed. Unfiltered reports (R parameter) display one extra cycle of data, and S128 unfiltered reports display two extra cycles of data.

L Display 32 samples per cycle; same as the S32 parameter.

R Specifies the unfiltered (raw) event report. Defaults to 32 samples per cycle unless overridden with the S*x* parameter.

A Specifies that only the analog section of the event is displayed (current, voltage, station battery, frequency, contact outputs, optoisolated inputs).

D Specifies that only the digital section (Protection and Control Elements) of the event is displayed.

V Specifies variable scaling for analog values.

C Display the report in Compressed ASCII format, with analog data at 16 samples per cycle, and digital data at 4 samples per cycle default.

M Specifies only the Communication element section of the event is displayed (only available in Firmware Version 6 or 7).

P Precise to synchrophasor-level accuracy for signal content at nominal frequency. This option is available only for event triggered when TSOK = logical 1. The P option implies R as only raw analog data are available with this accuracy. When M or D are specified with P, then the P option is ignored because it only pertains to analog data.

Below are example **EVE** commands.

Serial Port Command	Description
EVE	Display the most recent event report at 1/4 cycle resolution.
EVE 2	Display the second event report at 1/4 cycle resolution.
EVE S16 L10	Display 10 cycles of the most recent report at 1/16 cycle resolution.
EVE C 2	Display the second report in Compressed ASCII format at, with analog data at 16 samples per cycle, and digital data at 4 samples per cycle.
EVE L	Display most recent report at 1/32-cycle resolution.
EVE R	Display most recent report at 1/32-cycle resolution; analog data and digital data (for IN101–IN106) are unfiltered (raw).
EVE 2 D L10	Display 10 cycles of the protection and control elements section of the second event report at 1/4 cycle resolution.
EVE 2 A R S4 V	Display the unfiltered analog section of the second event report at 1/4 cycle resolution, with variable scaling of the analog values.

If an event report is requested that does not exist, the relay responds:

```
Invalid Event
```

If the S*x* parameter is entered and *x* is not 4, 16, 32, or 128, the relay responds:

```
Only 4, 16, 32, or 128 samples per cycle allowed
```

If the L*y* parameter is entered and *y* = 0 or *y* > LER, the relay responds:

```
Event report length exceeded
```

Synchrophasor-Level Accuracy in Event Reports

The SEL-351 provides the option to display event report data aligned to a high-accuracy time source by adding the P parameter. The header indicates the availability of a high-accuracy time source by displaying the status of Relay Word bit TSOK. The `Time:` value in the header includes three additional digits. These represent 100 µs, 10 µs, and 1 µs. The `Time:` value contains the time stamp of the analog value associated with the trigger point.

Furthermore, the `FREQ` column in the analog section of the report is replaced by a `DT` column. DT means “difference time.” It represents the difference time in units of microseconds from another row. The trigger point has a DT value of 0000 because the trigger time corresponds to the time displayed in the event report header. The DT value for rows preceding the trigger point is referenced to the following row (so they increment backwards in time). The DT value for rows following the trigger point is referenced to the previous row (so they increment forwards in time). If TSOK = logical 0, this event report display option is not available.

Figure 12.6 shows how an event report is modified with the P parameter. Because event report information is stored at a sample rate that depends on the power system frequency, the DT column data will show a minimally changing number when the power system frequency is stable. If the power system frequency changes during the event reporting window and the relay is connected to a voltage reference, the sample rate may vary during the event report, and the DT values may vary accordingly.

```
=>>EVE P<Enter>

FEEDER 1                              Date: 04/02/09    Time: 14:26:27.792959
STATION A                             TSOK = 1

FID=SEL-351-7-R5xx-V0-Zxxxxxx-D2009xxxx       CID=xxxx

                                                                     Out  In
      Currents (Amps Pri)               Voltages (kV Pri)            1357 135
    IA    IB    IC    IN    IG     VA     VB     VC     VS Vdc    DT  246A 246
[0]
   -33   -94    83   -25   -45    3.5  -11.9    8.0   -0.1 139   521 1... ...
   -10  -110    74   -26   -45    5.6  -12.2    6.1   -0.1 139   521 1... ...
    13  -121    62   -27   -46    7.6  -12.0    4.0   -0.1 145   521 1... ...
.
.
.
   -97   -30    81   -20   -46   -3.6   -8.4   11.6   -0.1  77   521 1... ...
   -78   -54    86   -22   -46   -1.3  -10.0   10.8   -0.1 121   521 1... ...
   -56   -75    87   -23   -44    1.1  -11.1    9.6   -0.1 121   521 1... ...
[4]
   -33   -95    82   -25   -45    3.4  -11.9    8.0   -0.1 139   521 1... ...
   -10  -110    74   -26   -46    5.6  -12.2    6.1   -0.1 139   521 1... ...
    13  -121    62   -27   -46    7.6  -12.0    4.0   -0.1 144   521 1... ...
    36  -128    48   -26   -44    9.2  -11.4    1.7   -0.1 144   521 1... ...
    57  -128    29   -25   -41   10.5  -10.3   -0.6   -0.1 132   521 1... ...
    75  -125     9   -24   -41   11.4   -8.8   -3.0   -0.1 132   521 1... ...
    90  -117   -14   -23   -42   11.9   -7.1   -5.2   -0.1  91   521 1... ...
   100  -105   -37   -20   -41   11.9   -5.0   -7.3   -0.1  91   521 1... ...
   107   -87   -57   -15   -38   11.4   -2.8   -9.0   -0.1  39   521 1... ...
   111   -66   -76   -10   -31   10.5   -0.4  -10.4   -0.1  39   521 1... ...
   110   -41   -91    -5   -22    9.2    1.9  -11.5   -0.1 -18   521 1... ...
   106   -14  -105     1   -12    7.5    4.2  -12.0   -0.1 -18   521 1... ...
    96    13  -115     6    -6    5.5    6.4  -12.2   -0.1 -75   521 1... ...
    81    38  -123    10    -3    3.3    8.2  -11.8   -0.1 -75   521 1... ...
    62    63  -128    12    -3    1.0    9.8  -11.1   -0.1-119   521 1... ...
    40    84  -128    13    -4   -1.4   10.9   -9.9   -0.1-119   521 1... ...
    18   104  -124    15    -3   -3.7   11.7   -8.3   -0.1-137   521 1... ...
    -6   119  -116    16    -3   -5.8   12.0   -6.4   -0.1-137   521 1... ...
   -29   130  -104    16    -3   -7.8   11.8   -4.3   -0.1-143   521 1... ...
   -52   137   -88    15    -4   -9.5   11.2   -2.0   -0.1-143   521 1... ...
   -73   138   -71    15    -6  -10.8   10.1    0.4   -0.1-130   521 1... ...
   -91   134   -50    13    -6  -11.7    8.6    2.7   -0.1-130   521 1... ...
  -105   127   -27    13    -5  -12.1    6.9    5.0   -0.1 -89   521 1... ...
  -116   114    -5     9    -7  -12.1    4.8    7.0   -0.1 -89   521 1... ...
  -122    97    16     5   -10  -11.6    2.5    8.8   -0.1 -36   521 1... ...
  -126    75    34    -1   -17  -10.7    0.2   10.2   -0.1 -36   521 1... ...
  -126    50    50    -6   -26   -9.4   -2.2   11.2   -0.1  20   521 1... ...
  -121    23    62   -12   -36   -7.7   -4.4   11.8   -0.1  20   521 1... ...
  -112    -4    73   -16   -42   -5.8   -6.6   11.9   -0.1  77   521 1... ...
   -97   -30    81   -20   -46   -3.6   -8.4   11.6   -0.1  77   521 1... ...
   -78   -54    86   -22   -45   -1.3  -10.0   10.8   -0.1 121   521 1... ...
   -56   -75    87   -24   -44    1.1  -11.1    9.6   -0.1 121  0000>1... ...
[5]
   -33   -94    82   -25   -45    3.4  -11.9    8.0   -0.1 140   521 1... ...
   -10  -110    74   -26   -46    5.6  -12.2    6.1   -0.1 140   521 1... ...
    13  -121    63   -27   -46    7.6  -12.0    4.0   -0.1 145   521 1... ...
.
.
.
=>>
```

Figure 12.6 Example Synchrophasor-Level Precise Event Report 1/32-Cycle Resolution

Compressed ASCII Event Reports

The SEL-351 provides Compressed ASCII event reports to facilitate event report storage and display. The SEL Communications Processors, QuickSet, and SYNCHROWAVE Event take advantage of the Compressed ASCII format. Use the **EVE C** command or **CEVENT** command to display Compressed ASCII event reports. See the **CEVENT** command discussion in *Appendix K: Compressed ASCII Commands* for further information. You can also use the **Tools > Events > Get Events** menu in QuickSet to collect events.

NOTE: Compressed ASCII Event Reports contain all of the Relay Word bits and automatic variable analog scaling, and are easily analyzed using no-charge software. Regular, uncompressed event reports only contain a subset of the Relay Word bits, do not have automatic variable scaling, and are not fully supported by software. SEL recommends that you use compressed event reports for all event analysis.

Compressed ASCII event reports are the preferred method for retrieving event data, because the machine-readable format allows the use of time-saving software. Standard ASCII event reports are best-suited for rapid analysis, and for situations where only a portion of the event data is under study.

Filtered and Unfiltered Event Reports

The SEL-351 samples the basic power system measurands (ac voltage, ac current, station battery, and optoisolated inputs) 128 times per power system cycle. The relay filters the measurands at 32 samples per cycle to remove transient signals. The relay operates on the filtered values and reports them in the event report.

To view the raw inputs to the relay, select the unfiltered event report (e.g., **EVE R** or **CEV R**). Use the unfiltered event reports to observe:

- Power system harmonics on channels IA, IB, IC, IN, VA, VB, VC, VS
- Decaying dc offset during fault conditions on IA, IB, IC
- Optoisolated input contact bounce, updated at 16 samples/cycle
- Transients on the station dc battery channel Vdc (power input terminals **Z25** and **Z26**), updated at 16 samples /cycle

NOTE: When a properly rated ac control signal is applied to an optoisolated input, the unfiltered event report data for that input have an asserting/deasserting pattern at twice the applied signal frequency. See *Input Debounce Timers* on page 7.3. The status of extra I/O board optoisolated inputs is available only in compressed ASCII event reports.

The filters for ac current and voltage and station battery are fixed. You can adjust the optoisolated input debounce via debounce settings (see *Figure 7.1* and *Figure 7.2*).

Raw event reports display one extra cycle of data at the beginning of the report (or two extra cycles when S128 is specified).

Unfiltered Event Reports With PTCONN = DELTA

When Global setting PTCONN = DELTA, the raw event report voltage columns reflect the signals applied to relay terminals **VA-N**, **VB-N**, **VC-N**, even though the relay is configured for an open-delta PT connection (see *Figure 2.27*). If the relay is properly wired, the value shown in column VB should be at or near 0 kV, because input terminal **VB** is tied to terminal **N**. Column VA should reflect power system voltage V_{AB}, and column VC should reflect power system voltage V_{CB} (or $-V_{BC}$).

Retrieving Event Reports Via Ethernet File Transfer

Selected event reports are available as read-only files that can be retrieved using Ethernet File Transfer Protocol (FTP) or Manufacturing Messaging Specification (MMS). MMS is only available in models that support IEC 61850 and only when IEC 61850 is enabled (E61850 = Y). See *File Transfer Protocol (FTP) and MMS File Transfer* on page 10.22, *Virtual File Interface* on page 10.26, and *MMS* on page P.5 for additional information.

The Ethernet file server EVENTS folder contains two types of files for each event stored in the relay:

- ➤ Compressed, 4 sample/cycle, filtered event, equivalent to issuing a **CEV** command. These files are named C4.*nnnnn*.cev, where *nnnnn* is the unique event identifier.
- ➤ Compressed, 128 sample/cycle, unfiltered event, equivalent to issuing a **CEV R S128** command. These files are named CR.*nnnnn*.cev, where *nnnnn* is the unique event identifier.

The date and time displayed for events are from the time of event trigger. The times are UTC.

The EVENTS folder also contains the event history with unique event identification number (equivalent to the **HIS E** command) and the compressed event history (equivalent to the **CHIS** command). See *Event History (HIS)* on page 12.9 and *CHISTORY Command—SEL-351* on page K.4.

Clearing Standard Event Report Buffer

Via Serial Port

NOTE: The unique event identification number cannot be reset.

The **HIS C** command clears the event summaries and corresponding standard event reports from nonvolatile memory. The **HIS C** command does not reset the unique event identification number to 10000. See *Section 10: Communications* for more information on the **HIS** command.

Via DNP or Modbus

The DNP binary output DRST_HIS can be used to reset the event summaries and clear event reports from nonvolatile memory, and is similar in function to the **HIS C** command. See *Appendix L: DNP3 Communications* for more details.

The Modbus protocol can be used to reset the event summaries and clear event reports from nonvolatile memory, with functions similar to the **HIS C** command. Two methods are available:

- ➤ Writing to the Reset History Data output coil.
- ➤ Writing a specific analog value to the RSTDAT register.

See *Appendix O: Modbus RTU and TCP Communications* for details.

Reset Via SELogic Control Equation

The RST_HIS SELogic control equation setting can be used to reset the event summaries and clear event reports from nonvolatile memory. The relay resets the function when the setting first asserts (rising edge, e.g., a logical 0 to a logical 1 transition).

Standard Event Report Column Definitions

Refer to the example event report in *Figure 12.7* to view event report columns. This example event report displays rows of information each 1/4 cycle and was retrieved with the **EVE** command.

The columns contain ac current, ac voltage, station dc battery voltage, frequency, output, input, and protection and control element information.

Current, Voltage, and Frequency Columns

Table 12.3 summarizes the event report current, voltage, and frequency columns.

NOTE: *Figure 12.7* is on multiple pages.

NOTE: When Global setting PTCONN = SINGLE, the event report voltage data follows the terminal voltage inputs, even when phantom voltages are being used for metering. See *Phantom Metering for Single-Phase Voltage Connections* on page 8.24 for more information.

Table 12.3 Standard Event Report Current, Voltage, and Frequency Columns

Column Heading	Definition
IA	Current measured by channel IA (primary A)
IB	Current measured by channel IB (primary A)
IC	Current measured by channel IC (primary A)
IN	Current measured by channel IN (primary A)
IG	Calculated residual current IG = $3I_0$ = IA + IB + IC (primary A)
VA	Voltage measured by channel VA (primary kV, PTCONN = WYE or SINGLE)[a]
VB	Voltage measured by channel VB (primary kV, PTCONN = WYE or SINGLE)[a]
VC	Voltage measured by channel VC (primary kV, PTCONN = WYE or SINGLE)[a]
VAB	Power system phase-to-phase voltage V_{AB} (primary kV, PTCONN = DELTA)[b]
VBC	Power system phase-to-phase voltage V_{BC} (primary kV, PTCONN = DELTA)[b]
VCA	Power system phase-to-phase voltage V_{CA} (primary kV, PTCONN = DELTA)[b]
VS	Voltage measured by channel VS (primary kV)
Vdc	Voltage measured at power input terminals Z15 and Z16 (Vdc)
Freq[c]	System frequency (Hz)[d]
DT[e]	Difference time referenced to previous row (microseconds)

[a] Also for Global setting PTCONN = DELTA when viewing unfiltered (raw) event reports.

[b] When Global setting PTCONN = DELTA, and relay terminals VA, VB, VC, and N are properly wired as shown in *Figure 2.27*, the filtered event report voltage values are determined as follows:
VAB reflects the measured value from relay terminals VA-N
VBC reflects the measured value from relay terminals VC-N rotated by 180° ($V_{BC} = -V_{CB}$)
VCA reflects the value derived from the subtraction of the measured value from relay terminals VA-N from the measured value from relay terminals VC-N ($V_{CA} = V_{CB} - V_{AB}$).

[c] Not available in the EVE P command.

[d] See *Potential Transformer Inputs* on page 2.11 for details on frequency measurement for the various PTCONN settings.

[e] Available with precise time event (EVE P) reports and Compressed ASCII event (CEV) reports. See *Synchrophasor-Level Accuracy in Event Reports* on page 12.16.

Note that the ac values change from plus to minus (–) values in *Figure 12.7*, indicating the sinusoidal nature of the waveforms.

Other figures help in understanding the information available in the event report current columns:

Figure 12.9: shows how event report current column data relates to the actual sampled current waveform and RMS current values.

Figure 12.10: shows how event report current column data can be converted to phasor rms current values.

Variable Scaling for Analog Values

The following example shows the difference between two cycles of the analog values of an event report without variable scaling (command **EVE**) and with variable scaling (command **EVE V**). Variable scaling event reports display data for currents less than 10 A with two decimal places and data for voltages less than 10 kV with three decimal places.

Example without variable scaling (**EVE**), wye-connected:

```
=>>EVE <Enter>

                                                                      Out  In
      Currents (Amps Pri)           Voltages (kV Pri)                 1357 135
    IA     IB     IC     IN     IG     VA      VB      VC      VS Vdc Freq  246A 246
[1]
   181   -103    -92    -14    -14   14.8    -7.5    -7.5    13.8 125 60.00 .45. ...
     1    158   -161     -3     -3   -0.0    13.2   -13.0    -8.0 125 60.00 .45. ...
  -181    102     93     14     14  -14.8     7.4     7.6   -13.7 125 60.00 .45. ...
     1   -159    161      3      3    0.1   -13.3    13.0     8.1 125 60.00 .45. ...
[2]
   181   -100    -94    -14    -14   14.8    -7.3    -7.7    13.7 125 60.01 .45. ...
    -2    159   -160     -3     -3   -0.2    13.3   -12.9    -8.2 125 60.01 .45. ...
  -181     99     95     14     14  -14.8     7.2     7.8   -13.6 125 60.01 .45. ...
     3   -160    159      3      3    0.3   -13.4    12.9     8.2 125 60.01 .45. ...
```

NOTE: The "V" option has no effect for compressed event reports (**EVE C**) because the analog values automatically have variable scaling. Variable scaling for compressed data displays both currents less than 1000 A and voltages less than 1000 kV with three decimal places.

Example with variable scaling (**EVE V**), wye-connected:

```
=>>EVE V <Enter>

                                                                      Out  In
      Currents (Amps Pri)           Voltages (kV Pri)                 1357 135
    IA     IB     IC     IN     IG     VA      VB      VC      VS Vdc Freq  246A 246
[1]
   181   -103    -92    -14    -14   14.8  -7.477  -7.547    13.8 123 60.00 .45. ...
  0.58    158   -161  -2.81  -2.96 -0.036    13.2   -13.0  -7.956 123 60.00 .45. ...
  -181    102     93     14     14  -14.8   7.375   7.644   -13.7 123 60.00 .45. ...
  0.73   -159    161   2.71   2.73  0.145   -13.3    13.0   8.057 123 60.00 .45. ...
[2]
   181   -100    -94    -14    -14   14.8  -7.282  -7.736    13.7 123 60.01 .45. ...
 -1.97    159   -160  -2.62  -2.57 -0.250    13.3   -12.9  -8.154 123 60.01 .45. ...
  -181     99     95     14     14  -14.8   7.190   7.822   -13.6 123 60.01 .45. ...
  3.14   -160    159   2.52   2.54  0.347   -13.4    12.9   8.243 123 60.01 .45. ...
```

Output, Input, and Protection and Control Columns

NOTE: The event report does not show the output contacts (**OUT201–OUT212**) or optoisolated inputs (**IN201–IN216**) for the extra I/O board.

Table 12.4 summarizes the event report output, input, protection and control columns. See *Table D.2* for more information on Relay Word bits shown in *Table 12.4*.

Some of the column definitions are different for single-phase connected PT (Global setting PTCONN = SINGLE), wye-connected PT applications (Global setting PTCONN = WYE), and delta-connected PT applications (Global setting

PTCONN = DELTA). These differences are noted in *Table 12.4*. *Figure 12.7* shows a wye-connected example event report, and *Figure 12.8* shows a delta-connected example event report.

To limit report size, the SEL-351 does not include all Relay Word bits in a standard ASCII event report. Some examples are local bits LB9–LB16, remote bits RB9–RB32, latch bits LT9–LT16, logic variables LV1–LV32, optoisolated inputs IN201–IN216, and virtual bits VB001–VB128. These and all other Relay Word bits are available in compressed ASCII event reports, and are viewable using PC software. See *Compressed ASCII Event Reports* on page 12.18 for more information.

Table 12.4 Output, Input, Protection and Control, and Communication Element Event Report Columns (Sheet 1 of 10)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
All columns		.	Element/input/output not picked up or not asserted, unless otherwise stated.
Out 12[a]	OUT101, OUT102	1 2 b	Output contact OUT101 asserted. Output contact OUT102 asserted. Both OUT101 and OUT102 asserted.
Out 34[a]	OUT103, OUT104	3 4 b	Output contact OUT103 asserted. Output contact OUT104 asserted. Both OUT103 and OUT104 asserted.
Out 56[a]	OUT105, OUT106	5 6 b	Output contact OUT105 asserted. Output contact OUT106 asserted. Both OUT105 and OUT106 asserted.
Out 7A[a]	OUT107, ALARM	7 A b	Output contact OUT107 asserted. Output contact ALARM asserted. Both OUT107 and ALARM asserted.
In 12	IN101, IN102	1 2 b	Optoisolated input IN101 asserted. Optoisolated input IN102 asserted. Both IN101 and IN102 asserted.
In 34	IN103, IN104	3 4 b	Optoisolated input IN103 asserted. Optoisolated input IN104 asserted. Both IN103 and IN104 asserted.
In 56	IN105, IN106	5 6 b	Optoisolated input IN105 asserted. Optoisolated input IN106 asserted. Both IN105 and IN106 asserted.
51 A	51A, 51AT, 51AR	.	Time-overcurrent element reset (51_R).
51 B	51B, 51BT, 51BR		
51 C	51C, 51CT, 51R	p	Time-overcurrent element picked up and timing (51_).
51 P	51P, 51PT, 51PR		
51 N	51N, 51N, 51NR	T	Time-overcurrent element timed out (51_T).
51 G	51G, 51GT, 51GR		
51 G2	51G2, 51G2T, 51G2R		
51 Q	51Q, 51QT, 51QR	r	Time-overcurrent element timing to reset.
		1	Time-overcurrent element timing to reset after having timed out (when element reset is set for 1 cycle, not electromechanical reset).

Table 12.4 Output, Input, Protection and Control, and Communication Element Event Report Columns (Sheet 2 of 10)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
50 P	50A, 50B, 50C	A	Single-phase instantaneous overcurrent element 50A picked up.
		B	Single-phase instantaneous overcurrent element 50B picked up.
		C	Single-phase instantaneous overcurrent element 50C picked up.
		a	Both 50A and 50B picked up.
		b	Both 50B and 50C picked up.
		c	Both 50C and 50A picked up.
		3	50A, 50B, and 50C picked up.
50 PP	50AB1, 50AB2, 50AB3, 50AB4, 50BC1, 50BC2,	A	Phase-to-phase instantaneous overcurrent element 50AB1, 50AB2, 50AB3, or 50AB4 picked up.
	50BC3, 50BC4, 50CA1, 50CA2, 50CA3, 50CA4	B	Phase-to-phase instantaneous overcurrent element 50BC1, 50BC2, 50BC3, or 50BC4 picked up.
		C	Phase-to-phase instantaneous overcurrent element 50CA1, 50CA2, 50CA3, or 50CA4 picked up.
		a	50AB_ and 50CA_ picked up.
		b	50AB_ and 50BC_ picked up.
		c	50BC_ and 50CA_ picked up.
		3	50AB_, 50BC_, and 50CA_ picked up.
32 PQ	F32P	P	Forward phase directional element F32P picked up. Forward negative-sequence directional element F32Q may also be picked up.
	R32P	p	Reverse phase directional element R32P picked up. Reverse negative-sequence directional element R32Q may also be picked up.
	F32Q	Q	Forward negative-sequence directional element F32Q picked up.
	R32Q	q	Reverse negative-sequence directional element R32Q picked up.
32 NG	F32QG	Q	Forward negative-sequence directional element F32QG picked up.
	R32QG	q	Reverse negative-sequence R32QG picked up.
	F32V	V	Forward zero-sequence voltage-polarized element F32V picked up.
	R32V	v	Reverse zero-sequence voltage-polarized R32V picked up.
	F32I	I	Forward channel IN current-polarized directional element F32I picked up.
	R32I	i	Reverse channel IN current-polarized directional element R32I picked up.
	F32N	N	Forward element F32N picked up (low-impedance grounded, Petersen Coil-grounded [wattmetric element], and ungrounded/high-impedance grounded systems).
	R32N	n	Reverse element R32N picked up (low-impedance grounded, Petersen Coil-grounded [wattmetric element], and ungrounded/high-impedance grounded systems).
	F32C	C	Forward conductance element F32C picked up (Petersen Coil-grounded system)
	R32C	c	Reverse conductance element R32C picked up (Petersen Coil-grounded system)

Table 12.4 Output, Input, Protection and Control, and Communication Element Event Report Columns (Sheet 3 of 10)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
67 P 67 N 67 G 67 Q	67P1–67P4 67N1–67N4 67G1–67G4 67Q1–67Q4	4	Level 4 instantaneous element 67_4 picked up; levels 1, 2, and 3 not picked up.
		3	Level 3 instantaneous element 67_3 picked up; levels 1 and 2 not picked up.
		2	Level 2 instantaneous element 67_2 picked up; level 1 not picked up.
		1	Level 1 instantaneous element 67_1 picked up.
DM PQ	PDEM, QDEM	P	Phase demand ammeter element PDEM picked up.
		Q	Negative-sequence demand ammeter element QDEM picked up.
		b	Both PDEM and QDEM picked up.
DM NG	NDEM, GDEM	N	Neutral ground demand ammeter element NDEM picked up.
		G	Residual ground demand ammeter element GDEM picked up.
		b	Both NDEM and GDEM picked up.
27 P (wye-connected or single-phase voltage)	27A1, 27A2, 27B1, 27B2, 27C1, 27C2	A B	A-phase instantaneous undervoltage element 27A1 or 27A2 picked up. B-phase instantaneous undervoltage element 27B1 or 27B2 picked up.
		C	C-phase instantaneous undervoltage element 27C1 or 27C2 picked up.
		a	27A_ and 27B_ elements picked up.
		b	27B_ and 27C_ elements picked up.
		c	27C_ and 27A_ elements picked up.
		3	27A_, 27B_ and 27C_ elements picked up.
27 PP[b]	27AB, 27BC, 27CA	A	AB phase-to-phase instantaneous undervoltage element 27AB picked up.
		B	BC phase-to-phase instantaneous undervoltage element 27BC picked up.
		C	CA phase-to-phase instantaneous undervoltage element 27CA picked up.
		a	27AB and 27CA elements picked up.
		b	27AB and 27BC elements picked up.
		c	27BC and 27CA elements picked up.
		3	27AB, 27BC and 27CA elements picked up.
27 PP2 (delta-connected)	27AB2, 27BC2, 27CA2	A	AB phase-to-phase instantaneous undervoltage element 27AB2 picked up.
		B	BC phase-to-phase instantaneous undervoltage element 27BC2 picked up.
		C	CA phase-to-phase instantaneous undervoltage element 27CA2 picked up.
		a	27AB2 and 27CA2 elements picked up.
		b	27AB2 and 27BC2 elements picked up.
		c	27BC2 and 27CA2 elements picked up.
		3	27AB2, 27BC2 and 27CA2 elements picked up.
27 S	27S	*	Channel VS instantaneous undervoltage element 27S picked up.

Table 12.4 Output, Input, Protection and Control, and Communication Element Event Report Columns (Sheet 4 of 10)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
59 P (wye-connected or single-phase voltage)	59A1, 59A2, 59B1, 59B2, 59C1, 59C2	A	A-phase instantaneous overvoltage element 59A1 or 59A2 picked up.
		B	B-phase instantaneous overvoltage element 59B1 or 59B2 picked up.
		C	C-phase instantaneous overvoltage element 59C1 or 59C2 picked up.
		a	59A_ and 59B_ elements picked up.
		b	59B_ and 59C_ elements picked up.
		c	59C_ and 59A_ elements picked up.
		3	59A_, 59B_ and 59C_ elements picked up.
59 PP[b]	59AB, 59BC, 59CA	A	AB phase-to-phase instantaneous overvoltage element 59AB picked up.
		B	BC phase-to-phase instantaneous overvoltage element 59BC picked up.
		C	CA phase-to-phase instantaneous overvoltage element 59CA picked up.
		a	59AB and 59CA elements picked up.
		b	59AB and 59BC elements picked up.
		c	59BC and 59CA elements picked up.
		3	59AB, 59BC and 59CA elements picked up.
59 PP2 (delta-connected)	59AB2, 59BC2, 59CA2	A	AB phase-to-phase instantaneous overvoltage element 59AB2 picked up.
		B	BC phase-to-phase instantaneous overvoltage element 59BC2 picked up.
		C	CA phase-to-phase instantaneous overvoltage element 59CA2 picked up.
		a	59AB2 and 59CA2 elements picked up.
		b	59AB2 and 59BC2 elements picked up.
		c	59BC2 and 59CA2 elements picked up.
		3	59AB2, 59BC2 and 59CA2 elements picked up.
59 V1Q[b] (wye-connected)	59V1, 59Q	1	Positive-sequence instantaneous overvoltage element 59V1 picked up.
		Q	Negative-sequence instantaneous overvoltage element 59Q picked up.
		b	Both 59V1 and 59Q picked up.
59 V1 (delta-connected)	59V	*	Positive-sequence instantaneous overvoltage element 59V1 picked up.
59 Q (delta-connected)	59Q, 59Q2	1	Negative-sequence instantaneous overvoltage element 59Q picked up.
		2	Negative-sequence instantaneous overvoltage element 59Q2 picked up.
		b	Both 59Q and 59Q2 picked up.
59 N[b] (wye-connected)	59N1, 59N2	1	Zero-sequence instantaneous overvoltage element 59N1 picked up.
		2	Zero-sequence instantaneous overvoltage element 59N2 picked up.
		b	Both 59N1 and 59N2 picked up.
59 S	59S1, 59S2	1	Channel VS instantaneous overvoltage element 59S1 picked up.
		2	Channel VS instantaneous overvoltage element 59S2 picked up.
		b	Both 59S1 and 59S2 picked up.

Table 12.4 Output, Input, Protection and Control, and Communication Element Event Report Columns (Sheet 5 of 10)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
59 V	59VP, 59VS	P	Phase voltage window element 59VP picked up (used in synchronism check).
		S	Channel VS voltage window element 59VS picked up (used in synchronism check).
		b	Both 59VP and 59VS picked up.
25 SF	SF	*	Slip frequency element SF picked up (used in synchronism check).
25 A	25A1, 25A2	1	Synchronism-check element 25A1 element picked up.
		2	Synchronism-check element 25A2 element picked up.
		b	Both 25A1 and 25A2 picked up.
81 27B	27B81	*	Frequency logic instantaneous undervoltage element 27B81 picked up.
81 12	81D1, 81D2	1	Frequency element 81D1 picked up.
		2	Frequency element 81D2 picked up.
		b	Both 81D1 and 81D2 picked up.
81 34	81D3, 81D4	3	Frequency element 81D3 picked up.
		4	Frequency element 81D4 picked up.
		b	Both 81D3 and 81D4 picked up.
81 56	81D5, 81D6	5	Frequency element 81D5 picked up.
		6	Frequency element 81D6 picked up.
		b	Both 81D5 and 81D6 picked up.
79	RCSF, CF, 79RS,	.	Reclosing relay nonexistent.
	79CY, 79LO	S	Reclose supervision failure condition (RCSF asserts for only 1/4 cycle).
		F	Close failure condition (CF asserts for only 1/4 cycle).
		R	Reclosing relay in Reset State (79RS).
		C	Reclosing relay in Reclose Cycle State (79CY).
		L	Reclosing relay in Lockout State (79LO).
Time	OPTMN, RSTMN	o	Recloser open interval timer is timing.
		r	Recloser reset interval timer is timing.
Shot	SH0, SH1, SH2	.	Reclosing relay nonexistent.
	SH3, SH4	0	shot = 0 (SH0).
		1	shot = 1 (SH1).
		2	shot = 2 (SH2).
		3	shot = 3 (SH3).
		4	shot = 4 (SH4).
Zld[b]	ZLIN, ZLOUT	i	Load-encroachment “load in” element ZLIN picked up.
		o	Load-encroachment “load out” element ZLOUT picked up.
LOP[b]	LOP	*	Loss-of-potential element LOP picked up.
Vdc	DCHI, DCLO	H	Station battery instantaneous overvoltage element DCHI picked up.
		L	Station battery instantaneous undervoltage element DCLO picked up.
		b	Both DCHI and DCLO asserted.

Table 12.4 Output, Input, Protection and Control, and Communication Element Event Report Columns (Sheet 6 of 10)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
Lcl 12	LB1, LB2	1	Local bit LB1 asserted.
		2	Local bit LB2 asserted.
		b	Both LB1 and LB2 asserted.
Lcl 34	LB3, LB4	3	Local bit LB3 asserted.
		4	Local bit LB4 asserted.
		b	Both LB3 and LB4 asserted.
Lcl 56	LB5, LB6	5	Local bit LB5 asserted.
		6	Local bit LB6 asserted.
		b	Both LB5 and LB6 asserted.
Lcl 78	LB7, LB8	7	Local bit LB7 asserted.
		8	Local bit LB8 asserted.
		b	Both LB7 and LB8 asserted.
Rem 12	RB1, RB2	1	Remote bit RB1 asserted.
		2	Remote bit RB2 asserted.
		b	Both RB1 and RB2 asserted.
Rem 34	RB3, RB4	3	Remote bit RB3 asserted.
		4	Remote bit RB4 asserted.
		b	Both RB3 and RB4 asserted.
Rem 56	RB5, RB6	5	Remote bit RB5 asserted.
		6	Remote bit RB6 asserted.
		b	Both RB5 and RB6 asserted.
Rem 78	RB7, RB8	7	Remote bit RB7 asserted.
		8	Remote bit RB8 asserted.
		b	Both RB7 and RB8 asserted.
Rem OC	OC, CC	o	**OPE** (Open) command executed.
		c	**CLO** (Close) command executed.
Ltch 12	LT1, LT2	1	Latch bit LT1 asserted.
		2	Latch bit LT2 asserted.
		b	Both LT1 and LT2 asserted.
Ltch 34	LT3, LT4	3	Latch bit LT3 asserted.
		4	Latch bit LT4 asserted.
		b	Both LT3 and LT4 asserted.
Ltch 56	LT5, LT6	5	Latch bit LT5 asserted.
		6	Latch bit LT6 asserted.
		b	Both LT5 and LT6 asserted.
Ltch 78	LT7, LT8	7	Latch bit LT7 asserted.
		8	Latch bit LT8 asserted.
		b	Both LT7 and LT8 asserted.

Table 12.4 Output, Input, Protection and Control, and Communication Element Event Report Columns (Sheet 7 of 10)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
SELOGIC Var 1	SV1, SV1T	p	SELOGIC control equation variable timer input SV_ asserted; timer timing on pickup time; timer output SV_T not asserted.
SELOGIC Var 2	SV2, SV2T		
SELOGIC Var 3	SV3, SV3T		
SELOGIC Var 4	SV4, SV4T		
SELOGIC Var 5	SV5, SV5T	T	SELOGIC control equation variable timer input SV_ asserted; timer timed out on pickup time; timer output SV_T asserted.
SELOGIC Var 6	SV6, SV6T		
SELOGIC Var 7	SV7, SV7T		
SELOGIC Var 8	SV8, SV8T		
SELOGIC Var 9	SV9, SV9T		
SELOGIC Var 10	SV10, SV10T	d	SELOGIC control equation variable timer input SV_ not asserted; timer previously timed out on pickup time; timer output SV_T remains asserted while timer timing on dropout time.
SELOGIC Var 11	SV11, SV11T		
SELOGIC Var 12	SV12, SV12T		
SELOGIC Var 13	SV13, SV13T		
SELOGIC Var 14	SV14, SV14T		
SELOGIC Var 15	SV15, SV15T		
SELOGIC Var 16	SV16, SV16T		
3PO[c]	3PO	*	Three-pole open condition 3PO asserted.
SOTF	SOTFE	*	Switch-onto-fault SOTF enable asserted.
PT[b]	PT	*	Permissive trip signal to POTT logic PT asserted.
PTRX[b]	PTRX1, PTRX2	1	Permissive trip 1 signal from DCUB logic PTRX1 asserted.
		2	Permissive trip 2 signal from DCUB logic PTRX2 asserted.
		b	Both PTRX1 and PTRX2 asserted
Z3RB[b]	Z3RB	*	Zone (level) 3 reverse block Z3RB asserted.
KEY[b]	KEY	*	Key permissive trip signal start KEY asserted.
EKEY[b]	EKEY	*	Echo key EKEY asserted.
ECTT[b]	ECTT	*	Echo conversion to trip condition ECTT asserted.
WFC[b]	WFC	*	Weak infeed condition WFC asserted.
UBB[b]	UBB1, UBB2	1	Unblocking block 1 from DCUB logic UBB1 asserted.
		2	Unblocking block 2 from DCUB logic UBB2 asserted.
		b	Both UBB1 and UBB2 asserted.
Z3XT[b]	Z3XT	*	Logic output from zone (level) 3 extension timer Z3XT asserted.
DSTR[b]	DSTRT	*	Directional carrier start DSTRT asserted.
NSTR[b]	NSTRT	*	Nondirectional carrier start NSTRT asserted.
STOP[b]	STOP	*	Carrier stop STOP asserted.
BTX[b]	BTX	*	Block trip input extension BTX asserted.
TMB A 12	TMB1A, TMB2A	1	MIRRORED BITS Channel A Transmit Bit 1 TMB1A asserted.
		2	MIRRORED BITS Channel A Transmit Bit 2 TMB2A asserted.
		b	Both TMB1A and TMB2A asserted.

Table 12.4 Output, Input, Protection and Control, and Communication Element Event Report Columns (Sheet 8 of 10)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
TMB A 34	TMB3A, TMB4A	3	MIRRORED BITS channel A transmit bit 3 TMB3A asserted.
		4	MIRRORED BITS channel A transmit bit 4 TMB4A asserted.
		b	Both TMB3A and TMB4A asserted.
TMB A 56	TMB5A, TMB6A	5	MIRRORED BITS channel A transmit bit 5 TMB5A asserted.
		6	MIRRORED BITS channel A transmit bit 6 TMB6A asserted.
		b	Both TMB5A and TMB6A asserted.
TMB A 78	TMB7A, TMB8A	7	MIRRORED BITS channel A transmit bit 7 TMB7A asserted.
		8	MIRRORED BITS channel A transmit bit 8 TMB8A asserted.
		b	Both TMB7A and TMB8A asserted.
RMB A 12	RMB1A, RMB2A	1	MIRRORED BITS channel A receive bit 1 RMB1A asserted.
		2	MIRRORED BITS channel A receive bit 2 RMB2A asserted.
		b	Both RMB1A and RMB2A asserted.
RMB A 34	RMB3A, RMB4A	3	MIRRORED BITS channel A receive bit 3 RMB3A asserted.
		4	MIRRORED BITS channel A receive bit 4 RMB4A asserted.
		b	Both RMB3A and RMB4A asserted.
RMB A 56	RMB5A, RMB6A	5	MIRRORED BITS channel A receive bit 5 RMB5A asserted.
		6	MIRRORED BITS channel A receive bit 6 RMB6A asserted.
		b	Both RMB5A and RMB6A asserted.
RMB A 78	RMB7A, RMB8A	7	MIRRORED BITS channel A receive bit 7 RMB7A asserted.
		8	MIRRORED BITS channel A receive bit 8 RMB8A asserted.
		b	Both RMB7A and RMB8A asserted.
TMB B 12	TMB1B, TMB2B	1	MIRRORED BITS channel B transmit bit 1 TMB1B asserted.
		2	MIRRORED BITS channel B transmit bit 2 TMB2B asserted.
		b	Both TMB1B and TMB2B asserted.
TMB B 34	TMB3B, TMB4B	3	MIRRORED BITS channel B transmit bit 3 TMB3B asserted.
		4	MIRRORED BITS channel B transmit bit 4 TMB4B asserted.
		b	Both TMB3B and TMB4B asserted.
TMB B 56	TMB5B, TMB6B	5	MIRRORED BITS channel B transmit bit 5 TMB5B asserted.
		6	MIRRORED BITS channel B transmit bit 6 TMB6B asserted.
		b	Both TMB5B and TMB6B asserted.
TMB B 78	TMB7B, TMB8B	7	MIRRORED BITS channel B transmit bit 7 TMB7B asserted.
		8	MIRRORED BITS channel B transmit bit 8 TMB8B asserted.
		b	Both TMB7B and TMB8B asserted.
RMB B 12	RMB1B, RMB2B	1	MIRRORED BITS channel B receive bit 1 RMB1B asserted.
		2	MIRRORED BITS channel B receive bit 2 RMB2B asserted.
		b	Both RMB1B and RMB2B asserted.
RMB B 34	RMB3B, RMB4B	3	MIRRORED BITS channel B receive bit 3 RMB3B asserted.
		4	MIRRORED BITS channel B receive bit 4 RMB4B asserted.
		b	Both RMB3B and RMB4B asserted.

Table 12.4 Output, Input, Protection and Control, and Communication Element Event Report Columns (Sheet 9 of 10)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
RMB B 56	RMB5B, RMB6B	5	MIRRORED BITS channel B receive bit 5 RMB5B asserted.
		6	MIRRORED BITS channel B receive bit 6 RMB6B asserted.
		b	Both RMB5B and RMB6B asserted.
RMB B 78	RMB7B, RMB8B	7	MIRRORED BITS channel B receive bit 7 RMB7B asserted.
		8	MIRRORED BITS channel B receive bit 8 RMB8B asserted.
		b	Both RMB7B and RMB8B asserted.
ROK	ROKA, ROKB	A	MIRRORED BITS channel A receive ok ROKA asserted.
		B	MIRRORED BITS channel B receive ok ROKB asserted.
		b	Both ROKA and ROKB asserted.
RBAD	RBADA, RBADB	A	MIRRORED BITS channel A extended outage RBADA asserted.
		B	MIRRORED BITS channel B extended outage RBADB asserted.
		b	Both RBADA and RBADB asserted.
CBAD	CBADA, CBADB	A	MIRRORED BITS channel A unavailability CBADA asserted.
		B	MIRRORED BITS channel B unavailability CBADB asserted.
		b	Both CBADA and CBADB asserted.
LBOK	LBOKA, LBOKB	A	MIRRORED BITS channel A loop back ok LBOKA asserted.
		B	MIRRORED BITS channel B loop back ok LBOKB asserted.
		b	Both LBOKA and LBOKB asserted.
PWR A 12[d] (wye-connected or single-phase voltage)	PWRA1, PWRA2	1	Level 1 A-phase power element PWR1A picked up.
		2	Level 2 A-phase power element PWR2A picked up.
		b	Both PWR1A and PWR2A picked up.
PWR A 34[d] (wye-connected or single-phase voltage)	PWRA3, PWRA4	3	Level 3 A-phase power element PWR3A picked up.
		4	Level 4 A-phase power element PWR4A picked up.
		b	Both PWR3A and PWR4A picked up.
PWR B 12[d] (wye-connected or single-phase voltage)	PWRB1, PWRB2	1	Level 1 B-phase power element PWR1B picked up.
		2	Level 2 B-phase power element PWR2B picked up.
		b	Both PWR1B and PWR2B picked up.
PWR B 34[d] (wye-connected or single-phase voltage)	PWRB3, PWRB4	3	Level 3 B-phase power element PWR3B picked up.
		4	Level 4 B-phase power element PWR4B picked up.
		b	Both PWR3B and PWR4B picked up.
PWR C 12[d] (wye-connected or single-phase voltage)	PWRC1, PWRC2	1	Level 1 C-phase power element PWR1C picked up.
		2	Level 2 C-phase power element PWR2C picked up.
		b	Both PWR1C and PWR2C picked up.
PWR C 34[d] (wye-connected or single-phase voltage)	PWRC3, PWRC4	3	Level 3 C-phase power element PWR3C picked up.
		4	Level 4 C-phase power element PWR4C picked up.
		b	Both PWR3C and PWR4C picked up.
PWR 3P 12[b, d]	3PWR1, 3PWR2	1	Level 1 three-phase power element 3PWR1 picked up.
		2	Level 2 three-phase power element 3PWR2 picked up.
		b	Both 3PWR1 and 3PWR2 picked up.

Table 12.4 Output, Input, Protection and Control, and Communication Element Event Report Columns (Sheet 10 of 10)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
PWR 3P 34[b, d]	3PWR3, 3PWR4	3	Level 3 three-phase power element 3PWR3 picked up.
		4	Level 4 three-phase power element 3PWR4 picked up.
		b	Both 3PWR3 and 3PWR4 picked up.

[a] Output contacts can be Form A- or Form B-type contacts (see *Output Contact Jumpers* on page 2.40 and *Figure 7.28–Figure 7.29*).
[b] When PTCONN = SINGLE, this column is present, but the elements are inactive and will always display as ".".
[c] The Communications Elements section of the event report (column headings 3PO through PWR 3P 34) is not available in Firmware Version 5.
[d] Available in Firmware Version 7.

Sequential Events Recorder (SER) Report

See *Figure 12.11* for an example SER report.

SER Triggering

The relay triggers (generates) an entry in the SER report for a change of state of any one of the elements listed in the SER1, SER2, and SER3 trigger settings. The factory default settings are:

SER1 = **51P,51G,50P1**

SER2 = **LB3,LB4,IN101,IN102,OUT101,OUT102,OUT103**

SER3 = **CF,79CY,79LO**

The elements are Relay Word bits referenced in *Table D.1*. The relay monitors each element in the SER lists every 1/4 cycle. If an element changes state, the relay time-tags the changes in the SER. For example, setting SER1 contains:

- time-overcurrent element pickups (51P and 51G)
- instantaneous overcurrent element (50P1)

Thus, any time one of these overcurrent elements picks up or drops out, the relay time-tags the change in the SER.

Each entry in the SER includes SER row number, date, time, element name, and element state.

The SER stops recording all Relay Word bits except ALARM, HALARM, HALARML, SETCHG, and GRPSW when the relay is disabled.

Automatic SER Triggers

The SEL-351 automatically logs special SER entries as shown in *Table 12.5*. There are no SER trigger settings associated with these automatic SER trigger entries.

Table 12.5 Automatic SER Triggers

Event	SER Entry	Reference
Power-up	`Relay newly powered up`	*Section 9: Setting the Relay*
Settings change, active group change, or CID file uploaded	`Relay settings changed`	*Section 7: Inputs, Outputs, Timers, and Other Control Logic*, *Section 9: Setting the Relay*, and *Appendix P: IEC 61850*
Active setting group changed	Relay group changed	*Section 7: Inputs, Outputs, Timers, and Other Control Logic*
SER C command issued	`SER archive cleared`	*Clearing SER Report* on page 12.34
Start of SER data loss	`SER data loss begin`	*SER Memory Operation* on page 12.34
End of SER data loss	`SER data loss end`	
Invalid SER data	`Invalid Data`	
Data overwritten while relay is responding to **SER** command	Command aborted, data overwrite occurred	
Diagnostic restart	`Diagnostic restart`	*Section 13: Testing and Troubleshooting*

All of the automatic SER entries except "Invalid Data" include a date and time stamp.

Making SER Trigger Settings

Enter as many as 24 element names in each of the SER settings via the **SET R** command. See *Table D.1* for references to valid relay element (Relay Word bit) names. See the **SET R** command in *Table 9.2* and corresponding *Report Settings (Serial Port Command SET R)* on page SET.30. Use commas or spaces to delimit the elements. For example, if you enter setting SER1 as:

SER1 = **51P,51G,51PT,,51GT , 50P1, , 50P2**

The relay displays the setting as:

```
SER1 = 51P,51G,51PT,51GT,50P1,50P2
```

The relay can monitor as many as 72 elements in the SER (24 in each of SER1, SER2, and SER3).

Make SER Settings With Care

The relay triggers a row in the Sequential Events Recorder (SER) event report for any change of state in any one of the elements listed in the SER1, SER2, or SER3 trigger settings. Nonvolatile memory is used to store the latest 512 rows of the SER event report so they can be retained during power loss. The nonvolatile memory is rated for a finite number of "writes." Exceeding the limit can result in an EEPROM self-test failure. An average of one state change every three minutes can be made for a 25-year relay service life.

Retrieving SER Reports

Via Serial Port

The relay saves the latest 1024 rows of the SER in nonvolatile memory. Row 1 is the most recently triggered row, and row 1024 is the oldest. View the SER report by date or SER row number as outlined in the examples below.

Example SER Serial Port Commands	Format
SER	If **SER** is entered with no numbers following it, all available rows are displayed (to row number 1024). They display with the oldest row at the beginning (top) of the report and the latest row (row 1) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SER 17	If **SER** is entered with a single number following it (**17** in this example), the first 17 rows are displayed, if they exist. They display with the oldest row (row 17) at the beginning (top) of the report and the latest row (row 1) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SER 10 33	If **SER** is entered with two numbers following it (**10** and **33** in this example; 10 < 33), all the rows between (and including) rows 10 and 33 are displayed, if they exist. They display with the oldest row (row 33) at the beginning (top) of the report and the latest row (row 10) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SER 47 22	If **SER** is entered with two numbers following it (**47** and **22** in this example; 47 > 22), all the rows between (and including) rows 47 and 22 are displayed, if they exist. They display with the newest row (row 22) at the beginning (top) of the report and the oldest row (row 47) at the end (bottom) of the report. *Reverse* chronological progression through the report is down the page and in ascending row number.
SER 3/30/2009	If **SER** is entered with one date following it (date **3/30/2009** in this example), all the rows on that date are displayed, if they exist. They display with the oldest row at the beginning (top) of the report and the latest row at the end (bottom) of the report, for the given date. Chronological progression through the report is down the page and in descending row number.
SER 2/17/2009 3/23/2009	If **SER** is entered with two dates following it (date **2/17/2009** chronologically *precedes* date **3/23/2009** in this example), all the rows between (and including) dates 2/17/2009 and 3/23/2009 are displayed, if they exist. They display with the oldest row (date 2/17/2009) at the beginning (top) of the report and the latest row (date 3/23/2009) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SER 3/16/2009 1/5/2009	If **SER** is entered with two dates following it (date **3/16/2009** chronologically *follows* date **1/5/2009** in this example), all the rows between (and including) dates 1/5/2009 and 3/16/2009 are displayed, if they exist. They display with the latest row (date 3/16/2009) at the beginning (top) of the report and the oldest row (date 1/5/2009) at the end (bottom) of the report. *Reverse* chronological progression through the report is down the page and in ascending row number.

NOTE: The SEL-351 accepts two or four digit years in the **SER** command. For example, **SER 3/30/09** is treated the same as **SER 3/30/2009**. In either case, the SER report only displays two digit years in the Date column.

The date entries in the above example **SER** commands are dependent on the Date Format setting DATE_F. If setting DATE_F = MDY, then the dates are entered as in the above examples (Month/Day/Year). If setting DATE_F = YMD, then the dates are entered Year/Month/Day.

If the requested SER event report rows do not exist, the relay responds:

```
No SER Data
```

Via File Transfer

The SER report is available via file transfer protocols. See *Virtual File Interface* on page 10.26.

Clearing SER Report

Clear the SER report from nonvolatile memory with the **SER C** command as shown in the following example:

NOTE: If any elements change state during the clearing process, the SER entries for these elements may be reported with time stamps that are prior to the `SER archive cleared` message.

```
=>SER C <Enter>
Clear the SER
Are you sure (Y/N) ? Y <Enter>
Clearing Complete
```

To indicate when the SER memory was cleared, an entry is added to the SER as shown in *Table 12.5*.

SER Memory Operation

The Sequential Events Recorder (SER) nonvolatile memory is updated soon after new SER data are generated. During some conditions, such as during event report capture, the update of SER data is momentarily interrupted, and then SER updating of nonvolatile memory resumes.

In rare cases with rapidly occurring SER triggers, the new SER information may arrive faster than the memory system can store it. When this occurs, the relay inserts a pair of entries in the SER to indicate the start and end of data loss, as shown in *Table 12.5*. This is normally seen only during testing. Normal SER operation resumes after the data loss.

Another situation that can affect SER data storage is when the power supply to the SEL-351 is interrupted while data are being recorded. If this results in incomplete data, the SER Command may report `Invalid Data` for the incomplete entry, as shown in *Table 12.5*. Normal SER operation resumes after the relay is powered up.

Example Standard 15-Cycle Event Report

The following example standard 15-cycle event report in *Figure 12.7* (from a Model 03517 relay, with wye-connected voltages) also corresponds to the example sequential events recorder (SER) report in *Figure 12.11*. The circled numbers in *Figure 12.7* correspond to the SER row numbers in *Figure 12.11*. The row explanations follow *Figure 12.11*.

In *Figure 12.7*, the arrow (>) in the column following the `Freq` column identifies the “trigger” row. This row corresponds to the `Date` and `Time` values at the top of the event report.

The asterisk (*) in the column following the `Freq` column identifies the row used for event summary currents. The currents are calculated from the row identified with the asterisk and the row one quarter-cycle before (see *Figure 12.9* and *Figure 12.10*). These currents are listed at the end of the event report in the event summary. If the “trigger” row (>) and the event summary current row (*) are the same row, the (*) symbol takes precedence. Because the event summary currents are determined from filtered values, the asterisk (*) is not displayed in the unfiltered (raw) event report. The asterisk (*) is only displayed in the filtered event report.

The event summary currents come from the event report row with the highest phase current when Global setting FLTDISP is set to MAX, and from the rows used for fault location when FLTDISP is set to FL. If FLTDISP is changed, the event summary currents change for all events stored in the relay, and the location of the (*) changes.

```
FEEDER 1                          Date: 04/12/09    Time: 09:28:31.721
```
See *Figure 12.2*

```
STATION A

FID=SEL-351-7-R5xx-V0-Zxxxxxx-D2009xxxx       CID=xxxx
```
Firmware Identifier

Firmware Checksum Identifier

```
Event Number = 10522
```
Unique Event Identification Number

```
                                                            Out  In
      Currents (Amps Pri)          Voltages (kV Pri)        1357 135

    IA    IB    IC    IN    IG     VA     VB     VC     VS Vdc Freq  246A 246
[1]
   241    26  -268    -1    -1    9.6    1.5  -11.1    0.0  24 60.01 .... b..
  -169   293  -124     0     0   -7.2   11.9   -4.7    0.0  24 60.01 .... b..
  -242   -26   267    -1    -1   -9.6   -1.5   11.0   -0.0  24 60.01 .... b..
   168  -294   124    -1    -2    7.2  -11.9    4.7    0.0  24 60.01 .... b..
```
One Cycle of Data

```
[Two cycles of data not shown in this example ]                     7
[4]
   243    22  -266    -1    -1    9.7    1.3  -11.0   -0.0  24 60.01 .... b..
  -166   294  -128     0    -0   -7.1   11.9   -4.8    0.0  24 60.01 .... b..
  -542   -32   255    -1  -319   -8.7   -1.9   10.8    0.0  24 60.01 .... b..
  -485  -271   107     0  -649    6.5  -11.7    4.8   -0.0  24 60.01>.... b..
[5]
  1586    37  -220    -1  1404    6.9    3.1  -10.2   -0.0  24 60.01 .... b..
  1295   226   -82     0  1439   -4.9   11.0   -4.9    0.0  24 59.81 1... b..
 -2332   -33   194     0 -2171   -6.2   -3.6    9.9    0.0  24 59.81 1... b..
 -1460  -208    77    -1 -1590    3.9  -10.5    5.0    0.0  24 59.70 1... b..
[6]
  2328    32  -194     0  2166    6.2    3.6   -9.9   -0.0  24 59.70 1... b..
  1465   207   -79     0  1594   -3.9   10.5   -5.0   -0.0  24 59.70 1... b..
 -2326   -32   193    -1 -2165   -6.2   -3.6    9.9    0.0  24 59.70 1... b..
 -1470  -208    79     0 -1599    3.9  -10.5    5.0    0.0  24 59.89 1... b..
[7]
  2323    31  -194     0  2160    6.2    3.5   -9.9   -0.0  24 59.89 1... b..
  1474   207   -80    -1  1601   -3.9   10.5   -5.0    0.0  24 60.01 1... b..
 -2320   -31   193     0 -2158   -6.2   -3.5    9.9    0.0  24 60.01 1... b..
 -1479  -208    80     0 -1607    3.8  -10.5    5.1    0.0  24 60.01 1... b..
```
See *Figure 12.8* and *Figure 12.9* for details on this example one cycle of A-Phase (Channel IA) current

Figure 12.7 Example Standard 15-Cycle Event Report 1/4 Cycle Resolution (Wye-Connected PTs)

```
  2317    31  -194     0  2154    6.2    3.5   -9.9   -0.0  24 60.01 1... b..
  1482   207   -80     0  1609   -3.8   10.5   -5.1   -0.0  24 60.01 1... b..
 -2317   -31   193    -1 -2154   -6.2   -3.5    9.9    0.0  24 60.01 1... b..
 -1484  -208    80    -1 -1612    3.8  -10.5    5.1    0.0  24 60.01 1... b..
[9]
  2317    30  -194    -1  2153    6.2    3.5   -9.9   -0.0  24 60.01*1... b..     Location of (*) changes according to Global
  1483   207   -80     0  1609   -3.8   10.5   -5.1    0.0  24 60.01 1... b..     setting FLTDISP
 -1965   -41   160     0 -1846   -7.2   -2.9   10.1    0.0  24 60.01 1... b..
  -849  -146    39    -1  -956    4.4  -10.7    5.1   -0.0  24 60.01 1... b..
[10]
   805    26   -64    -1   767    9.0    1.7  -10.6   -0.0  24 60.01 1... b..     ③
   108    41     0     0   149   -6.0   11.4   -5.1    0.0  24 60.25 1... b..
    -1     0     0    -1    -1   -9.8   -1.2   10.9    0.0  24 60.25 1... 2..
     0     0    -1    -1    -1    7.0  -12.0    5.0   -0.0  24 60.32 1... 2..
[11]
    -1    -1     0     0    -1    9.8    1.2  -10.9   -0.0  24 60.32 1... 2..
    -1     0     0     0    -1   -7.0   11.9   -4.9    0.0  24 60.32 1... 2..
     0     0    -1    -1    -1   -9.7   -1.2   10.9    0.0  24 60.32 1... 2..
    -1    -1    -1    -1    -2    7.0  -11.9    4.9   -0.0  24 60.08 1... 2..
       [Two cycles of data not shown in this example]
[14]
    -1     0    -1    -1    -1    9.7    1.2  -11.0    0.0  24 60.01 1... 2..     ②
     0     0     0    -1     0   -7.0   11.9   -4.9    0.0  24 60.01 .... 2..
     0    -1     0    -1    -1   -9.7   -1.2   10.9   -0.0  24 60.01 .... 2..
    -1    -1    -1     0    -2    7.0  -11.9    4.9    0.0  24 60.01 .... 2..

[15]
    -1    -1    -1     0    -2    9.8    1.2  -10.9   -0.0  24 60.01 .... 2..
     0     0     0    -1     0   -7.0   11.9   -5.0    0.0  24 60.01 .... 2..
     0     0     0     0     0   -9.8   -1.1   10.9    0.0  24 60.01 .... 2..
     0    -1    -1    -1    -1    7.0  -11.9    5.0    0.0  24 60.01 .... 2..
Protection and Control Elements
51     50 32 67   Dm 27 59     25  81   TS     Lcl Rem  Ltch SELogic
                          V   5   2     ih ZLV               Variable
      G  P PN      PN  P  P1   9S  7135 7mo lOd 1357135701357          1111111
ABCPNG2QPP QG PNGQ QG PPSPPQNS VFA B246 9et dPc 24682468C2468 1234567890123456
[1]
.......... .. .... .. ........ ... .... R.0 ... ............. ................
.......... .. .... .. ........ ... .... R.0 ... ............. ................
.......... .. .... .. ........ ... .... R.0 ... ............. ................
.......... .. .... .. ........ ... .... R.0 ... ............. ................

        [Two cycles of data not shown in this example]

[4]
.......... .. .... .. ........ ... .... R.0 ... ............. ................
.......... .. .... .. ........ ... .... R.0 ... ............. ................
.....p.... .. .... .. ........ ... .... R.0 ... ............. ................
...p.p.... .. .... .. ........ ... .... R.0 ... ............. ................     ⑧⑨⑩⑪
[5]
...p.p.... .. .... .. ........ ... .... R.0 ... ............. ................
...p.p..A. .. 1... .. ........ ... .... C.0 ... ............. p...............
...p.p..A. .. 1... .. ........ ... .... Cr0 ... ............. p...............
...p.p..A. .. 1... .. ........ ... .... Cr0 ... ............. p...............

[6]
...p.p..A. .. 1... .. ........ ... .... Cr0 ... ............. p...............
...p.p..A. .. 1... .. ........ ... .... Cr0 ... ............. p...............
...p.p..A. .. 1... .. ........ ... .... Cr0 ... ............. p...............
...p.p..A. .. 1... .. ........ ... .... Cr0 ... ............. p...............
[7]
...p.p..A. .. 1... .. ........ ... .... Cr0 ... ............. p...............
...p.p..A. .. 1... .. ........ ... .... Cr0 ... ............. p...............
...p.p..A. .. 1... .. ........ ... .... Cr0 ... ............. p...............
...p.p..A. .. 1... .. ........ ... .... Cr0 ... ............. p...............
[8]
...p.p..A. .. 1... .. ........ ... .... Cr0 ... ............. p...............
...p.p..A. .. 1... .. ........ ... .... Cr0 ... ............. p...............
...p.p..A. .. 1... .. ........ ... .... Cr0 ... ............. p...............
...p.p..A. .. 1... .. ........ ... .... Cr0 ... ............. p...............

[9]
...p.p..A. .. 1... .. ........ ... .... Cr0 ... ............. p...............
...p.p..A. .. 1... .. ........ ... .... Cr0 ... ............. p...............
...p.p..A. .. 1... .. ........ ... .... Cr0 ... ............. p...............
...p.p..A. .. 1... .. ........ ... .... Cr0 ... ............. p...............     ⑥
[10]
...p.p.... .. .... .. ........ ... .... Cr0 ... ............. p...............
...p.p.... .. .... .. ........ ... .... Cr0 ... ............. p...............
...r.r.... .. .... .. ........ ... .... Cr0 ... ............. p...............
...r.r.... .. .... .. ........ ... .... Cr0 ... ............. p...............     ⑤

[11]
...r.r.... .. .... .. ........ ... .... C.0 ... ............. p...............
...r.r.... .. .... .. ........ ... .... C.0 ... ............. p...............
.......... .. .... .. ........ ... .... C.0 ... ............. p...............
.......... .. .... .. ........ ... .... C.0 ... ............. p...............
```

Figure 12.7 Example Standard 15-Cycle Event Report 1/4 Cycle Resolution (Wye-Connected PTs) (Continued)

```
 [Two cycles of data not shown in this example ]
[14]
.......... .. .... .. ........ ... .... C.0 ... ............. p...............
.......... .. .... .. ........ ... .... CoO ... ............. ................    ②
.......... .. .... .. ........ ... .... CoO ... ............. ................
.......... .. .... .. ........ ... .... CoO ... ............. ................
[15]
.......... .. .... .. ........ ... .... CoO ... ............. ................
.......... .. .... .. ........ ... .... CoO ... ............. ................
.......... .. .... .. ........ ... .... CoO ... ............. ................
.......... .. .... .. ........ ... .... CoO ... ............. ................

(The Communication Elements Section is only available in Firmware Versions 6 and 7.)
Communication Elements
 S  PZ EE   ZDNS  TMB  RMB  TMB  RMB  RRCL PWR
3O  T3KKCWU 3SSTB A    A    B    B    OBBB A B C 3P
PT PRREETFB XTTOT 1357 1357 1357 1357 KAAO 13131313
OF TXBYYTCB TRRPX 2468 2468 2468 2468  DDK 24242424
[1]
.. ........ ..... .... .... .... .... .... ........
.. ........ ..... .... .... .... .... .... ........
.. ........ ..... .... .... .... .... .... ........
.. ........ ..... .... .... .... .... .... ........
[2]
.. ........ ..... .... .... .... .... .... ........
.. ........ ..... .... .... .... .... .... ........
.. ........ ..... .... .... .... .... .... ........
.. ........ ..... .... .... .... .... .... ........
                                       These columns are
                                       displayed only in
                                       Firmware Version 7

 [Thirteen cycles of data not shown in this example]

[15]
** ........ ..... .... .... .... .... .... ........
** ........ ..... .... .... .... .... .... ........
** ........ ..... .... .... .... .... .... ........
** ........ ..... .... .... .... .... .... ........
Event: AG T  Location:    2.36  Shot: 0  Frequency:  60.01
Targets: INST 50
Currents (A Pri), ABCNGQ:   2752 pk   209   209     1  2689  2689          See Figure 12.2

[Settings follow but are not shown in this example]

=>>
```

Figure 12.7 Example Standard 15-Cycle Event Report 1/4 Cycle Resolution (Wye-Connected PTs) (Continued)

Figure 12.9 and *Figure 12.10* look in detail at one cycle of A-phase current (channel IA) identified in *Figure 12.7*. *Figure 12.9* shows how the event report ac current column data relates to the actual sampled waveform and rms values. *Figure 12.10* shows how the event report current column data can be converted to phasor rms values. Voltages are processed similarly.

```
=>EVE L2 <Enter>

FEEDER 1                          Date: 02/18/02    Time: 17:57:22.114
STATION A

FID=SEL-351-7-R5xx-V0-Zxxxxxx-D2009xxxx       CID=xxxx
Event Number = 18199

                                                                    Out  In
      Currents (Amps Pri)             Voltages (kV Pri)             1357 135
    IA    IB    IC    IN    IG    VAB    VBC    VCA     VS Vdc Freq  246A 246
[1]
   124  -173    16     0   -33   23.9  -14.9   -9.0    0.0  23 59.99 .... ...
   148    21  -228    -0   -60    3.4   19.0  -22.4    0.0  23 59.99 .... ...
  -124   173   -17    -0    33  -23.9   14.9    9.0    0.0  23 59.99 .... ...
  -148   -20   228     0    60   -3.4  -18.9   22.4    0.0  23 59.99 .... ...
[2]
   123  -173    17     0   -33   23.9  -14.9   -8.9   -0.0  23 59.99 .... ...
   149    20  -228    -0   -59    3.5   18.9  -22.4   -0.0  23 59.99 .... ...
  -123   173   -18    -0    33  -23.9   15.0    8.9    0.0  23 59.99 .... ...
  -149   -20   228     0    59   -3.5  -18.9   22.4    0.0  23 59.99 .... ...

Protection and Control Elements

51     50 32 67   Dm 27 59     25  81   TS     Lcl Rem  Ltch SELogic
                      P  P    5   2     ih ZLV              Variable
      G  P PN      PN PP PPV   9S  7135 7mo lOd 1357135701357          1111111
ABCPNG2QPP QG PNGQ QG P2SP21QS VFA B246 9et dPc 24682468C2468 1234567890123456
[1]
.......... .. .... .. ........ ... .... L.1 ... ............. ................
.......... .. .... .. ........ ... .... L.1 ... ............. ................
.......... .. .... .. ........ ... .... L.1 ... ............. ................
.......... .. .... .. ........ ... .... L.1 ... ............. ................
[2]
.......... .. .... .. ........ ... .... L.1 ... ............. ................
.......... .. .... .. ........ ... .... L.1 ... ............. ................
.......... .. .... .. ........ ... .... L.1 ... ............. ................
.......... .. .... .. ........ ... .... L.1 ... ............. ................

(The Communication Elements Section is only in available in Firmware Versions 6 and
   7.)
(The PWR columns are only available in Firmware Version 7.)

Communication Elements

 S  PZ EE   ZDNS  TMB  RMB  TMB  RMB  RRCL PWR
30  T3KKCWU 3SSTB A    A    B    B    OBBB 3P
PT PRREETFB XTTOT 1357 1357 1357 1357 KAAO 13
OF TXBYYTCB TRRPX 2468 2468 2468 2468  DDK 24
[1]
.. ........ ..... .... .... .... .... .... ..
.. ........ ..... .... .... .... .... .... ..
.. ........ ..... .... .... .... .... .... ..
.. ........ ..... .... .... .... .... .... ..
[2]
.. ........ ..... .... .... .... .... .... ..
.. ........ ..... .... .... .... .... .... ..
.. ........ ..... .... .... .... .... .... ..
.. ........ ..... .... .... .... .... .... ..

Event: TRIG  Location: $$$$$$$  Shot: 1  Frequency:  59.99
Targets:
Currents (A Pri), ABCNGQ:    191   173   229     0    68    88

Group 1
Group Settings:
****** NOT SHOWN *****
```

Figure 12.8 Example Partial Event Report With Delta-Connected PTs

The event report in *Figure 12.8* is displaying filtered analog data. If the **EVE R** command had been used instead, the analog voltage column headings would be VA, VB, VC, as described in *Filtered and Unfiltered Event Reports* on page 12.18.

The event report sample in *Figure 12.8* is not related to the event report sample in *Figure 12.7*, or to the SER sample in *Figure 12.11*.

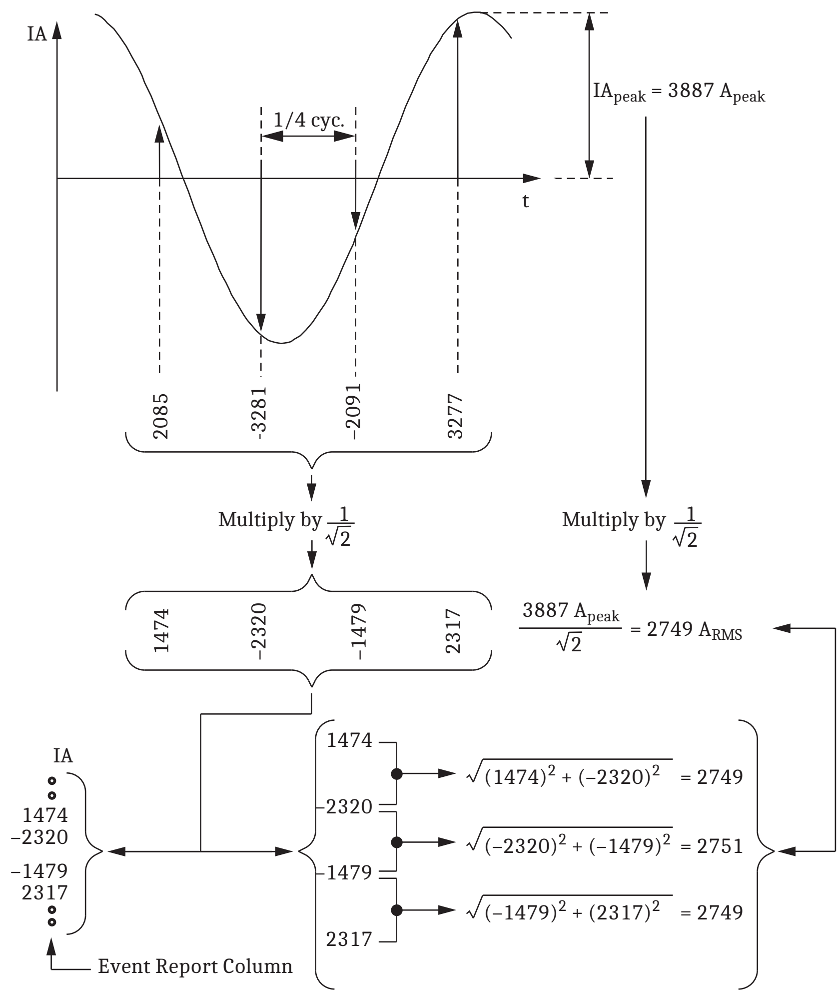
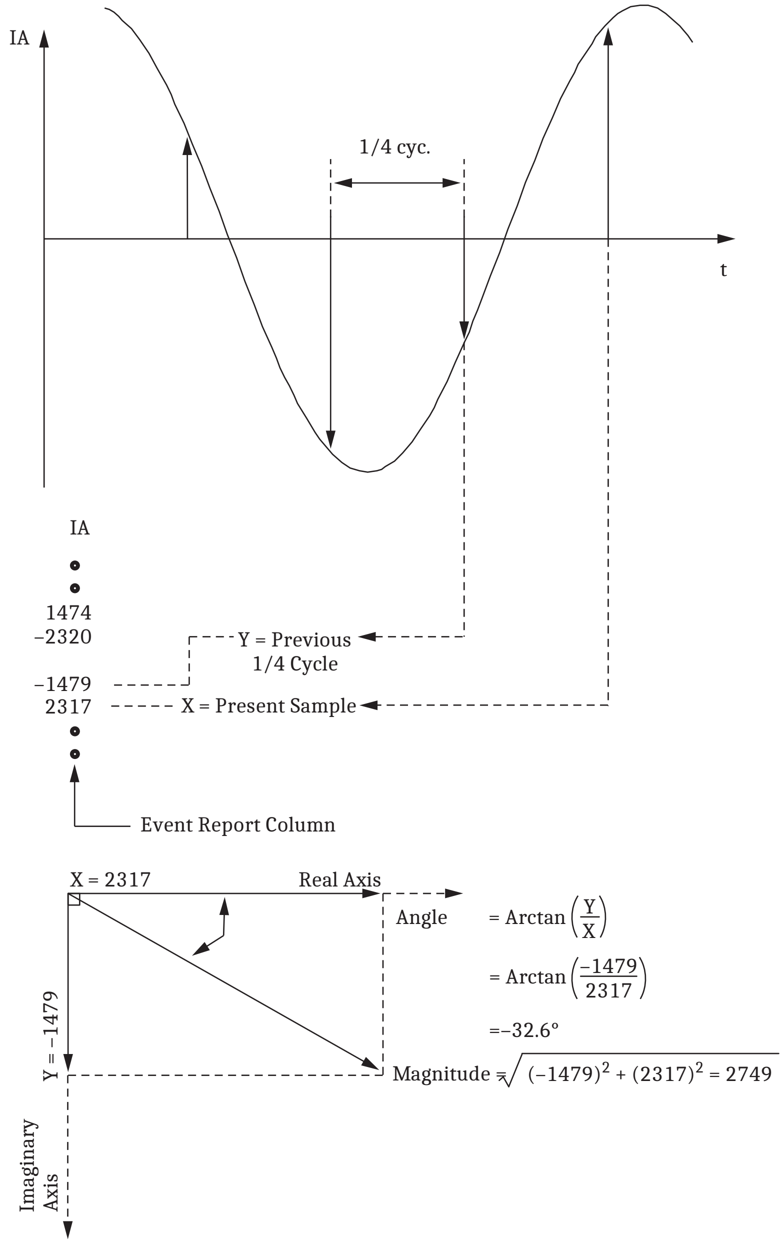


Figure 12.9 Derivation of Event Report Current Values and RMS Current Values From Sampled Current Waveform

In *Figure 12.9*, note that any two rows of current data from the event report in *Figure 12.7*, 1/4 cycle apart, can be used to calculate rms current values.



NOTE: The arctan function on 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 calculated angle is correct.

Figure 12.10 Derivation of Phasor RMS Current Values From Event Report Current Values

In *Figure 12.10*, note that two rows of current data from the event report in *Figure 12.7*, 1/4 cycle apart, can be used to calculate phasor rms current values. In *Figure 12.10*, at the present sample, the phasor rms current value is:

$$IA = 2749\ A\ \angle{-32.6°}$$

The present sample (IA = 2317 A) is a real rms current value that relates to the phasor rms current value:

$$2749\ A \bullet \cos(-32.6°) = 2317\ A$$

Example SER Report

The following example sequential events recorder (SER) report in *Figure 12.11* also corresponds to the example standard 15-cycle event report in *Figure 12.7*.

```
FEEDER 1                          Date: 04/12/09    Time: 10:20:16.896
STATION A

FID=SEL-351-7-R5xx-V0-Zxxxxxx-D2009xxxx       CID=xxxx

#     DATE      TIME           ELEMENT           STATE

19    04/12/09  08:30:33.222    Relay newly powered up
18    04/12/09  09:20:22.830   IN102             Asserted
17    04/12/09  09:27:58.364   LB4               Asserted
16    04/12/09  09:27:58.364   OUT102            Asserted
15    04/12/09  09:27:58.368   LB4               Deasserted
14    04/12/09  09:27:58.385   IN101             Asserted
13    04/12/09  09:27:58.385   OUT102            Deasserted
12    04/12/09  09:28:03.385   79LO              Deasserted
11    04/12/09  09:28:31.717   51G               Asserted
10    04/12/09  09:28:31.721   51P               Asserted
9     04/12/09  09:28:31.729   50P1              Asserted
8     04/12/09  09:28:31.729   79CY              Asserted
7     04/12/09  09:28:31.729   OUT101            Asserted
6     04/12/09  09:28:31.808   50P1              Deasserted
5     04/12/09  09:28:31.816   51G               Deasserted
4     04/12/09  09:28:31.816   51P               Deasserted
3     04/12/09  09:28:31.816   IN101             Deasserted
2     04/12/09  09:28:31.879   OUT101            Deasserted
1     04/12/09  09:28:36.874   OUT102            Asserted
```

Figure 12.11 Example Sequential Events Recorder (SER) Event Report

The SER event report rows in *Figure 12.11* are explained in the following text, numbered in correspondence to the # column. The boxed, numbered comments in *Figure 12.7* also correspond to the # column numbers in *Figure 12.11*. The SER event report in *Figure 12.11* contains records of events that occurred before and after the standard event report in *Figure 12.7*.

SER Row No.	Explanation
19	Relay newly powered up.
18	Input **IN102** is asserted to enable reclosing. Related setting: 79DTL = !IN102 + ...[=NOT(IN102) + ...]
17, 16	Local bit LB4 is operated from the front panel to assert close output contact **OUT102** to close the circuit breaker (see *Figure 6.2*). Related settings: CL = LB4 (LB4 operates as a manual close) OUT102 = CLOSE
15	Local bit LB4 deasserts automatically the next 1/4 cycle—close signal is latched in by close logic.
14, 13	Input **IN101** asserts, indicating that the circuit breaker closed. Close output contact **OUT102** consequently deasserts. Related setting: 52A = IN101
12	The relay leaves the Lockout State (79LO) and goes to the Reset State, 300 cycles after the circuit breaker closes. Related setting: 79RSLD = 300.000 cycles Time difference: 09:28:03.385–09:27:58.385 = 5.000 seconds (= 300 cycles)

SER Row No.	Explanation
11, 10	Time-overcurrent elements 51PT and 51GT pickup and start timing at fault inception (51P and 51G are the respective pickup indicators).
9, 8, 7	Instantaneous overcurrent element 50P1 picks up and asserts trip output contact OUT101 to trip the circuit breaker (see *Figure 5.1*). Relay goes to the Reclose Cycle State (79CY). Related settings: TR = ...+ 50P1 * SH0 OUT101 = TRIP
6, 5, 4	Instantaneous overcurrent element 50P1 and time-overcurrent element pickups 51P and 51G drop out as the circuit breaker interrupts fault current.
3	Input IN101 deasserts, indicating that the circuit breaker opened.
2	Trip output contact OUT101 deasserts after being asserted a minimum of 9 cycles. Related settings: TDURD = 9.000 cycles Time difference: 09:28:31.879–09:28:31.729 = 0.150 seconds (= 9 cycles) Open interval 79OI1 does not start timing until trip output contact OUT101 deasserts. Related settings: 79STL = TRIP
1	Close output contact OUT102 asserts for first automatic reclose. Related settings:79OI1 = 300.00 Time difference: 09:28:36.874–09:28:31.879 = 4.995 seconds (≈300 cycles)

Sag/Swell/Interruption (SSI) Report (Available in Firmware Version 7)

See *Figure 12.12* and *Figure 12.13* for an example SSI report.

SSI Triggering and Recording

The SEL-351-7 can perform automatic voltage disturbance monitoring for three-phase systems. The SSI Recorder uses the SSI Relay Word bits to determine when to start (trigger) and when to stop recording. The recorded data are available through the SSI Report.

See *Voltage Sag, Swell, and Interruption Elements* on page 3.66 for details on the operation of the SSI Relay Word bits.

NOTE: Because the SSI element logic requires a three-phase voltage connection, Group setting ESSI cannot be set to Y when Group setting VNOM = OFF. Similarly, the Group setting ESSI is hidden and set to N internally when Global setting PTCONN = SINGLE.

The SSI recorder operates (adds new entries to the stored SSI report) only when group setting ESSI = Y in the active setting group, although the SSI report can be viewed at any time.

The SSI recorder uses nonvolatile memory, so any stored SSI data will not be erased by de-energizing the relay. The relay needs some time to store new SSI data in nonvolatile memory, so if a system power outage also causes the relay power to fail, there may not be an SSI record of the disturbance. This is not a concern in substations where the relay is powered by a substation battery.

The relay triggers (generates) entries in the SSI report on the assertion of any sag, swell, or interruption relay element (Relay Word bits SAG*p*, SW*p*, INT*p*, where *p* = A, B, or C [wye-connected]; *p* = AB, BC, or CA [delta-connected]), or when manually triggered by the **SSI T** command.

SSI Report Entries

- Entry number (1 is the most recent entry)
- Date and time stamp of entry
- Phase current magnitudes (Ia,b,c) as a percentage of the nominal current rating of the phase current inputs (5 A or 1 A)
- Calculated residual current magnitude (Ig) as a percentage of the nominal current rating of the phase current inputs (5 A or 1 A)
- Neutral current magnitude (In) as a percentage of the nominal current rating of the neutral current input (5 A, 1 A, 0.2 A, or 0.05 A)
- Phase-neutral voltage magnitudes (V_A, V_B, V_C) as a percentage of Vbase (wye-connected) or phase-to-phase voltage magnitudes (V_{AB}, V_{BC}, V_{CA}) as a percentage of Vbase (delta-connected)
- Vs channel voltage magnitude as a percentage of Vbase; displayed value,

NOTE: Any current or voltage value greater than 999 percent will be replaced by "$$$" in the SSI report.

$$\text{VS} = \frac{\text{Vs (secondary)} \bullet \text{PTRS}}{1000 \bullet \text{Vbase}} \bullet 100\%$$

- Base voltage magnitude (Vbase) in kV primary
  Vbase = memorized positive-sequence voltage, V_1 (wye-connected)
  or
  Vbase = $\sqrt{3}$ • (memorized positive-sequence voltage, V_1) (delta-connected)
- A-, B-, and C-Phase SSI element status columns; see *Table 12.6*
- Trigger state, "*" if present (in the column marked "S")
- SSI recorder status; see *Table 12.7*

Table 12.6 SSI Element Status Columns

Symbol	Meaning (for Each Column A, B, or C)	
	Global Setting PTCONN = WYE Column A represents *p* = A Column B represents *p* = B Column C represents *p* = C	Global Setting PTCONN = DELTA Column A represents *pp* = AB Column B represents *pp* = BC Column C represents *pp* = CA
.	No SSI bits asserted for phase *p*	No SSI bits asserted for phases *pp*
O	Overvoltage (SW*p* asserted)	Overvoltage (SW*pp* asserted)
U	Undervoltage (SAG*p* asserted)	Undervoltage (SAG*pp* asserted)
I	Interruption (INT*p* asserted; SAG*p* asserted, unless setting VSAG = OFF)	Interruption (INT*pp* asserted; SAG*pp* asserted, unless setting VSAG = OFF)

Table 12.7 Status SSI Column (Sheet 1 of 2)

Symbol	Meaning (Action)	Duration
R	Ready (when the SSI logic first acquires a valid V_{BASE} value)	Single entry
P	Predisturbance (4 samples per cycle). Always signifies a new disturbance.	12 samples (3 cycles)
F	Fast recording mode (4 samples per cycle)	Varies. At least one SSI element must be asserted.
E	End (post-disturbance at 4 samples per cycle)	As many as 16 samples (4 cycles). No SSI elements asserted.
M	Medium recording mode (one sample per cycle)	Maximum of 176 cycles

Table 12.7 Status SSI Column (Sheet 2 of 2)

Symbol	Meaning (Action)	Duration
S	Slow recording mode (one sample per 64 cycles)	Maximum of 4096 cycles
D	Daily recording mode (one sample per day, just after midnight)	Indefinite
X	Data overflow (single entry that indicates that data was lost prior to the present entry)	Single entry

See *Figure 12.12* for an example Sag/Swell/Interruption (SSI) report.

SSI Recorder Operation: Overview

The SSI Recorder operation can be summarized as follows: When power is first applied to the relay and setting ESSI = “Y”, (or setting ESSI is changed from “N” to “Y”), the relay measures the voltage inputs to determine if a valid three-phase signal is present. When the conditions are satisfied for at least 12 seconds, the positive-sequence voltage, V_1, is memorized as the Vbase reference voltage. When Global setting PTCONN = DELTA, a factor of √3 is applied so that Vbase is in the phase-to-phase scale. This causes a single “R” entry to be placed in the SSI archive, which indicates that the recorder is ready. The Vbase value is allowed to change on a gradual basis to follow normal system voltage variations, but is “locked” when a disturbance occurs.

When any SSI Relay Word Bit asserts or the **SSI T** serial port command is issued, the recorder will begin recording.

When operating, the SSI Recorder archives the following information:

- Currents Ia, Ib, Ic, Ig, and In as a percentage of the nominal current rating (shown in the report heading)
- Voltages Va, Vb, Vc, and Vs as a percentage of the Vbase quantity (wye-connected)
- Voltages Vab, Vbc, Vca, and VS as a percentage of the Vbase quantity (delta-connected)
- The Vbase quantity, in kV primary
- The state of the Sag/Swell/Interruption Relay Word bits, by phase
- The trigger status
- The recorder status

Entries are made at a varying recording rate: fastest when the SSI Relay Word bits are changing states, and slowest if the SSI Relay Word bits are quiet. Eventually, it can get as slow as one sample per day. The faster recording mode will be initiated from any of the slower recording modes, as soon as any SSI bit or the SSI T condition changes state.

Recording is stopped when all SSI Relay Word bits and the trigger condition stay deasserted for at least four cycles.

SSI Recorder Operation: Detailed Description

From the SSI Recorder Ready state, upon the initial assertion of one of the SSI Relay Word bits or a manual trigger condition, the relay records SSI data in the following sequence:

Predisturbance recording: Record pretrigger entries at 1/4-cycle intervals with the SSI Recorder status field displaying P. Because no SSI elements are asserted, columns A, B, and C will display

.

The predisturbance state lasts for a total of 12 samples, or 3 cycles, unless there are "back-to-back" disturbances that reduce the number of "P" entries.

Fast recording (also End recording): Record one entry every 1/4-cycle, with the SSI Recorder status field displaying F (if any SSI elements are asserted or the manual trigger condition is asserted), or E (if none of the SSI elements are asserted). If the manual trigger condition is present, a "*" will be recorded. The SSI element status columns will show one of ., O, U, I. The Fast/End recording mode continues until four cycles elapse with no SSI element or manual trigger condition changing state. The relay then proceeds to the state determined by the following tests (processed in the order shown):

- If INT3P is asserted, switch to daily recording mode. (This keeps the relay from recording medium and slow speed detailed information during a complete outage.)
- Otherwise, if any SSI elements are asserted, switch to the medium recording mode.
- Otherwise, stop recording.

Medium recording: Record one entry per cycle, with the SSI Recorder status field displaying M. The phase columns will show one of ., O, U, I. The medium recording mode continues for 176 cycles, unless one of the SSI elements or the manual trigger condition changes state, which causes the recorder to start over in Fast mode (with as many as three samples prior to the change). At the end of medium recording mode, the recorder switches to the slow recording mode.

Slow recording: Record one entry every 64 cycles, with the SSI Recorder status field displaying S. The phase columns will show one of ., O, U, I. The slow recording mode continues for 4,096 cycles (64 entries), unless one of the SSI elements or the manual trigger condition changes state, which causes the recorder to start over in fast mode (with as many as eight samples prior to the change). At the end of slow recording mode, the recorder switches to the daily recording mode.

Daily recording: record one entry every day just past midnight (00:00:00), with the SSI Recorder status field displaying D. The phase columns will show one of ., O, U, I. The daily recording mode continues until any SSI Relay element or the manual trigger condition changes state, which causes the recorder to start over in fast mode (with as many as eight samples prior to the change).

An overflow condition can occur when the SSI recorder cannot keep up with the data generated during disturbances that create a large number of SSI entries. The nonvolatile memory that is used for the SSI archive has a longer "write" time than the Random Access Memory (RAM) that is used to temporarily store the SSI data, so it is possible that the data in RAM will overwrite itself if the transfer to Flash memory gets too far behind. The SSI report will show an "X" in the REC column if this happens, and it will be on the first entry after the overflow. The overflow condition may also occur if the relay is saving an event report to nonvolatile memory, because the memory can only be used by one procedure at a time.

SSI Report Memory Details

The relay retains a minimum of 3855 of the most recent SSI entries in nonvolatile memory. The relay can hold a maximum of 7710 entries. When the recorder memory reaches 7710 entries and further entries occur, the oldest 3855 memory locations are cleared in a block to make room for newer entries. Therefore, the apparent SSI memory size can vary between 3855 and 7710 entries. If the SSI recorder memory clears while an SSI report is being displayed, the SSI report will stop and display this message:

```
Command Aborted, Data overwrite occurred
```

Retrieving the SSI Report

Via Serial Port

The recorded SSI data can be viewed from any setting group, even if setting ESSI = N. Row 1 is the most recently triggered row. View the SSI report by date or SSI row number as outlined in the examples below.

Example SSI Serial Port Commands	Format
SSI	If **SSI** is entered with no numbers following it, all available rows are displayed. They display with the oldest row at the beginning (top) of the report and the latest row (row 1) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SSI 17	If **SSI** is entered with a single number following it (**17** in this example), the first 17 rows are displayed, if they exist. They display with the oldest row (row 17) at the beginning (top) of the report and the latest row (row 1) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SSI 10 33	If **SSI** is entered with two numbers following it (**10** and **33** in this example; 10 < 33), all the rows between (and including) rows 10 and 33 are displayed, if they exist. They display with the oldest row (row 33) at the beginning (top) of the report and the latest row (row 10) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SSI 47 22	If SSI is entered with two numbers following it (**47** and **22** in this example; 47 > 22), all the rows between (and including) rows 47 and 22 are displayed, if they exist. They display with the newest row (row 22) at the beginning (top) of the report and the oldest row (row 47) at the end (bottom) of the report. *Reverse* chronological progression through the report is down the page and in ascending row number.
SSI 3/30/2009	If **SSI** is entered with one date following it (date **3/30/2009** in this example), all the rows on that date are displayed, if they exist. They display with the oldest row at the beginning (top) of the report and the latest row at the end (bottom) of the report, for the given date. Chronological progression through the report is down the page and in descending row number.

NOTE: The SEL-351 accepts two or four digit years in the SSI command. For example, **SSI 3/30/09** is treated the same as **SSI 3/30/2009**. In either case, the SSI report only displays two digit years in the Date column.

Example SSI Serial Port Commands	Format
SSI 2/17/2009 3/23/2009	If **SSI** is entered with two dates following it (date **2/17/2009** chronologically *precedes* date **3/23/2009** in this example), all the rows between (and including) dates 2/17/2009 and 3/23/2009 are displayed, if they exist. They display with the oldest row (date 2/17/2009) at the beginning (top) of the report and the latest row (date 3/23/2009) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SSI 3/16/2009 1/5/2009	If **SSI** is entered with two dates following it (date **3/16/2009** chronologically *follows* date **1/5/2009** in this example), all the rows between (and including) dates 1/5/2009 and 3/16/2009 are displayed, if they exist. They display with the latest row (date 3/16/2009) at the beginning (top) of the report and the oldest row (date 1/5/2009) at the end (bottom) of the report. *Reverse* chronological progression through the report is down the page and in ascending row number.

The date entries in the above example **SSI** commands are dependent on the Date Format setting DATE_F. If setting DATE_F = MDY, then the dates are entered as in the above examples (Month/Day/Year). If setting DATE_F = YMD, then the dates are entered Year/Month/Day.

If the requested SSI event report rows do not exist, the relay responds:

```
No Voltage Sag/Swell/Interruption Data
```

Via File Transfer

The SSI report is available via file transfer protocols. See *Virtual File Interface* on page 10.26.

Clearing the SSI Report

Clear the SSI report from nonvolatile memory with the **SSI C** command as shown in the following example:

```
=>SSI C <Enter>
Clear the Voltage Sag/Swell/Interruption buffer
Are you sure (Y/N)? Y <Enter>
Clearing Complete
```

The **SSI C** command is available in any setting group and on any serial port.

If the **SSI C** command is issued on one serial port while another serial port is being used to display an SSI report, the clearing action will terminate the SSI report retrieval.

If maximum SSI recorder capacity is desired, the SSI Report should be checked periodically, with the data captured to a computer file using a terminal emulation program. Once the data has been viewed or captured, use the **SSI C** command to clear the SSI recorder.

Clearing the SSI Recorder makes it easier to tell if any new disturbances have been recorded, and it also allows the SSI Archive to record the maximum of 7710 entries. If more than 7710 entries occur, the oldest half of the SSI archive will be erased to make room for the new entries. The most recent 3855 entries are always available.

Triggering the SSI Recorder

Manually force the SSI Recorder to trigger using the **SSI T** command as shown in the following example:

```
=>SSI T <Enter>
Triggered
```

The **SSI T** command is only available if group setting ESSI = Y in the active setting group.

If an **SSI T** command is issued when setting ESSI = N, the relay will respond as follows:

```
Command is not available
```

If an **SSI T** command is issued before Vbase has initialized, the relay will respond as follows:

```
Did Not Trigger
```

See *Vbase Initialization* on page 3.70 for details on the initializing conditions.

The **SSI T** command is useful for testing, because it provides an easy method of creating some SSI Report entries without the need to remove voltage signals or connect a test set, providing Vbase has already been initialized.

Resetting the SSI Recorder Logic

During relay commissioning or test procedures, the SSI recorder may memorize the Vbase quantity when test voltages or settings are applied. This could cause the recorder to declare a false SAG or SWELL condition when normal system voltages are applied. Reset the SSI Recorder logic and clear the Vbase value by issuing the **SSI R** command as shown in the following example:

```
=>SSI R <Enter>
Reset the Voltage Sag/Swell/Interruption monitor
Are you sure (Y/N)? Y <Enter>
Voltage Sag/Swell/Interruption monitor reset
```

After the relay detects satisfactory voltage signals for at least 12 seconds, the SSI Recorder is armed and a Ready entry is written to the SSI archive.

The **SSI R** command is only available if group setting ESSI = Y in the active setting group. Attempting the **SSI R** command when ESSI = N will display:

```
Command is not available
```

The relay automatically performs an equivalent action to the **SSI R** command:

- ➤ When the relay is powered-up and setting ESSI = Y
- ➤ After a group change or setting change that changes active setting ESSI = N to ESSI = Y
- ➤ After a **STA C** command (Level 2)

Sample SSI Report

The Sag/Swell/Interruption (SSI) report in *Figure 12.12* shows a voltage sag on B-phase and a voltage swell on C-phase caused by a single-phase fault on B-phase that is cleared by a remote device. (Relay inputs **IN** and **VS** are not connected.)

```
=>SSI <Enter>

FEEDER A27                        Date: 02/06/09    Time: 09:12:07.369
CROWN SUB

FID=SEL-351-7-R5xx-V0-Zxxxxxx-D2009xxxx       CID=xxxx

                 I nom. A B C G = 5 Amp  N = 5 Amp

                           Current(% I nom.)   Voltage(% Vbase) Vbase  Ph ST
#     Date     Time         Ia  Ib  Ic  Ig  In  Va  Vb  Vc  Vs  (kV)   ABC

36    01/22/09 08:47:24.272  11  13  15   3   0 100  99 100   0  14.94 ... R
35    02/05/09 16:21:12.635  20  23  28   7   0  98  98  98   0  15.29 ... P
34    02/05/09 16:21:12.639  20  22  29   8   0  98  98  98   0  15.29 ... P
33    02/05/09 16:21:12.644  20  22  28   7   0  98  98  98   0  15.29 ... P
32    02/05/09 16:21:12.648  20  23  28   7   0  98  98  98   0  15.29 ... P
31    02/05/09 16:21:12.652  20  23  28   8   0  98  98  98   0  15.29 ... P
30    02/05/09 16:21:12.656  20  22  29   8   0  98  98  98   0  15.29 ... P
29    02/05/09 16:21:12.660  20  31  29  26   0  98  98  99   0  15.29 ... P
28    02/05/09 16:21:12.664  20  62  30  40   0  98  90 101   0  15.29 ... P
27    02/05/09 16:21:12.669  20  67  32  50   0  98  89 105   0  15.29 ... P
26    02/05/09 16:21:12.673  20 112  33  88   0  98  78 108   0  15.29 ... P
25    02/05/09 16:21:12.677  20 111  34  86   0  98  78 111   0  15.29 ... P
24    02/05/09 16:21:12.681  20 125  34  99   0  98  75 111   0  15.29 ... P
23    02/05/09 16:21:12.685  20 125  34  99   0  98  75 111   0  15.29 .U. F
22    02/05/09 16:21:12.689  20 125  35  99   0  98  75 111   0  15.29 .U. F
21    02/05/09 16:21:12.694  20 122  34  94   0  98  76 110   0  15.29 .UO F
20    02/05/09 16:21:12.698  20  88  33  62   0  98  82 108   0  15.29 .UO F
19    02/05/09 16:21:12.702  20  88  31  60   0  98  83 104   0  15.29 .UO F
18    02/05/09 16:21:12.706  20  34  30   8   0  98  94 101   0  15.29 .UO F
17    02/05/09 16:21:12.710  20  34  29   9   0  98  94  98   0  15.29 .UO F
16    02/05/09 16:21:12.714  20  15  28  12   0  98  98  98   0  15.29 .U. F
15    02/05/09 16:21:12.718  19  15  28  12   0  98  98  98   0  15.29 .U. F
14    02/05/09 16:21:12.723  20  14  29  12   0  98  98  98   0  15.29 ... E
13    02/05/09 16:21:12.727  20  14  28  12   0  98  98  98   0  15.29 ... E
12    02/05/09 16:21:12.731  20  15  28  12   0  98  98  98   0  15.29 ... E
11    02/05/09 16:21:12.735  20  15  29  12   0  98  98  98   0  15.29 ... E
10    02/05/09 16:21:12.739  20  14  29  12   0  98  98  98   0  15.29 ... E
9     02/05/09 16:21:12.743  20  14  28  12   0  98  98  98   0  15.29 ... E
8     02/05/09 16:21:12.748  20  15  28  12   0  98  98  98   0  15.29 ... E
7     02/05/09 16:21:12.752  19  15  28  12   0  98  98  98   0  15.29 ... E
6     02/05/09 16:21:12.756  19  14  28  12   0  98  98  98   0  15.29 ... E
5     02/05/09 16:21:12.760  20  14  28  12   0  98  98  98   0  15.29 ... E
4     02/05/09 16:21:12.764  20  15  28  12   0  98  98  98   0  15.29 ... E
3     02/05/09 16:21:12.768  19  15  28  12   0  98  98  98   0  15.29 ... E
2     02/05/09 16:21:12.773  19  14  29  12   0  98  98  98   0  15.29 ... E
1     02/05/09 16:21:12.777  20  14  28  12   0  98  98  98   0  15.29 ... E
```

Figure 12.12 Example Sag/Swell/Interruption (SSI) Report (PTCONN = WYE)

The Sag/Swell/Interruption (SSI) report in *Figure 12.13* shows the format of the SSI report headings when the relay is configured for delta-connected PTs (Global setting PTCONN = DELTA). In this case, the `Ph ABC` column represents the Relay Word bits as shown on the right-hand side of *Table 12.6*. Note that the voltage column headings are now `Vab`, `Vbc`, and `Vca`, and that the Vbase value is scaled by $\sqrt{3}$ to account for the phase-to-phase quantities (as compared to *Figure 12.12*).

```
=>SSI 32 36 <Enter>

FEEDER A27                        Date: 02/06/09 Time: 09:12:07.369
CROWN SUB

FID=SEL-351-7-R5xx-V0-Zxxxxxx-D2009xxxx       CID=xxxx

                 I nom. A B C G = 5 Amp  N = 5 Amp

                           Current(% I nom.)   Voltage(% Vbase) Vbase  Ph ST
#     Date     Time         Ia  Ib  Ic  Ig  In  Vab Vbc Vca Vs  (kV)   ABC

36    01/22/09 08:47:24.272  11  13  15   3   0 100  99 100   0  25.88 ... R
35    02/05/09 16:21:12.635  20  23  28   7   0  98  98  98   0  26.48 ... P
34    02/05/09 16:21:12.639  20  22  29   8   0  98  98  98   0  26.48 ... P
33    02/05/09 16:21:12.644  20  22  28   7   0  98  98  98   0  26.48 ... P
32    02/05/09 16:21:12.648  20  23  28   7   0  98  98  98   0  26.48 ... P

=>
```

Figure 12.13 Example Sag/Swell/Interruption (SSI) Report (PTCONN = DELTA)

Using the SSI Recorder on Ungrounded/High-Impedance Grounded and Petersen Coil Systems

In ungrounded/high-impedance grounded and Petersen Coil systems, the loss of one phase voltage (caused by a phase-to-ground fault) does not affect the delivery of power to the phase-to-phase connected loads on the distribution system. Depending on the relay PT connection (and Global setting PTCONN), the SSI Report may or may not capture data during a single-line-to-ground fault:

If PTCONN = WYE. the SSI Relay Word bits respond to single-phase voltages. The SSI report treats a single-line-to-ground fault as a sag (or interrupt) on one phase, and a swell on the other two phases (subject to the actual settings in use, and the fault characteristics). In this situation, the SSI Report can be used as a fault analysis tool, capturing the phase and duration of faults that are significant enough to cause a single-phase voltage SAG*p* element to assert.

If PTCONN = DELTA. the SSI Relay Word bits respond to phase-to-phase voltages. The SSI report will likely not trigger during a single-line-to-ground fault, because the phase-to-phase voltage quantities do not change materially. In this situation, the SSI Report is strictly a power quality tool, reporting disturbances actually experienced by the phase-to-phase connected load on the power system.

For both wye- and delta-connected PT systems, the SSI Report will capture disturbances caused by phase-to-phase and three-phase faults (subject to the actual settings in use, and the fault characteristics).

For details on the ungrounded/high-impedance grounded and Petersen Coil directional elements, see *Directional Control for Neutral-Ground and Residual-Ground Overcurrent Elements* on page 4.14.

SECTION 13

Testing and Troubleshooting

Overview

This section provides guidelines for determining and establishing test routines for the SEL-351 Relay. Included are discussions on testing philosophies, methods, and tools. Relay self-tests and troubleshooting procedures are shown at the end of the section.

The topics discussed in this section include the following:

Testing Philosophy

Protective relay testing may be divided into two categories: commissioning and maintenance.

The categories are differentiated by when they take place in the life cycle of the relay as well as in the test complexity.

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

Commissioning Testing

When: When installing a new protection system.

Goals:

1. Ensure that all system ac and dc connections are correct.
2. Ensure that the relay functions as intended using your settings.
3. Ensure that all auxiliary equipment operates as intended.

What to test: All connected or monitored inputs and outputs, polarity and phase rotation of ac connections, simple check of protection elements.

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

SEL performs a complete functional check and calibration of each relay before it is shipped. This helps ensure that you receive a relay that operates correctly and accurately. Commissioning tests should verify that the relay is properly connected to the power system and all auxiliary equipment. Verify control signal inputs and outputs. Check breaker auxiliary inputs, SCADA control inputs, and monitoring outputs. Use an ac connection check to verify that the relay current and voltage inputs are of the proper magnitude and phase rotation. Verify that all SELOGIC programming operates as intended.

Brief fault tests ensure that the relay settings are correct. It is not necessary to test every relay element, timer, and function in these tests.

At commissioning time, use the relay **METER** command to verify the ac current and voltage magnitude and phase rotation. Use the **PULSE** command to verify relay output contact operation. Use the **TARGET** command to verify optoisolated input operation.

Maintenance Testing

When: At regularly scheduled intervals or when there is an indication of a problem with the relay or system.

Goals:

1. Ensure that the relay is measuring ac quantities accurately.
2. Ensure that scheme logic and protection elements are functioning correctly.
3. Ensure that auxiliary equipment is functioning correctly.

What to test: Anything not shown to have operated during an actual fault within the past maintenance interval.

SEL relays use extensive self-testing capabilities and feature detailed metering and event reporting functions that lower the utility dependence on routine maintenance testing.

1. Use the SEL relay reporting functions as maintenance tools.

   Periodically verify that the relay is making correct and accurate current and voltage measurements by comparing the relay METER output to other meter readings on that line.
2. Review relay event reports in detail after each fault.

   Using the event report current, voltage, and relay element data, you can determine that the relay protection elements are operating properly.

   Using the event report input and output data, you can determine that the relay is asserting outputs at the correct instants, that all contact inputs are operating, and that auxiliary equipment is operating properly.
3. At the end of your maintenance interval, the only items that need testing are those that have not operated during the maintenance interval.

The basis of this testing philosophy is simple: If the relay is correctly set and connected, is measuring properly, and no self-test has failed, there is no reason to test it further.

Each time a fault occurs the protection system is tested. Use event report data to determine areas requiring attention. Slow breaker auxiliary contact operations and increasing or varying breaker operating time can be detected through detailed analysis of relay event reports.

Because SEL relays are microprocessor-based, their operating characteristics do not change over time. Time-overcurrent operating times are affected only by the relay settings and applied signals. It is not necessary to verify operating characteristics as part of maintenance checks.

At SEL, we recommend that maintenance tests on SEL relays be limited under the guidelines provided above. The time saved may be spent analyzing event data and thoroughly testing those systems that require more attention.

Testing Methods and Tools

Test Features Provided by the Relay

The features shown in *Table 13.1* assist you during relay testing.

Table 13.1 Helpful Commands for Relay Testing

Command	Description
METER	The **METER** command shows the ac currents and voltages (magnitude and phase angle) presented to the relay in primary values. In addition, the command shows power system frequency (FREQ) and the voltage input to the relay power supply terminals (VDC). Compare these quantities against other devices of known accuracy. The **METER** command is available at the serial ports and front-panel display. See *Section 10: Communications* and *Section 11: Front-Panel Interface*. Metering data are also available through the ACSELERATOR QuickSet SEL-5030 software and the web server. See *Using the Embedded Web Server (HTTP)* on page 10.19.
EVENT	The relay generates a 15-, 30-, or 60-cycle event report in response to faults or disturbances. Each report contains current and voltage information, relay element states, and input/output contact information. If you question the relay response or your test method, use the event report for more information. The **EVENT** command is available at the serial ports. See *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*. Event reports can also be gathered using QuickSet.
SER	The relay provides a Sequential Events Recorder (SER) event report that time tags changes in relay element and input/output contact states. The SER provides a convenient means to verify the pickup/dropout of any element in the relay. The **SER** command is available at the serial ports. See *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*. SER data can also be gathered using QuickSet or the web server. See *Using the Embedded Web Server (HTTP)* on page 10.19.
TARGET	Use the **TARGET** command to view the state of relay control inputs, relay outputs, and relay elements individually during a test. The **TARGET** command is available at the serial ports and the front panel. See *Section 10: Communications* and *Section 11: Front-Panel Interface*. Relay element status can also be viewed using the **Targets** screen of the QuickSet HMI or the web server. See *Using the Embedded Web Server (HTTP)* on page 10.19.
PULSE	Use the **PULSE** command to test the contact output circuits. The **PULSE** command is available at the serial ports and the front panel. *Section 10: Communications*. Contact outputs can also be pulsed through the **Control** window of the QuickSet HMI.

Low-Level Test Interface

The SEL-351 has a low-level test interface between the calibrated input module and the separately calibrated processing module. You may test the relay in either of two ways:

- ➤ By applying ac current signals to the relay inputs
- ➤ By applying low magnitude ac voltage signals to the low-level test interface

NOTE: The SEL-4000 Relay Test System, which includes the SEL Adaptive Multichannel Source, appropriate cables, and PC software, is specifically designed for use with the low-level test interface.

Access the test interface of the processing module by removing the relay front panel.

⚠CAUTION
The relay contains devices sensitive to Electrostatic Discharge (ESD). When working on the relay with the front panel removed, work surfaces and personnel must be properly grounded or equipment damage may result.

⚠CAUTION
Never apply voltage signals greater than 9 V peak-peak to the low-level test interface (J10) or equipment damage may result.

Figure 2.30 shows the location of the processing module input connector (J12) for low-level test interface connections. The output connector (J2) of the input module is below connector J12.

Figure 13.1 shows the low-level test interface (J2 and J12) connector information. *Table 13.2* shows the output (J2) value of the input module (for a given input value into the relay rear panel). The processing module input (J12) has a maximum 9 V p-p voltage damage threshold. Remove the ribbon cable between the two modules to access the outputs (J2) of the input module and the inputs (J12) to the processing module (relay main board).

You can test the relay-processing module (via input J12) using signals from the SEL-4000 Relay Test System. The power supply for the relay main board is provided through the ribbon cable between J2 and J12. SEL cable C724 is used to connect the relay to the SEL-4000 Relay Test System while maintaining the power supply connection. *Table 13.2* shows the resultant signal scale factor information for the calibrated input module. These scale factors are used in the SEL-5401 program, which is part of the SEL-4000.

You can test the input module two different ways:

1. Remove the ribbon cable from the input module (output J1). Measure the outputs from the input module with an accurate voltmeter (measure signal pin to GND pin), and compare the readings to accurate instruments in the relay input circuits, or
2. Replace the ribbon cable, press the front-panel **METER** pushbutton, and compare the relay readings to other accurate instruments in the relay input circuits.

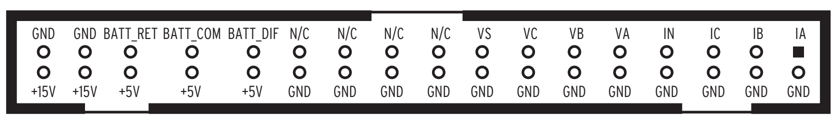


Figure 13.1 Low-Level Test Interface (J2 or J12) Connector

Table 13.2 Resultant Scale Factors for Input Module

Input Channels (Relay Rear Panel)	Input Channel Nominal Rating	Input Value	Corresponding J1 Output Value	Scale Factor (Input/Output)
IA, IB, IC, IN	1 A	1 A	45.6 mV	21.92 A/V
IA, IB, IC, IN	5A	5 A	45.2 mV	110.60 A/V
IN	0.2 A	200 mA	45.3 mV	4411.76 mA/V[a]
IN	0.05 A	50 mA	11.3 mV	4411.76 mA/V[a]
VA, VB, VC, VS	300 V	67 V_{LN}	299.1 mV	223.97 V/V

[a] SEL-5401 neutral channel input currents must be entered in mA when using the given scale factor.

Scale factor calculation examples:

$$\frac{67\ \text{V}}{0.2911\ \text{V}} = 223.97\left(\frac{\text{V}}{\text{V}}\right)$$

$$\frac{5\ \text{A}}{0.045\ \text{V}} = 110.60\left(\frac{\text{A}}{\text{V}}\right)$$

Using the Low-Level Test Interface When Global Setting PTCONN = DELTA

When simulating a delta PT connection with the low-level test interface referenced in *Figure 13.1*, apply the following signals:

- ➤ Apply low-level test signal V_{AB} to pin VA.
- ➤ Apply low-level test signal $-V_{BC}$ (equivalent to V_{CB}) to pin VC.
- ➤ Do not apply any signal to pin VB.

Refer to *Delta-Connected Voltages (Global Setting PTCONN = DELTA)* on page 2.12 for more information on the delta connection.

Logic and Protection Element Test Methods

Test the pickup and dropout of relay elements using one of three methods: target command indication, output contact closure, or sequential events recorder (SER).

The examples below show the settings necessary to route the phase time-overcurrent element 51PT to the output contacts and the SER. The 51PT element, like many in the SEL-351, is controlled by enable settings and/or torque-control SELOGIC control equations. To enable the 51PT element, set the E51P enable setting and 51PTC torque-control settings to the following:

E51P = **1** (via the **SET** command)

51PTC = **1** (set directly to logical 1, via the **SET L** command)

Testing Via Target Commands

Display the state of relay elements, inputs, and outputs using the front-panel or serial port **TAR** commands. Use this method to verify the pickup settings of protection elements.

Testing With the Front-Panel TAR Command

Access the front-panel TAR command from the front-panel **OTHER** pushbutton menu. To display the state of the 51PT element on the front-panel display, press the **OTHER** pushbutton, cursor to the TAR option, and press **SELECT**. Press the **Up Arrow** pushbutton until TAR 6 is displayed on the top row of the LCD. The bottom row of the LCD displays all elements asserted in Relay Word Row 6. The relay maps the state of the elements in Relay Word Row 6 on the bottom row of LEDs. The 51PT element state is reflected on the LED labeled **RS**. See *Table D.1* for the correspondence between the Relay Word elements and the **TAR** command.

Testing With the Serial Port TAR Command

To view the 51PT element status from the serial port, issue the **TAR 51PT** command. The relay will display the state of all elements in the Relay Word row containing the 51PT element.

Review **TAR** command descriptions in *Section 10: Communications* and *Section 11: Front-Panel Interface* for further details on displaying element status via the **TAR** commands.

Testing Via Output Contacts

You can set the relay to operate an output contact for testing a single element. Use the **SET L** command (SELOGIC control equations) to set an output contact (e.g., **OUT101–OUT107**) to the element under test. The available elements are the Relay Word bits referenced in *Table D.1*.

Use this method especially for time testing time-overcurrent elements. For example, to test the phase time-overcurrent element 51PT via output contact **OUT104**, make the following setting:

OUT104 = **51PT**

Time-overcurrent curve and time-dial information can be found in *Section 9: Setting the Relay*.

Do not forget to reenter the correct relay settings when you are finished testing and ready to place the relay in service.

Testing Via Sequential Events Recorder

You can set the relay to generate an entry in the Sequential Events Recorder (SER) for testing relay elements. Use the **SET R** command to include the element(s) under test in any of the SER trigger lists (SER1 through SER3). See *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*.

To test the phase time-overcurrent element 51PT with the SER, make the following setting:

SER1 = **51P 51PT**

Element 51P asserts when phase current is above the pickup of the phase time-overcurrent element. Element 51PT asserts when the phase time-overcurrent element times out. The assertion and deassertion of these elements is time-stamped in the SER report. Use this method to verify timing associated with time-overcurrent elements, reclosing relay operation, etc.

Do not forget to reenter the correct relay settings when you are ready to place the relay in service.

Communications Test Methods

The **TEST DB** command provides a method to override Relay Word bits or analog values to facilitate testing of communications interfaces. The command overwrites values in the communications interfaces (SEL Fast Messages, DNP, Modbus, and IEC 61850) only. The actual values used by the relay for protection and control are not overridden. See ***TDP Command*** on page 10.82.

Relay Self-Tests

The relay runs a variety of self-tests. Hardware alarm conditions are generated by the self-test logic and are classified as warnings or failures, depending on severity. The relay may take the following actions for out-of-tolerance conditions (see *Table 13.3*):

- Relay Word bits HALARMP and HALARM assert for five seconds to indicate that a hardware warning has occurred. Relay Word bits HALARML and HALARM assert and remain asserted to indicate most hardware failures. *Table 13.3* lists the various hardware warning and failure conditions. Some hardware failures prevent the relay from operating. In such cases, Relay Word bits HALARML and HALARM do not assert.

  Once HALARMP asserts, Relay Word bit HALARMA continues to assert for approximately five seconds once per minute to indicate that a hardware warning has occurred. HALARMA continues to pulse until it is reset by pulsing SELOGIC control equation RST_HAL, DNP binary output DRST_HAL, or the Modbus Reset Hardware Alarm coil. Restarting the relay also resets HALARMA. HALARMP does not assert again for the same alarm condition, unless the condition is cleared and returns.

  Depending on SELOGIC settings, the ALARM output contact may signal an alarm condition for hardware warnings. The ALARM output is always de-energized for hardware failures, regardless of settings. See *Output Contacts* on page 7.33 for an explanation of ALARM contact operation for various SELOGIC settings and hardware configurations.
- Protection Disabled: The relay disables protection and control elements and trip/close logic. All output contacts are de-energized. The **EN** front-panel LED is extinguished.
- The relay generates automatic STATUS reports at the serial port for warnings and failures (ports with setting AUTO = Y).
- The relay displays failure messages on the relay LCD display for selected warnings and failures.
- For certain failures, the relay automatically restarts as many as three times within 24 hours. In many instances, this will correct the failure. A “diagnostic restart” entry is recorded in the Sequential Events Recorder (SER), but the automatic restart may occur before Relay Word bits ALARM, HALARM and HALARML are recorded in the SER and before front-panel failure messages are displayed.

Use the serial port **STATUS** command or front-panel **STATUS** pushbutton to view relay self-test status. Based on the self-test type, issue the **STA C** command as directed in the Corrective Actions column. Contact SEL if this does not correct the problem or if the relay directs you to do so in response to the **STA C**.

Relay Troubleshooting

Inspection Procedure

Complete the following procedure before disturbing the relay. After you finish the inspection, proceed to *Troubleshooting Procedure* on page 13.10.

Step 1. Measure and record the power supply voltage at the power input terminals.

Step 2. Check to see that the power is on. Do not turn the relay off.

Step 3. Measure and record the voltage at all control inputs.

Step 4. Measure and record the state of all output relays.

Table 13.3 Relay Self-Tests (Sheet 1 of 2)

Self-Test	Description	Normal Range	Alarm Relay Word Bits	Protection Disabled on Failure[a]	Port Auto Message on Failure	Front Panel Message	Corrective Action
I/O Board Failure	Invalid interface board ID or relay settings do not match installed interface boards		HALARML	Yes	Yes	STATUS FAIL IO_BRD FAIL	**STA C**
I/O Board Warning	Actual and expected board IDs do not match.		HALARMP, HALARMA	No	Yes	STATUS WARNING IO_BRD WARNING	**STA C**
Temperature		–40°C to 100°C	HALARMP, HALARMA	No	Yes		
Communications Board Warning	Installed communications card does not match relay Part Number			No	Yes		**STA C**
Communications Board Failure	Communications board has failed			No	Yes	STATUS FAIL COM BRD WARNING	**STA C**
USB Board Warning	Installed USB board does not match relay Part Number			No	No	STATUS WARNING USB WARNING	**STA C**
USB Board Failure	USB communications board has failed			No	No	STATUS FAIL USB FAILURE	**STA C**
FPGA	FPGA fails to program		HALARML	Yes	Yes		
FPGA	FPGA failure		HALARML	Yes	Yes	STATUS FAIL FPGA FAILURE	Automatic restart. Contact SEL if failure returns.
RTC Chip	Unable to communicate with clock, or clock fails time keeping test		HALARMP, HALARMA	No	No		
HMI	Invalid HMI board ID		HALARMP, HALARMA	No	Yes	STATUS WARNING HMI WARNING	
HMI	HMI timeout		HALARMP, HALARMA	No	Yes	STATUS WARNING HMI WARNING	
External Ram	Failure of read/write test on system RAM			Yes	No		

Table 13.3 Relay Self-Tests (Sheet 2 of 2)

Self-Test	Description	Normal Range	Alarm Relay Word Bits	Protection Disabled on Failure[a]	Port Auto Message on Failure	Front Panel Message	Corrective Action
Internal/External RAM	Failure of internal or external RAM		HALARML	Yes	Yes	STATUS FAIL RAM FAILURE	Automatic restart. Contact SEL if failure returns.
Code Flash Failure	Failure of checksum test on firmware code			Yes	No		
Code Flash Failure	Firmware relay type code does not match part number		HALARML	Yes	Yes	STATUS FAIL ROM FAILURE	Verify correct version of firmware installed
Operating System	Operating system check fails			Yes	Yes	CPU ERROR RELAY DISABLED	Automatic restart. Contact SEL if failure returns.
Data Flash Failure	Failure of checksum test on relay settings		HALARML	Yes	Yes	STATUS FAIL FLASH FAILURE	
EEPROM Failure	Failure to determine latch bit status on power-up		HALARML	Yes	Yes	STATUS FAIL EEPROM FAILURE	
EEPROM Warning	Failure of read/write to EEPROM		HALARMP, HALARMA	No	Yes		
Exception Failure	CPU Error			Yes	Yes	CPU ERROR RELAY DISABLED	Automatic restart. Contact SEL if failure returns.
A/D Offset Warning	DC offset on A/D channel outside of normal range	<30 mV	HALARMP, HALARMA	No	Yes		
Master Offset	DC offset in A/D ground channel outside of normal range	<10 mV	HALARMP, HALARMA	No	Yes		
A/D Failure	Analog-to-digital converter failure		HALARML	Yes	Yes	STATUS FAIL A/D FAILURE	
+15V Warning	+15V Power supply outside of warning range	14.25 V to 15.75 V	HALARMP, HALARMA	No	Yes		
+15V Failure	+15V Power supply outside of failure range	14.00 V to 16.00 V	HALARML	Yes	Yes	STATUS FAIL +15V FAILURE	
+5V Warning	+5V Power supply outside of warning range	4.76 V to 5.23 V	HALARMP, HALARMA	No	Yes		
+3.3V Warning	+3.3V Power supply outside of warning range	3.16 V to 3.46 V	HALARMP, HALARMA	No	Yes		

[a] ALARM output de-energizes when protection is disabled.

Troubleshooting Procedure

All Front-Panel LEDs Dark

1. Input power not present or internal power supply fuse is blown.
2. Self-test failure.

Cannot See Characters on Relay LCD Screen

1. Relay is de-energized. Check to see if the ALARM contact is closed.
2. LCD contrast is out of adjustment. Use the steps below to adjust the contrast.
   a. Press and hold down the OTHER front-panel pushbutton.
   b. Use the UP and DOWN arrow pushbuttons to adjust the contrast.

Relay Does Not Respond to Commands From Device Connected to Serial Port

1. Communications device not connected to relay. Connect a communications device to the relay. See *Section 10: Communications* for details on connecting and configuring communications.

NOTE: The SEL-351 default baud rate (SPEED setting) is 9600 on all serial ports. This is different than some earlier SEL-351 Relays.

2. Relay or communications device at incorrect baud rate or other communication parameter incompatibility, including cabling error.
3. Relay serial port has received an XOFF, halting communications. Type **<Ctrl+Q>** to send relay an XON and restart communications.
4. The relay serial port is disabled (setting EPORT = N). Change the setting using the **SET P *n*** command from another communications interface (serial port, USB, or Telnet session) or using the front-panel interface. When Port F is disabled, the USB port is also disabled and cannot be used to change the EPORT setting. See *Port Enable Settings* on page 9.27.

Relay Does Not Respond to Commands From Device Connected to USB Port

1. The USB driver is not installed on the PC, or an incorrect driver was installed.
2. The USB cable was disconnected while a PC application was communicating with the relay.
3. The relay USB port is disabled (Port F setting EPORT = N). Change the setting using the **SET P F** command from another communications interface (serial port or Telnet session) or using the front-panel interface. See *Port Enable Settings* on page 9.27.
4. The USB cable is faulty or is not USB 2.0 compliant.
5. The relay USB Board has failed. Use steps below to attempt to correct the problem:
   a. Check USB Board status using the **STATUS** command using serial port or Ethernet connection.
   b. If STATUS is FAIL, issue **STA C** command to attempt to clear the condition.

c. If STATUS is OK, connect the USB cable between the PC and the relay and use Windows Device Manager to verify the Schweitzer Engineering Laboratories Fast CDC USB device appears under **Ports**.

d. Use the Task Manager (if necessary) to confirm any PC application that was using the port has terminated. If any such application remains running, close the application.

e. Disconnect the USB cable. Use Windows Device Manager to verify the Schweitzer Engineering Laboratories Fast CDC USB device does not appear under **Ports**. Reconnect the USB cable and verify that Schweitzer Engineering Laboratories Fast CDC USB device appear*s* under **Ports**.

f. If these steps fail to correct the problem, contact SEL for further assistance.

Relay Does Not Respond Via Telnet, FTP, or HTTP (Web Server) Interface

1. Communications device not connected to relay. Connect a communications device to the relay. See *Section 10: Communications* for details on connecting and configuring communications.
2. The relay Ethernet port is disabled (setting EPORT = N). Change the setting using the **SET P 5** command from another communications interface (serial port or USB session) or using the front-panel interface. See *Port Enable Settings* on page 9.27.
3. Relay or communications device not properly configured for Ethernet connection. Check the relay settings for the port, including ETELNET, EFTPSERV, or EHTTP and associated settings.
4. Maximum number of sessions exceeded. See *Session Limits* on page 10.15.
5. Firmware upgrade option is not available on the web server. Check HTTPACC setting. See *Method Three: Using a Web Browser* on page B.21.

Relay Does Not Respond to Faults

1. Relay improperly set.
2. Improper test source settings.
3. CT or PT input wiring error.
4. Analog input cable between transformer secondary and main board loose or defective.
5. Failed relay self-test.

Relay Meter Command Does Not Respond as Expected

1. Global settings PTCONN, VSCONN, NFREQ, or PHROT not set correctly.
2. Group Settings CTR, CTRN, PTR or PTRN not set correctly.
3. Relay analog inputs not connected correctly.
4. External jumper not installed between VB (Terminal Z10) and N (Terminal Z12) for delta potential transformers.

5. PTCONN = SINGLE and PHANTV is not OFF. The phantom voltage function creates pseudo-three phase voltage, power, and energy metering data from a single-phase voltage connected to the VA input (Z09). Voltages connected to VB (Z10) and VC (Z11) are not considered in voltage, power, and energy calculations.
6. PTCONN = SINGLE and PHANTV = OFF. Power, power factor, energy values, positive-sequence voltage, negative-sequence voltage, and zero-sequence voltage are forced to zero.
7. Current or voltage signals are below the small signal cutoff threshold for metering display. Refer to *Section 8: Breaker Monitor, Metering, and Load Profile Functions*.
8. During some test procedures, the relay may be unable to measure the system frequency, or Global setting NFREQ is incorrectly set. See *Potential Transformer Inputs* on page 2.11 for details on frequency measurement for the various PTCONN settings.

   To ensure that the relay has adjusted to the applied frequency, test signals should be applied for at least five seconds before checking the metering functions.

   If only currents are being injected and the signal frequency does not match the nominal setting (50 or 60 Hz), the metering accuracy may suffer.

Power Elements Not Operating as Expected When PTCONN = SINGLE

1. Although the power elements may be enabled when PTCONN = SINGLE, the specific system connections may not give the elements meaningful operating quantities. For meaningful operation of a single-phase power element, the calculation path requires that the element be connected to like-phase current and voltage signals. See *Special Considerations for Using Power Elements When PTCONN = SINGLE* on page 3.74.

Relay Optoisolated Inputs Not Operating

1. Applied voltage not correct for input ratings. See *Specifications* on page 1.4.
2. AC voltage applied. Set input debounce setting IN*xxx*D = AC, where IN*xxx* is the input number. See *Input Debounce Timers* on page 7.3.

SafeLock Pushbuttons Appear to Be Closed Continuously

1. AC voltage applied with arc suppression enabled. Apply dc voltages or disable arc suppression.
2. DC voltage applied with incorrect polarity. See *SafeLock Trip and Close Pushbuttons* on page 2.9.

Breaker Open/Closed Indication Lights Associated With SafeLock Pushbuttons Not Operating Properly

1. Lights not wired properly. These indication lights require external voltage.
2. **BREAKER OPEN** LED or **BREAKER CLOSED** LED jumpers not configured properly for applied voltage.

Output Contacts Appear to Be Closed Continuously

1. AC voltage applied to High-Current Interrupting Output contact. Apply dc voltage only.
2. DC voltage applied with incorrect polarity. See *High-Current Interrupting Output Contacts* on page 2.9.
3. Applied voltage exceeds rating of output contact MOV protection. See *Specifications* on page 1.4.
4. Peak applied voltage from capacitor trip unit exceeds rating of output contact MOV protection. See *Specifications* on page 1.4.

Protection Elements Appear to Be Out of Tolerance

1. Verify tolerance used in test acceptance criteria matches published tolerance. Protection element tolerances include a fixed tolerance and a percentage tolerance. These tolerances are additive and both must be included when establishing test acceptance criteria.
2. During some test procedures, the relay might be unable to measure the system frequency, or Global setting NFREQ is incorrectly set. See *Potential Transformer Inputs* on page 2.11 for details on frequency measurement for the various PTCONN settings. The minimum recommended test voltage level for frequency tracking is 20 V, secondary.

   For tests that involve off-nominal frequency signals, an initial steady-state period of at least five seconds ensures that the relay has adjusted to the applied frequency. Relay Word bit FREQOK indicates that the relay is measuring the system frequency.

Relay Time Stamp Entries Appear Out of Order for Fast Changes in SER or SSI Reports

1. Simple Network Time Protocol (SNTP) is changing the system time too frequently, and that time source is not sufficiently accurate. Consider changes to SNTP configuration—see *Section 10: Communications* for information on SNTP.
2. DNP is updating the system time too frequently, and that time source is not sufficiently accurate. Consider changes to TIMERQ and TIMERQ*n* settings—See *Appendix L: DNP3 Communications*.

Relay Calibration

The SEL-351 is factory-calibrated. If you suspect that the relay is out of calibration, contact the factory.

Technical Support

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

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APPENDIX A

Firmware, ICD, and Manual Versions

Firmware

Determining the Firmware Version

To determine the firmware version, view the status report by using the serial port **STATUS** command or the front-panel **STATUS** pushbutton. The status report displays the Firmware Identification (FID) number).

The firmware version will be either a standard release or a point release.
A standard release adds new functionality to the firmware beyond the specifications of the existing version. A point release is reserved for modifying firmware functionality to conform to the specifications of the existing version.

A standard release is identified by a change in the R-number of the device FID number.

Existing firmware:

FID=SEL-351-x-**R500**-V0-Z001001-Dxxxxxxxx

Standard release firmware:

FID=SEL-351-x-**R501**-V0-Z001001-Dxxxxxxxx

A point release is identified by a change in the V-number of the device FID number.

Existing firmware:

FID=SEL-351-x-R500-**V0**-Z001001-Dxxxxxxxx

Point release firmware:

FID=SEL-351-x-R500-**V1**-Z001001-Dxxxxxxxx

The date code is after the D. The single *x* after "SEL-351" is the firmware version number and will be a 5, 6, or 7, depending on the firmware features ordered with the relay:

x = 5	Basic Features
x = 6	Standard (includes MIRRORED BITS communications and Load Profile)
x = 7	Standard, plus Power Elements and Voltage Sag/Swell/Interrupt Elements

For example, the following is firmware version number R500, date code December 10, 2003, for the SEL-351-5:

FID=SEL-351-5-R500-V0-Z001001-D20031210

Revision History

Table A.1 lists the firmware versions, a description of modifications, and the instruction manual date code that corresponds to firmware versions. The most recent firmware version is listed first. Relays with firmware revisions earlier than R500 are not covered by this instruction manual. See *SEL-351 Models* on page 1.1 for details.

Table A.1 Firmware Revision History (Sheet 1 of 11)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-351-x-R518-V4-Z107106-D20250428	Includes all the functions of SEL-351-x-R518-V3-Z107106-D20250111 with the following addition: ➤ Enhanced SEL Livestream protocol to resume data streaming after an interruption of power to the relay and destination device.	20250428
SEL-351-x-R518-V3-Z107106-D20250111	Includes all the functions of SEL-351-x-R518-V2-Z107106-D20240709 with the following addition: ➤ Added support for the SEL Livestream protocol feature.	20250111
SEL-351-x-R518-V2-Z107106-D20240709	Includes all the functions of SEL-351-x-R518-V1-Z107106-D20210917 with the following additions: ➤ [Cybersecurity] Improved web server security against session hijacking. ➤ [Cybersecurity] Improved web server security against intentionally large files causing denial of service. ➤ [Cybersecurity] Improved web server security against cross-site scripting and misuse of session tokens. ➤ [Cybersecurity] Removed advanced diagnostic commands from Access Level C. ➤ [Cybersecurity] Resolved an issue where a user logged into the web server at ACC access level can restart the relay. ➤ [Cybersecurity] Resolved an issue where third party could make use of the account session to access information from the relay web server. ➤ [Cybersecurity] Resolved an issue where logging into the relay web server at the same time as a relay settings change would cause the relay to perform a diagnostic restart. ➤ [Cybersecurity] Resolved an issue where MMS authentication did not limit incorrect password attempts. ➤ Resolved an issue where certain relay settings no longer accept incorrect ASCII characters.	20240709
SEL-351-x-R518-V1-Z107106-D20210917	Includes all the functions of SEL-351-x-R518-V0-Z107106-D20201217 with the following additions: ➤ [Cybersecurity] Resolved an issue where the relay may lose communications after processing thousands of file or directory reads since startup. ➤ Modified the application of the 27B81A undervoltage element so that the derived pickup threshold is automatically adjusted when PTCONN = DELTA. This change allows undervoltage blocking elements 27B81 and 27B81A to operate the same when PTCONN = DELTA. ➤ Resolved an issue where deliberately crafted Ethernet traffic or a misconfigured network could cause the relay to perform a diagnostic restart. By design, three diagnostic restarts in 24 hours causes the relay to disable.	20210917
SEL-351-x-R518-V0-Z107106-D20201217	➤ Modified the data source for the voltage blocking attribute in the frequency element logical node from Relay Word bit 27B81 to 27B81A.	20201217

Table A.1 Firmware Revision History (Sheet 2 of 11)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-351-x-R517-V0-Z107105-D20201201	**Note:** This firmware version did not production release. See firmware version R518. ➤ Enhanced the frequency estimation algorithm to use the alpha voltage component for frequency estimation. This change allows for the over- and underfrequency and rate-of-change-of-frequency elements to react faster during transient power system conditions. ➤ Added the torque-control setting 81TC to the over- and underfrequency elements. ➤ Added FRQ81OK, FRQ81FZ, and 27B81A Relay Word bits to the enhanced frequency estimation algorithm. ➤ Added supervision to the over- and underfrequency elements to ensure the relay is actively measuring frequency. ➤ Added the difference time field, DT, to all the Compressed ASCII event reports to provide time stamps for each row.	20201217
SEL-351-x-R516-V7-Z106105-D20250428	Includes all the functions of SEL-351-x-R516-V6-106105-D20250111 with the following addition: ➤ Enhanced SEL Livestream protocol to resume data streaming after an interruption of power to the relay and destination device.	20250428
SEL-351-x-R516-V6-Z106105-D20250111	Includes all the functions of SEL-351-x-R516-V5-Z106105-D20240709 with the following addition: ➤ Added support for the SEL Livestream protocol feature.	20250111
SEL-351-x-R516-V5-Z106105-D20240709	Includes all the functions of SEL-351-x-R516-V4-Z106105-D20210917 with the following additions: ➤ [Cybersecurity] Improved web server security against session hijacking. ➤ [Cybersecurity] Improved web server security against intentionally large files causing denial of service. ➤ [Cybersecurity] Improved web server security against cross-site scripting and misuse of session tokens. ➤ [Cybersecurity] Removed advanced diagnostic commands from Access Level C. ➤ [Cybersecurity] Resolved an issue where a user logged into the web server at ACC access level can restart the relay. ➤ [Cybersecurity] Resolved an issue where third party could make use of the account session to access information from the relay web server. ➤ [Cybersecurity] Resolved an issue where logging into the relay web server at the same time as a relay settings change would cause the relay to perform a diagnostic restart. ➤ [Cybersecurity] Resolved an issue where MMS authentication did not limit incorrect password attempts. ➤ Resolved an issue where certain relay settings no longer accept incorrect ASCII characters.	20240709
SEL-351-x-R516-V4-Z106105-D20210917	Includes all the functions of SEL-351-x-R516-V3-Z106105-D20201008 with the following addition: ➤ [Cybersecurity] Resolved an issue where the relay may lose communications after processing thousands of file or directory reads since startup. ➤ Resolved an issue where deliberately crafted Ethernet traffic or a misconfigured network could cause the relay to perform a diagnostic restart. By design, three diagnostic restarts in 24 hours causes the relay to disable.	20210917

Table A.1 Firmware Revision History (Sheet 3 of 11)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-351-x-R516-V3-Z106105-D20201008	Includes all the functions of SEL-351-x-R516-V2-Z106105-D20190111 with the following addition: ➤ Resolved an extremely rare issue that could cause the relay to perform a diagnostic restart when configured for Parallel Redundancy Protocol (NETMODE = PRP) and the relay received abnormal Ethernet traffic.	20201008
SEL-351-x-R516-V2-Z106105-D20190111	Includes all the functions of SEL-351-x-R516-V1-Z106105-D20170818 with the following addition: ➤ Modified Ethernet communications to automatically correct a loss of synchronization between the communications subsystem and the other relay subsystems. ➤ Resolved an issue where certain Ethernet traffic could cause the relay to safely restart.	20190111
SEL-351-x-R516-V1-Z106105-D20170818	Includes all the functions of SEL-351-x-R516-V0-Z106105-D20150202 with the following addition: ➤ Resolved an issue where certain Ethernet traffic could cause diagnostic restarts.	20170818
SEL-351-x-R516-V0-Z106105-D20150202	➤ Added IEEE C37.111-1999 COMTRADE standard event reports. ➤ Added the ability to remotely upgrade relay firmware over an Ethernet network. ➤ Added support for **PING** command. ➤ Added Parallel Redundancy Protocol (PRP). ➤ Improved fault location accuracy. ➤ Increased DNP binary outputs from 33 to 71. ➤ Added support for * and ? wildcards with Y-modem, FTP, and MMS file transfers. ➤ Made events (COMTRADE file format and Compressed ASCII) and reports (Metering, History, diagnostics, etc.) available for Ymodem, FTP, and MMS file transfer. ➤ Made fault impedance magnitude and angle available over DNP3 and Modbus. ➤ Added MAXWEAR analog quantity; made MAXWEAR available for display points, DNP, Modbus, and IEC 61850. ➤ Modified IEC 61850 GOOSE virtual bit behavior to be reset when CID file is loaded. ➤ Modified DNP binary outputs so that they are no longer reported as offline when the binary output is present in the binary input map and the Sequential Events Recorder (SER). ➤ Addressed issue where relay rejected a settings file because of hidden settings. In previous firmware revisions, when NETMODE = FIXED and NETPORT = A, hidden setting NET5BSPD was transmitted in the settings file and caused the settings file to be rejected. Similarly, when NETMODE = FIXED and NETPORT = B, hidden setting NET5ASPD was transmitted in the settings file and caused the settings file to be rejected. ➤ Added support for MMS authentication. ➤ Added support for CID file transfer through MMS, and added EMMSFS setting to enable/disable MMS file services. ➤ Added feature to retain the existing valid CID file when an invalid CID file is sent. ➤ Added COMTRADE events directory for MMS file transfer.	20150202

Table A.1 Firmware Revision History (Sheet 4 of 11)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Added FLRNUM and FLREP analog quantities and made available for IEC 61850. ➤ Increased MMS client sessions to seven. ➤ Increased number of MMS reports to 14. ➤ Added Modbus Map labels to set, clear, or pulse remote bits using Modbus Function Code 06h or 10h. ➤ Addressed an issue where the CID file may be cleared when upgrading from firmware version R510 or earlier to firmware version R511 through R515.	
SEL-351-x-R515-V6-Z105104-D20250428	Includes all the functions of SEL-351-x-R515-V5-Z105104-D20250224 with the following addition: ➤ Enhanced SEL Livestream protocol to resume data streaming after an interruption of power to the relay and destination device.	20250428
SEL-351-x-R515-V5-Z105104-D20250224	Includes all the functions of SEL-351-x-R515-V4-Z105104-D20240709 with the following additions: ➤ [Cybersecurity] Resolved an issue affecting IEC 61850 protocol that results in the relay performing a diagnostic restart. ➤ Added support for SEL Livestream protocol feature.	20250224
SEL-351-x-R515-V4-Z105104-D20240709	Includes all the functions of SEL-351-x-R515-V3-Z105104-D20210917 with the following additions: ➤ [Cybersecurity] Improved web server security against session hijacking. ➤ [Cybersecurity] Improved web server security against intentionally large files causing denial of service. ➤ [Cybersecurity] Improved web server security against cross-site scripting and misuse of session tokens. ➤ [Cybersecurity] Removed advanced diagnostic commands from Access Level C. ➤ [Cybersecurity] Resolved an issue where a user logged into the web server at ACC access level can restart the relay. ➤ [Cybersecurity] Resolved an issue where third party could make use of the account session to access information from the relay web server. ➤ [Cybersecurity] Resolved an issue where logging into the relay web server at the same time as a relay settings change would cause the relay to perform a diagnostic restart. ➤ Resolved an issue where certain relay settings no longer accept incorrect ASCII characters.	20240709
SEL-351-x-R515-V3-Z105104-D20210917	Includes all the functions of SEL-351-x-R515-V2-Z105104-D20190111 with the following addition: ➤ [Cybersecurity] Resolved an issue where the relay may lose communications after processing thousands of file or directory reads since startup. ➤ Resolved an issue where deliberately crafted Ethernet traffic or a misconfigured network could cause the relay to perform a diagnostic restart. By design, three diagnostic restarts in 24 hours causes the relay to disable.	20210917
SEL-351-x-R515-V2-Z105104-D20190111	Includes all the functions of SEL-351-x-R515-V1-Z105104-D20170818 with the following addition: ➤ Modified Ethernet communications to automatically correct a loss of synchronization between the communications subsystem and the other relay subsystems.	20190111

Table A.1 Firmware Revision History (Sheet 5 of 11)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Resolved an issue where certain Ethernet traffic could cause the relay to safely restart.	
SEL-351-x-R515-V1-Z105104-D20170818	Includes all the functions of SEL-351-x-R515-V0-Z105104-D20130620 with the following addition: ➤ Resolved an issue where certain Ethernet traffic could cause diagnostic restarts. ➤ Corrected handling of unrecognized Ethertype frames that can cause Ethernet to stop responding. ➤ Corrected issue that could cause rejection of GOOSE CID files containing the TRIP_LED label. ➤ Corrected issue where GOOSE messages were not reporting the correct Front-Panel Target information.	20170818
SEL-351-x-R515-V0-Z105104-D20130620	➤ UDP port is no longer reported as open by a port scanner when 61850 is enabled.	20130620
SEL-351-x-R514-V0-Z105104-D20130304	➤ Made changes for manufacturing process improvements.	20130304
SEL-351-x-R513-V0-Z105104-D20121206	**Note:** This firmware version did not production release. See firmware version R514. ➤ Added support for Ethernet communications option with 10/100BASE-T and 100BASE-FX ports. ➤ Added support for fiber-optic serial port option. ➤ Added support for extra I/O board option with 16 inputs and 4 outputs. ➤ Relay now accepts IRIG-B signals with either even or odd parity. ➤ Improved metering accuracy when current is low. ➤ Global setting PMSTN now accepts upper and low case characters. ➤ Reformatted relay web server. ➤ Corrected issue which could occasionally cause USB port to become unresponsive when a connected PC goes into hibernation or when the port is left connected to a powered USB hub with no PC connected. ➤ Corrected checksum in the settings section of compressed event reports. ➤ Updated ICD file to include logical node (BKGGIO22) for real time status of breaker contacts. ➤ Modified GOOSE receive Message Quality indication to exclude messages processed out-of sequence. If two messages are received in a single processing interval, the most recent message is processed and out-of-sequence is incremented, however it does not indicate poor message quality. ➤ Corrected MMS reporting issue that caused missing events when BufTm was set to 500 ms or multiples of 500 ms. ➤ Corrected MMS reporting issue that caused incorrect report data when same data item was included in multiple reports and BufTm had a non-zero value. ➤ Corrected issue with **GOO** command where some received GOOSE subscriptions were not displayed when VLAN tags were stripped from incoming GOOSE messages.	20130304
SEL-351-x-R512-V0-Z104104-D20120830	➤ Corrected issue with GOOSE data timestamps not updating with SER quality timestamp. ➤ Corrected GOOSE update delay for Pos.stVal attribute in BSXCBR1 and BCCSWI1 logical nodes.	20120830

Table A.1 Firmware Revision History (Sheet 6 of 11)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Corrected MMS file transfer issue with sending last element of directory request. ➤ Corrected MMS reporting issue generating events for rapidly changing points. ➤ Corrected MMS reporting issue of Pos.stVal attribute in BSXCBR1 and BCCSWI1 logical nodes not updating correctly for buffered and unbuffered reporting. ➤ Corrected issue that caused MMS unbuffered reports not to contain full data reference.	
SEL-351-x-R511-V0-Z104104-D20120321	➤ Added 25RCF setting to allow dissimilar voltage magnitudes on the phase and synchronism-check inputs. ➤ Added second harmonic elements for blocking sensitive overcurrent elements during transformer inrush. ➤ Added high-speed dropout breaker failure logic with CT subsidence detection. ➤ Added rate-of-change-of-frequency (81R) elements. ➤ Added 51G2 residual ground overcurrent element. ➤ Added TRQUAL and EDDSOTF Disturbance Detector supervised tripping. ➤ Enhanced frequency tracking to use VA, VB, or VC for frequency tracking, reject frequency changes greater than 20 Hz/s, and use only the VA input when PTCONN = SINGLE. ➤ Improved directional logic for phase overcurrent element for evolving faults. ➤ Increased 25SF maximum setting to 1.0 Hz. ➤ Modified LOP logic to add LOPBLK SELOGIC control equation, add frequency tracking supervision, and add Relay Word bits for enhanced monitoring. ➤ DIR3 must now be set reverse whenever communications-assisted tripping is enabled. ➤ Added deadbands for Relay Word bits SSLOW and SFAST. ➤ Changed the dropout time of Relay Word bit 27B81 to 15 cycles to improve performance when the frequency measurement is switching between sources. ➤ The default for settings 81D1D–81D6D is now 60 cycles. ➤ Added breaker open and close time reporting and alarms. ➤ Corrected breaker monitor function to properly handle test settings that prevented the relay from enabling. ➤ Added **SUM** and **CSUM** commands, which provide long event summaries. ➤ Added unique event numbering and **HIS E** command. ➤ Added SELOGIC control equations for ALARM output and Relay Word bits for various self-test alarms. ➤ FTP and MMS can now transfer event files and selected ASCII commands. ➤ Improved fault locator accuracy for evolving faults. ➤ Enhanced front panel events display to show fractional seconds.	20120321

Table A.1 Firmware Revision History (Sheet 7 of 11)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Modified event reports to save and display settings active at the time of event trigger. ➤ Modified unfiltered compressed event reports to record the status of extra I/O board inputs before debounce timers. ➤ Added **TIME Q** and **TIME DST** commands. ➤ Improved resolution of MIRRORED BITS unavailability calculation. ➤ Added more statistics in **ETH** command response and ability to clear **ETH** command statistics. ➤ Pulsing outputs on extra I/O boards now triggers an event report. ➤ Settings group switch messages are now automatically included in SER records. ➤ Event report summary frequency is now always reported from a visible event report row. ➤ Large values of power demand and peak demand are now displayed properly in Display Points. ➤ Relay can now store ACSELERATOR QuickSet design templates. ➤ Revised CFG.txt file to include settings checksum. ➤ Expanded range of optoisolated input debounce settings from one cycle to two cycles. ➤ Relay now correctly handles text settings with embedded double quotes. ➤ Added MAXACC = 0 setting to restrict access to ports while allowing SEL Fast protocols to function and allow **SNS**, **BNA**, and **DNA** commands at Access Level 0. ➤ Relay now allows Calibration Level access on any port. ➤ Added settings for the user policy banners for the web server and TCP. ➤ Increased size of user-defined FTP banner. ➤ Added relay serial number to the **ID** command response. ➤ Added Remote Bits RB17–RB32. ➤ Added support for **DNA X** and **DNA T** commands. ➤ Revised IP addressing to use Classless addressing scheme and restricted addresses so that the first octet cannot be zero and the host portion of the IP address cannot be all ones or all zeros. ➤ Web Server now always displays the settings from the active settings group by default. ➤ Improved time stamp accuracy for SEL Fast Meter quantities. ➤ Serial ports can no longer time out during **FILE SHO** command responses. ➤ Fast SER protocol now reports setting group Relay Word bits properly. ➤ The SEL Fast Meter status byte now uses bit 1 for settings change and bit 2 for power-up. ➤ IPADDR setting now accepts all valid IP addresses when settings PMOIPA1 or PMOIPA2 are hidden. ➤ The relay now supports as many as six DNP sessions. ➤ Added EVEMODE setting to force the relay to start in single or multiple event mode.	

Table A.1 Firmware Revision History (Sheet 8 of 11)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Added DNP binary output SINGEVE to allow the DNP master to place the outstation in single-event mode. ➤ Added RSTDNPE SELOGIC control equation and DRSTDNPE DNP binary output to reset relay event queue. ➤ Added MINDIST and MAXDIST fault location settings to limit event reports made available via DNP. ➤ Added RPEVTYP setting to control which event types are made available via DNP. ➤ Added FLTDISP setting to allow user to control currents displayed in event summary, event history, Modbus, and IEC 61850. ➤ Added new DNP analog input labels for fault locator currents. ➤ Added BOOPTCC and BOOPPUL settings to allow customized DNP binary output behavior. ➤ Relay serial number and firmware revision are now available as DNP and Modbus quantities. ➤ Default dead band of all DNP analog input angle quantities is now 500. ➤ Phase-to-phase voltage quantities are now available through communications interfaces when PTCONN = WYE. ➤ Added support for DNP Function Code 22 (Assign Class). ➤ Added DNPSRC setting to specify whether the DNP time source is UTC or local. ➤ DNP and Modbus event currents now report bipolar peak detector currents when the peak detector operates. ➤ SELOGIC group switch equations now have priority over DNP or Modbus group switch commands. ➤ DNP sessions on Ethernet ports now include a keep-alive signal and close the session if communication with the DNP master is lost. This ensures that the DNP master can reconnect to the session. ➤ DNP Binary outputs are no longer accepted when relay is disabled. ➤ RTS is now forced high and CTS is ignored when PREDLY setting is OFF to power certain fiber-optic transceivers. ➤ Fault location, fault currents, and fault impedance are now available as IEC 61850 quantities. ➤ VS voltage magnitude and angle are now available as IEC 61850 quantities. ➤ Relay serial number is now available as an IEC 61850 quantity. ➤ Changed dead band for IEC 61850 ZBAT logical note from 500 to 5. ➤ Increased energy metering resolution in front panel display and **MET E** command. ➤ Added support for zipped and digitally signed (.ZDS) firmware files. Firmware files with the .s19 extension cannot be sent to relays with this firmware. ➤ Added self-test test to verify operating system health. ➤ Added self-tests to better detect analog-to-digital converter failures. ➤ Added multicasting support for UDP_S for synchrophasors.	

Table A.1 Firmware Revision History (Sheet 9 of 11)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Relay Word bit PMDOK now asserts when the measured frequency is between 40Hz and 65Hz. It is not necessary for the relay to be tracking the frequency. ➤ The relay now enables TCP keep-alive for PMU sessions regardless of ETCPKA setting. ➤ Modified retransmit intervals for outgoing GOOSE messages. ➤ Minimum GOOSE retransmit time is now configurable. ➤ Changed logical node METMMXU1 per-phase power factor (PF.), real power (W.), and reactive power (VAr.) objects to use CMV cdc instead of MV cdc. ➤ Data references within the OptFlds attribute are no longer included in the default report control blocks of the ICD file. ➤ MMS inactivity timeout is now user configurable. ➤ CID files with APPID or VLAN-ID strings shorter than the maximum length are now accepted. ➤ Smallest maximum MMS PDU size changed to 512 bytes. ➤ Maximum number of MMS variables that can be read or written reduced to 256. ➤ Improved synchrophasor frequency accuracy when PHCOMP = Y. ➤ Changed the size of the fixed portion of a C37.118 message from 16 to 18 bytes when calculating port speed and message size limit dependencies. ➤ appID in a GOOSE control block and rptID in a Report control block may be left empty, and if so, will be automatically replaced with the control block reference. ➤ GOOSE mAddr attribute may now contain nonmulticast addresses. ➤ The messages provided when no GOOSE subscriptions or publications are configured have been changed to `No GOOSE subscriptions configured` and `No GOOSE publications configured`, respectively. ➤ Corrected issue where GOOSE confRev field was limited to the range of 0–255 in received messages. ➤ Change report is now sent if integrity or GI report is sent before BufTM expires. ➤ Different segments of segmented reports now have different sequence numbers. ➤ The buffer overflow flag is now set in the first report to be transmitted after a buffered report control block (BRCB) re-enable. ➤ Corrected Str.dirGeneral datasource for ICD file logical nodes DCUBPSCH1 and POTTPSCH1.	
SEL-351-x-R510-V0-Z103103-D20110429	➤ Made changes for manufacturing process improvements. ➤ Ensure C37.118 configuration frame (CFG-2) is sent at top of minute when PMU Output Transport Scheme is UDP_S and IRIG-B is not connected. ➤ Corrected issue that may cause the relay to restart when LER=60 and several events are triggered after a power cycle and Global settings change.	20110429

Table A.1 Firmware Revision History (Sheet 10 of 11)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-351-x-R509-V0-Z103103-D20110412	➤ Ensure front-panel targets (Relay Word rows 0 and 1) are properly displayed after power is restored to the relay or after an STA C or R_S command is issued.	20110412
SEL-351-x-R508-V0-Z103103-D20100908	➤ Allowed SEL Fastoperate commands when serial port setting PROTO = PMU. ➤ Allowed either even or odd parity in IRIG-B data streams. ➤ Prevented Telnet timeout when Telnet session is used for Fast Message protocol. ➤ Improved FTP server compatibility with some clients such as Microsoft Explorer. ➤ Forced ROKA and ROKB to deassert when associated serial connection is removed. ➤ Fixed possible serial port lockup for Modbus Function Code 03 or 04 reads that end at address FFFF. ➤ Fixed possible front-panel and serial port lockup caused when a Group switch occurs during multiple back-to-back triggered oscillographic event reports. ➤ Ensured relay never accepts a **DNP** command when the relay is disabled. ➤ Added capability to copy DNP maps with the **COP** command. ➤ Added new Global setting METHRES, which allows selecting if the meter reports are forced to zero when the current or voltage is small.	20100908
SEL-351-x-R507-V0-Z102102-D20100315	➤ Prevented port lockup in response to CTRL+X during **COP**y command. ➤ Changed format of DNP event summary register FTYPE to accurately create what is reported in *Appendix L: DNP3 Communications*. *Appendix L: DNP3 Communications* states values are packed into adjacent bytes which is how R507 acts. R506 and prior packed values into one byte. ➤ Corrected handling of large blocks of data pasted into user name or password fields of embedded web server.	20100315
SEL-351-x-R506-V0-Z102102-D20100105	➤ Added ordering option for IEC 61850 MMS and GOOSE (available on relays with single 100BASE-FX fiber, dual 100BASE-FX fiber, or dual 100BASE-TX copper Ethernet ordering option). ➤ Added harmonic metering functions including Total Harmonic Distortion (THD), RMS magnitude, fundamental magnitude, and 2nd through 16th harmonic of each current and voltage channel. ➤ Added Port 5 settings SET/SHO capability to the front-panel interface (LCD). ➤ Added Logic Variables LV1–LV32, and associated Relay Word bits. ➤ Added virtual bits VB001–VB128 to Relay Word. ➤ Increased the maximum number of elements per SELOGIC Equation to 30. ➤ Added support for Simple Network Time Protocol (SNTP). ➤ Reduced the number of available Telnet sessions when IEC 61850 is enabled and the web server, DNP, or Modbus protocols are enabled over Ethernet. ➤ Added support for HTTP (Web) Server.	20100105

Table A.1 Firmware Revision History (Sheet 11 of 11)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Added a single session of FTP (File Transfer Protocol) to support FTP client software or ACSELERATOR Architect transfer of the Substation Configuration Language (SCL) Configured IED Description (CID) files to the relay. ➤ Added OFF setting choice to Port 5 Failover Time-out (FTIME) setting. ➤ Added EPORT setting to Port F, which also covers the optional USB port. ➤ Changed Access jumper function to override MAXACC setting on all ports. ➤ Changed name of Relay Word bit LINKFAIL to LNKFAIL. ➤ Added signed integer versions of fault type and fault time labels for proper DNP analog input mapping when using 16-bit variations. ➤ DNP conformance: Added Object 0 support. ➤ Changed the DNP event summary analog input behavior for single-event mode. The relay now creates analog change events for all of the event summary registers (FTYPE, FLOC, FI, etc.) when any one of the registers exceeds its dead band, because these event registers refer to the same event summary record. ➤ Reduced the number of available DNP and Modbus sessions over Ethernet to 2 (total) when IEC 61850 is enabled. ➤ Reduced the number of available Ethernet Phasor Measurement Unit (PMU) sessions from 2 to 1 when IEC 61850 is enabled. ➤ Changed **TARGET RESET** pushbutton behavior to no longer restore default LCD contrast. ➤ Corrected operation of Relay Word bits IAMET, INMET, ICMET, and INMET for highly distorted current signals. ➤ Corrected relay diagnostics calculation of A/D offset to prevent erroneous warnings when highly distorted current or voltage signals are present.	
SEL-351-x-R504-V0-Z101101-D20091103	➤ Corrected an issue that caused 59V1 to operate at incorrect voltage when Global setting PTCONN = DELTA. ➤ Fixed year rollover when IRIG-B is connected and Global setting IRIGC = NONE.	20091103
SEL-351-x-R503-V0-Z101101-D20090720	➤ Fixed a problem that sometimes disabled the relay after a SELOGIC settings change, including changing to a settings group with different SELOGIC settings.	20090720
SEL-351-x-R502-V0-Z101101-D20090707	➤ Added DNP Binary Output BO_032.	20090707
SEL-351-x-R501-V0-Z100100-D20090602	➤ Corrected problem with latch bits being incorrectly recalled from non-volatile memory. This problem causes latch bit values to revert to their previous state when latch bits are used to initiate a settings group change via Global settings SS1 through SS6, or when latch bit values change less than one second before a settings change.	20090602
SEL-351-x-R500-V0-Z100100-D20090324	➤ Initial version.	20090324

SELBOOT Firmware Version and Relay Firmware Compatibility

The SELBOOT version and the compatible relay firmware versions are listed in *Table A.2*.

Table A.2 SEL-351 Protection System SELBOOT Versions

Boot Firmware Identification Number (BFID)	Summary of Revisions	Firmware Version Supported	Manual Date Code
SLBT-3CF1-R200	Added support for zipped and digitally signed (.ZDS) firmware files. Firmware files with the .s19 extension cannot be sent to relays with this firmware.	R511–R518-V2 Only supports R511–R518	20120321
SLBT-3CF1-R102	Manufacturing improvement	Released on R506 Supports R500–R510	20100105
SLBT-3CF1-R101	Manufacturing improvement	Released on R505 Supports R500–R510	(R505 did not production release)
SLBT-3CF1-R100	Manufacturing improvement	Released on R500–R504 Supports R500 - R510	20090324

ICD File

Determining the ICD File Version in Your Relay

To find the ICD revision number in your relay, view the configVersion using the serial port **ID** command. The configVersion is the last item displayed in the information returned from the **ID** command.

configVersion=ICD-351-R204-V0-Z516005-D2015xxxx

The ICD revision number is after the R (e.g., 204) and the release date is after the D. This revision number is not related to the relay firmware revision number. The configVersion revision displays the ICD file version used to create the CID file that is loaded in the relay.

NOTE: The Z number representation is implemented with ClassFileVersion 005. Previous ClassFileVersions do not provide an informative Z number.

The configVersion contains other useful information. The Z number consists of six digits. The first three digits following the Z represent the minimum IED firmware required to be used with the ICD (e.g., 516). The second three digits represent the ICD ClassFileVersion (e.g., 005). The ClassFileVersion increments when there is a major addition or change to the 61850 implementation of the relay.

Table A.3 lists the ICD file versions, a description of modifications, and the instruction manual date code that corresponds to the versions. The most recent version is listed first.

Table A.3 SEL-351 ICD File Revision History (Sheet 1 of 2)

configVersion	Summary of Revisions	Min. Relay Firmware	ClassFile Version	Manual Date Code
ICD-351-R205-V0-Z518005-D20201217	➤ Modified the data source for the voltage blocking attribute in the frequency element logical node from Relay Word bit 27B81 to 27B81A. **Note:** It may not be necessary to modify existing ICD files to reflect the change of Relay Word bit 27B81 to 27B81A if the default setting of the frequency element torque-control setting, 81TC, has not changed from the default setting of !27B81.	518	005	20201217
ICD-351-R204-V0-Z516005-D20150202	➤ Corrected SCBR logical nodes logical device to PRO. ➤ Corrected ReportControl rptID attributes to display report name instead of dataset name. ➤ Made corrections per KEMA recommendations. ➤ Increased number of MMS reports to 14. ➤ Modified all MMS report and dataset names. ➤ Updated ClassFileVersion to 005. ➤ Updated all ReportControls. ➤ Made MMS Inactivity Timeout user-configurable. ➤ Added new MMS Authentication Support. ➤ Updated configVersion for new format. ➤ Added new RDRE logical node and attributes. ➤ Added new SCBR MaxAbrPrt (MAXWEAR) attributes. ➤ Added filehandling service. ➤ Removed maxEntries and maxMappedItems. ➤ Removed extra space from BRDSet03 and URDSet03 dataset descriptions. ➤ Updated orCat control instances to proprietary node. ➤ Increased default MMS inactivity timeout from 120 to 900 seconds. ➤ Corrected ldNs and InNs values.	516	005	20150202
ICD-351-R203-V0-Z001001-D20140730	➤ Made MMS inactivity timeout user configurable. ➤ Added filehandling service. ➤ Removed maxEntries and maxMappedItems. ➤ Updated orCat control instances to proprietary node.	513	004	20140730

Table A.3 SEL-351 ICD File Revision History (Sheet 2 of 2)

configVersion	Summary of Revisions	Min. Relay Firmware	ClassFile Version	Manual Date Code
ICD-351-R202-V0-Z001001-D20121206	➤ Increased number of inputs for IN2GGIO2 logical node. ➤ Made corrections per KEMA recommendations.	513	004	20130304
ICD-351-R201-V0-Z001001-D20120615	➤ Corrected nseq DOIs with cdcNs and cdcName. ➤ Created new BKGGIO22 logical node with 52a and 3PO status.	511	004	20130304
ICD-351-R200-V0-Z001001-D20120325	➤ Updated ClassFileVersion to 004. ➤ Increased remote bits to 32. ➤ New RFLO logical node and attributes. ➤ Made corrections per KEMA recommendations. ➤ Added new serNum DAI. ➤ Added new LOP attributes to LOPPTUV1 logical node. ➤ Added new XCBR OpCntEx attribute. ➤ Added new RBRF logical nodes and attributes. ➤ Added new Ind07 attribute for SGGGIO15 logical node. ➤ Added new ALMGGIO18 logical node and attributes. ➤ Corrected LPHD1 PhyHealth stVal datasource. ➤ Corrected datatype for MMXU W, VAr, and PF attributes. ➤ Added new MinTime support. ➤ Set all ReportControl dataRef OptFields to false. ➤ Corrected DCUB and POTT Str.dirGeneral. ➤ Added new SCBR logical nodes and attributes datasourse. ➤ Added new H2BLKGGIO21 logical node and attributes.	511	004	20120321
ICD-351-R102-V0-Z001001-D20110818	➤ Added VSyn attribute to METMMXU1 logical node. ➤ Corrected DCZBAT Vol deadband.	510	003	20110429
ICD-351-R101-V0-Z001001-D20100825	➤ Initial ICD file release.	506	003	20100105

Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date.

Table A.4 lists the instruction manual date codes and a description of modifications. The most recent instruction manual revision is listed at the top.

Table A.4 Instruction Manual Revision History (Sheet 1 of 11)

Date Code	Summary of Revisions
20250909	Section 3 ➤ Updated *Frequency Element Settings and Supervision*. ➤ Updated *Examples for Calculating 27B81P Setting Values*.
20250428	Appendix A ➤ Updated for firmware version R518-V4, R516-V7, and R515-V6.
20250401	Appendix A ➤ [Cybersecurity] Updated firmware revision entries for R515-V3, R516-V4, and R518-V1.
20250224	Appendix A ➤ Updated for firmware version R515-V5.
20250127	General ➤ Removed references to CDs throughout.
20250111	Section 10 ➤ Updated *Table 10.19: ASCII Command Summary*. ➤ Added *TDP Command*. ➤ Updated *SEL-351-5, -6, -7 Command Summary*. Appendix A ➤ Updated for firmware versions R518-V3 and R516-V6. ➤ Corrected date code for firmware versions R518-V2, R516-V5, and R515-V4 to 20240709. ➤ Corrected date code in *Table A.4: Manual Revision History* to 20240709.
20240709	Section 1 ➤ Updated *Specifications*. Appendix A ➤ Updated for firmware versions R518-V2, R516-V5, and R515-V4.
20230831	Section 6 ➤ Updated *Lockout State*. Section 7 ➤ Updated *Logic Variable Behavior After Power Loss, Settings Change, or Group Change*. Section 13 ➤ Updated *Testing Philosophy*. Appendix A ➤ Added *SELboot Firmware Version and Relay Firmware Compatibility*. Appendix F ➤ Added *Maximum Total Number of Elements, Rising-Edge, and Falling-Edge Operators*. Appendix Q ➤ Updated *Appendix*.
20221103	Section 1 ➤ Added UKCA Mark in *Specifications*.
20211203	Section 1 ➤ Updated *Type Tests* in *Specifications*.
20210917	Section 3 ➤ Added *Figure 3.38: Undervoltage Block Element for 81 Supervision (Global Setting PTCONN = DELTA)*. ➤ Updated *Frequency Element Voltage Control*. ➤ Added *Examples for Calculating 27B81P Setting Values*. Appendix A ➤ Updated for firmware version R518-V1, R516-V4, and R515-V3.

Table A.4 Instruction Manual Revision History (Sheet 2 of 11)

Date Code	Summary of Revisions
20201217	Section 1 ➤ Updated *Specifications*. Section 2 ➤ Updated *Wye-Connected Voltages (Global Setting PTCONN = WYE)* and *Delta-Connected Voltages (Global Setting PTCONN = DELTA)*. ➤ Updated *Table 2.1: Voltage-Based Functions Retained When Single-Phase Voltage Connected to Relay*. ➤ Updated notes for *Figure 2.15: SEL-351S Provides Overcurrent Protection and Reclosing for a Utility Distribution Feeder, Including Fast Bus Trip Scheme (Wye-Connected PTs)*, *Figure 2.16: SEL-351S Provides Overcurrent Protection for a Distribution Bus, Including Fast Bus Trip Scheme (Wye-Connected PTs)*, *Figure 2.19: SEL-351S Provides Overcurrent Protection for a Delta-Wye Transformer Bank (Wye-Connected PTs)*, and *Figure 2.20: SEL-351S Provides Overcurrent Protection for a Transformer Bank With a Tertiary Winding (Wye-Connected PTs)*. Section 3 ➤ Added alpha component for frequency estimation. ➤ Added frequency estimation specifications. ➤ Updated over- and underfrequency element specifications. Appendix A ➤ Updated for firmware version R518-V0. ➤ Updated for ICD version R205-V0. Appendix D ➤ Updated *Table D.1: Relay Word Bit Mapping* and *Table D.2: Alphabetic List of Relay Word Bits*. Appendix F ➤ Updated *Table F.4: Processing Order of Relay Elements and Logic (Top to Bottom)*. Appendix P ➤ Updated *Table P.25: Logical Device: PRO (Protection)*.
20201008	Appendix A ➤ Updated for firmware version R516-V3.
20200812	Preface ➤ Updated Safety Information. ➤ Added *Wire Sizes and Insulation*. Section 1 ➤ Updated *Specifications*. Section 2 ➤ Added notes for IEC 60255-26 and IEC 60255-27 requirements.
20191107	Section 1 ➤ Updated *Specifications*.
20190809	Section 1 ➤ Updated *Specifications*. Section 2 ➤ Updated *Table 2.2: Link Budget for Fiber-Optic Serial Ports.* Section 10 ➤ Updated *Detailed Instructions for USB Port Driver Installation* in *Introduction* to remove a reference to the QuickSet CD. Section 12 ➤ Updated *Introduction* and *Standard 15/30/60-Cycle Event Reports* to replace SEL-5601 with SEL-5601-2. Appendix C ➤ Updated to replace SEL-5601 with SEL-5601-2.
20190111	Section 1 ➤ Updated *Specifications*.

Table A.4 Instruction Manual Revision History (Sheet 3 of 11)

Date Code	Summary of Revisions
	Appendix A ➤ Updated for firmware versions R515-V2 and R516-V2.
20171023	Section 1 ➤ Updated *Specifications*.
20170818	Appendix A ➤ Updated for firmware versions R515-V1 and R516-V1.
20170215	Section 1 ➤ Updated *Specifications*.
20160715	Section 4 ➤ Enhanced the *Directional Control Settings* subsection to include a description of specific applications for the E32 setting.
20150820	Section 2 ➤ Updated power supply rear-panel connection information.
20150202	Section 1 ➤ Updated *Specifications*. Section 4 ➤ Improved description of zero-sequence maximum torque angle setting Z0MTA. Section 7 ➤ Added virtual bit reset behavior to *Virtual Bits*. Settings Sheets ➤ Updated the setting range for NETMODE. ➤ Added new PRPTOUT, PRPADDR, and PRPINTV settings. ➤ Added new HTTPACC and FWFPC settings. ➤ Added new EMMSFS IEC 61850 Protocol Setting. Section 10 ➤ Added description of PRP Connection Mode. ➤ Added description of PING command. ➤ Added description of Virtual File Interface. ➤ Updated description of Embedded Web Server. ➤ Updated Access Control description for MMS for new EMMSFS setting and authentication. Section 12 ➤ Added description of COMTRADE event report. Appendix A ➤ Updated for firmware version R516. ➤ Added *ICD File* section. Appendix B ➤ Added description for firmware upgrade over an Ethernet connection. Appendix C ➤ Modified reference to ACSELERATOR QuickSet SEL-5030 Software Instruction Manual. Appendix E ➤ Added *Fault Location* section. ➤ Moved FLOC, FZ, and FZFA to new *Fault Location* section. ➤ Updated FZ and FZFA quantities for DNP and Modbus use. ➤ Corrected FSHO units. ➤ Added MAXWEAR quantity. ➤ Added FLRNUM and FLREP quantities. ➤ Corrected FLOC units.

Table A.4 Instruction Manual Revision History (Sheet 4 of 11)

Date Code	Summary of Revisions
	Appendix H ➤ Added description of Ethernet Synchrophasor settings. Appendix L ➤ Added Obj. Type 34 to all Analog Inputs in *Table L.10: DNP3 Reference Data Map*. ➤ Added FZ and FZFA quantities to *Table L.10: DNP3 Reference Data Map*. ➤ Added MAXWEAR to *Table L.10: DNP3 Reference Data Map*. ➤ Updated *Table L.11:DNP3 Default Data Map format*. ➤ Added BO_033 through BO_70 to *Table L.11:DNP3 Default Data Map*. ➤ Increased number of Binary Outputs to 71. ➤ Corrected *Figure L.7: Sample Custom DNP3 BO Map Settings* for new binary outputs. ➤ Updated *Event Data* section with new fault data. ➤ Added more detail to FTYPE description and numbered FTYPE tables. ➤ Made corrections to *Reading Relay Event Data* section. ➤ Added BO_033 through BO_070 to *DNP Settings Sheets*. ➤ Updated 51P, 51G, 51Q, and 51N settings in *Table L.10: DNP Reference Data Map* with note on behavior if setting is off. Appendix N ➤ Improved description of Ethernet Port Settings for IEEE C37.118 Synchrophasors. ➤ Added *Table N.24: Time Quality Decoding*. Appendix O ➤ Added description of reading event data using Modbus. ➤ Added FZ and FZFA, quantities to *Table O.22: Modbus Quantities Table*. ➤ Added MAXWEAR to *Table O.22: Modbus Quantities Table*. ➤ Added Modbus Map labels to set, clear, or pulse remote bits using Modbus Function Code 06h or 10h to *Table O.22: Modbus Quantities Table*. ➤ Added information on new remote bit set, clear, and pulse labels to *Bit Operations Using Function Codes 06h and 10h* section. Appendix P ➤ Changed MMS Object Explorer to AX-S4 61850 Explorer and AX-S4 MMS to AX-S4 61850. ➤ Added description of MMS authentication. ➤ Updated *Datasets* section with new data sets (total of 15 data sets now) and new data set naming and *Figure P.1: SEL-351 Datasets*. ➤ Updated *Reports* section with new reports (total of 14 now) and new report naming and *Figure P.2: SEL-351 Predefined Reports*. ➤ Updated *Table P.5: Buffered Report Control Block Client Access*. ➤ Updated *Table P.6: Unbuffered Report Control Block Client Access*. ➤ Updated GOOSE Construction Tips section with new figures (*Figure P.3: Example of a Poorly Constructed GOOSE Dataset* through *Figure P.6: Example Transmit GOOSE Dataset*). ➤ Updated *IEC 61850 Configuration* section and *IEC 61850 Operation* section for MMS File Services modifications. ➤ Updated *IEC 61850 Configuration* section for virtual bit reset behavior. ➤ Added information to *SEL ICD File Versions* section. ➤ Added MaxAbrPrt (MAXWEAR) attribute to *Table P.18: Circuit Breaker Supervision (Per-Phase) Logical Node Class Definition*. ➤ Removed TotVA from *Table P.20: Measurement Logical Node Class Definition*. ➤ Moved SCBR logical node items from *Table P.28: Logical Device: ANN (Annunciation)* to *Table P.25: Logical Device: PRO (Protection)*. ➤ Updated virtual bit reset behavior for footnote b in *Table P.28: Logical Device: ANN (Annunciation)*. ➤ Added RcdMade (FLREP) and FltNum (FLRNUM) attributes to *Table P.25: Logical Device: PRO (Protection)*. ➤ Added MAXWEAR Logical Node value in *Table P.28: Logical Device: PRO (Protection)* for SCBR per-phase logical nodes (BSASCBR1, BSBSCBR2, BSCSCBR3). ➤ Updated MMS client session to seven. ➤ Added description of CID file load with MMS file transfer.

Table A.4 Instruction Manual Revision History (Sheet 5 of 11)

Date Code	Summary of Revisions
	Appendix R ➤ Added new *Appendix R: Fault Location and Supplemental Fault Location and Impedance Data*.
20150105	Preface ➤ Updated *Safety Information*. Section 1 ➤ Renamed *Certifications* to *Compliance* and moved to the beginning of *Specifications*.
20130620	Appendix A ➤ Updated for firmware version R515.
20130403	Section 13 ➤ Removed A/D Failure corrective action note in *Table 13.3: Relay Self-Tests*. Appendix A ➤ Updated firmware version R511 summary of revisions (see *Table A.1*). Appendix P ➤ Corrected DmdA.nseq and PkDmdA.nseq Attribute Type to be MV in *Table P.17: Demand Metering Logical Node Class Definition*. ➤ Modified *Table P.17: Demand Metering Logical Node Class Definition–Table P.19: Circuit Breaker Supervision Logical Node Class Definition* and *Table P.21: Measurement Logical Node Class Definition–Table P.24: Circuit Breaker Logical Node Class Definition* formats to match IEC 61850 standard.
20130304	Preface ➤ Updated descriptions of *Section 5: Trip and Target Logic* and *Section 7: Inputs, Outputs, and Other Control Logic*. Section 1 ➤ Revised *Time-Code Inputs* for new fiber-optic serial port option and added current metering accuracy specifications for low currents. ➤ Added specifications for fiber-optic serial port option. ➤ Increased accuracy range for current channel synchrophasor. Section 2 ➤ Revised rear-panel views for new communications and extra I/O board options. ➤ Revised *Making Rear-Panel Connections* for new extra I/O board option. ➤ Revised *Making Communications Connections* for new fiber-optic serial port option. ➤ Revised *Figure 2.30: Jumper, Connector, and Major Component Locations on the SEL-351 Main Board* to show Factory Use for JMP1C and JMP1D. ➤ Revised *Figure 2.31: Jumper, Connector, and Major Component Locations on the SEL-351 Extra I/O Board (Extra I/O Options 2 and 6)* and associated text for new extra I/O board option. ➤ Added *Figure 2.32: Jumper, Connector, and Major Component Locations on the SEL-351 Extra I/O Board With Four Standard Outputs (Extra I/O Option 4)* for new extra I/O board option. Section 3 ➤ Added Note for *Table 3.14: Synchronism-Check Elements Settings and Settings Ranges*. ➤ Changed *Table 3.16: Frequency Elements Settings and Settings Ranges* footnote to a margin note. Section 4 ➤ Revised *Figure 4.26: Positive-Sequence Voltage-Polarized Directional Element for Phase Overcurrent Element* to clarify influence of distance-type elements on the directional decision. There is no change in function. Section 5 ➤ Added discussion of MIRRORED BITS security counter settings in Trip Setting DTT. Section 7 ➤ Updated *Optoisolated Inputs* and *Output Contacts* for new extra I/O board option. ➤ Added ALRMOUT equation to *Output Contacts*. Section 8 ➤ Added references to IEC 61850 for various analog quantities.

Table A.4 Instruction Manual Revision History (Sheet 6 of 11)

Date Code	Summary of Revisions
	Section 9 ➤ Revised Input debounce timers and output equations for new extra I/O board option. ➤ Revised PMSTN setting to allow mixed case. Section 10 ➤ Revised for new communications and extra I/O board options. ➤ Added *Ethernet Port Speed*. ➤ Revised *Figure 10.4: Web Server Login Screen* through *Figure 10.6: Web Server Show Settings Screen* for revised Web server format. ➤ Clarified **GOO** command syntax and response data fields. Section 12 ➤ Clarified how event report targets are determined. ➤ Added S*x* and L*y* error cases for **EVE** command, ➤ Revised for new extra I/O board option. ➤ Added FLTDISP note to *Figure 12.5: Example Standard 15-Cycle Event Report 1/4-Cycle Resolution (Wye-Connected PTs)*. Section 13 ➤ Added references to HALARMA in *Table 13.3: Relay Self-Tests*. Appendix A ➤ Updated for firmware version R513 and R514. Appendix C ➤ Described licensed versions of ACSELERATOR QuickSet in *Table C.1: SEL Software Solutions*. Appendix D ➤ Updated *Table D.1: Relay Word Bit Mapping* and *Table D.2: Alphabetical List of Relay Word Bits* for new extra I/O board option. Appendix E ➤ Clarified availability of phase-to-phase voltages when PTCONN = WYE. Appendix F ➤ Updated *Table F.4: Processing Order of Relay Elements and Logic* and *Table F.5: Asynchronous Processing Order of Relay Elements* for new extra I/O board option and general clarifications. Appendix H ➤ Clarified relationship between security counters and IEC 60834-1. Appendix L ➤ Revised Qualifier Codes for Object 21 in *Table L.9: SEL-351 Object List*. ➤ Added SINGEVE and clarified scaling for various quantities in *Table L.10: DNP3 Reference Data Map*. ➤ Corrected DNP Device Profile points lists to eliminate unused points. Appendix N ➤ Revised PMSTN setting to allow mixed case. ➤ Revised *Configuring High Accuracy Timekeeping* for new fiber-optic serial port option and for change in parity checking. Appendix O ➤ Added function codes and scaling for various quantities in *Table O.22: Modbus Quantities Table*. Appendix P ➤ Added more detail to IEC 61850 Datasets and Reports. ➤ Added more detail to IEC 61850 Configuration Settings. ➤ Removed Quality Bit Strings Data Type from *Table P.12: Score for Data Types Contained in Published Messages* because transmit quality counts as 0 points. ➤ Corrected score example. ➤ Updated *Table P.25: Logical Device: PRO (Protection)* through *Table P.28: Logical Device: ANN (Annunciation)*. ➤ Modified receive Message Quality indication to exclude messages processed out-of sequence.

Table A.4 Instruction Manual Revision History (Sheet 7 of 11)

Date Code	Summary of Revisions
20120830	**Appendix A** ➤ Updated for firmware version R512.
20120321	**Section 1** ➤ Updated *Terminal Connections (Tightening Torque)*, *Frequency and Rotation*, *SafeLock Trip/Close Pushbuttons (MOV Protection)*, *Type Tests*, *Certification*, *Synchronism-Check Elements*, *Under- and Overfrequency Elements*, *Fundamental Metering Accuracy*, and *Synchrophasor Accuracy* in *Specifications*. ➤ Added *Breaker Failure Current Detectors and Logic*, *Second-Harmonic Blocking Elements*, and *Rate-of-Change-of-Frequency Elements* to *Specifications*. **Section 2** ➤ Updated *Potential Transformer Inputs* subsection with new frequency source information. **Section 3** ➤ Added *Second-Harmonic Blocking Logic* subsection. ➤ Added *Rate-of-Change-of-Frequency (81R) Protection* subsection. ➤ Updated *Synchronism Check Elements* subsection to include the new 25RCF ratio correction factor setting, the increased 25SF setting range, and the new deadband between the SFAST and SSLOW operating zones. ➤ Updated *Frequency Elements* subsection with increased dropout time on 27B81 undervoltage block for frequency elements, and added instantaneous frequency element response time and frequency element time delay considerations. **Section 4** ➤ Updated *Loss-of-Potential Logic* subsection. ➤ Updated *Figure 4.1: Loss-of-Potential Logic*. ➤ Added *Figure 4.2: Overall LOP Logic*, *Figure 4.3: LOP2 Logic Processing Overview (Relay Word Bit LOP2)*, *Figure 4.4: LOP Latch Logic (Relay Word Bit LOP3)*, and *Figure 4.5: LOP Reset Logic (Relay Word Bit LOPRST).* ➤ Added *Table 4.2: Loss-of-Potential Logic Outputs*. ➤ Added SELOGIC control equation LOPBLK. ➤ Updated *Directional Control for Negative-Sequence and Phase Overcurrent Elements* subsection to show the newly added F32Q and R32Q priority over the positive-sequence voltage-polarized directional element. **Section 5** ➤ Added SELOGIC control equation TRQUAL for qualified trip conditions to *Trip Logic and Switch-Onto-Fault (SOTF) Trip Logic*. ➤ Added disturbance detector (DD) Relay Word input to *Trip Logic and Switch-Onto-Fault (SOTF) Trip Logic*. ➤ Added EDDSOTF disturbance detector supervision for switch-onto-fault logic to *Trip Logic and Switch-Onto-Fault (SOTF) Trip Logic*. ➤ Added *Breaker Failure Protection* subsection. **Section 7** ➤ Input debounce timer settings IN*xxx*D can now be set as long as 2.00 cycles. ➤ Added remote bits RB17–RB32. ➤ Added Relay Word bit GRPSW to indicate when a settings group change occurs. ➤ Added programmable ALARM functionality, including new Relay Word bits and the SALARM and ALRMOUT SELOGIC control equations. **Section 8** ➤ Added *Mechanical and Electrical Operate Timers and Alarms*. **Section 9** ➤ Added Relay Word bit SETCHG to *Settings Change Confirmation*. ➤ Updated *Coordinated Universal Time (UTC) Offset Setting* and *Automatic Daylight-Saving Time Settings* in *Settings Explanations*. ➤ Updated *Settings Sheets* for Global, Group, Logic, and Port settings classes.

Table A.4 Instruction Manual Revision History (Sheet 8 of 11)

Date Code	Summary of Revisions
	Section 10 ➤ Updated *Session Limits* to include as many as six DNP sessions. ➤ Added *File Transfer Protocol (FTP) and MMS File Transfer* subsection. ➤ Updated *Limit Maximum Access Level or Disable Any Port* subsection to include new MAXACC = 0 setting. ➤ Revised **BRE** and **BRE W** commands to include mechanical and electrical operate timers and station battery voltage. ➤ Added **BRE H** command. ➤ Added **ETH C** command. ➤ Added **GOO S** command. ➤ Added **HIS E** command, and updated **CEV** and **EVE** commands to accept unique event numbers. ➤ Added **SUM** command, and updated **HIS** command description to include FLTDISP setting. ➤ Updated **FILE** command description to include explanations of file types CFG.TXT, ERR.TXT, and SWCFG.ZIP. ➤ Added **TIME Q** and **TIME DST** commands. ➤ Updated *Command Summary*. Section 12 ➤ Updated description of settings stored with event reports in *Introduction*. ➤ Added SELOGIC control equation TRQUAL to *Standard Event Report Triggering*. ➤ Added Global setting FLTDISP to *Standard Event Report Summary and Event History (HIS)* description. ➤ Added **HIS E** command (unique event numbers). ➤ Added **SUM** command description. ➤ Added *Retrieving Event Reports Via Ethernet File Transfer* subsection. ➤ Updated *Sequential Events Recorder (SER) Report* subsection to include discussion of ALARM, HALARM, HALARML, SETCHG, and GRPSW under SER Triggering. ➤ Added Relay Group Changed message to *Table 12.5: Automatic SER Triggers*. Section 13 ➤ Updated *Relay Troubleshooting* to include Relay Word bits for programmable alarm operation. Appendix A ➤ Updated for firmware version R511. Appendix B ➤ Added *Upgrading to Digitally Signed Firmware Files* subsection. Appendix C ➤ Updated *Table C.1: SEL Software Solutions*. ➤ Updated ACSELERATOR QuickSet settings, including Design Templates. Appendix D ➤ Updated with Relay Word bits for the new firmware features. Appendix E ➤ Added new analogs for mechanical and electrical operate timers and alarms under *Breaker Monitor*. ➤ Added fault locator maximum current analogs for DNP3. ➤ Added relay information analogs for DNP3, Modbus, and IEC 61850. Appendix F ➤ Updated *Processing Order* and *Processing Interval* with new Relay Word bits and SELOGIC control equations. Appendix J ➤ Updated *A5B9 Fast Meter Status Acknowledge Message*. ➤ Updated Fast Operate tables to include 32 Remote Bits. ➤ Updated *DNA Message* to include **DNA T** and **DNA X** commands. Appendix K ➤ Updated *CHISTORY Command—SEL-351* and *CEVENT Command—SEL-351* descriptions to include the REF_-NUM (unique event number) field. ➤ Added *CSU Command*.

Table A.4 Instruction Manual Revision History (Sheet 9 of 11)

Date Code	Summary of Revisions
	Appendix L ➤ Updated discussion of dead band changes (Object 34) in *Event Data* subsection. ➤ Updated *Table L.6: SEL-351 Event Buffer Capacity*. ➤ Updated *Time Synchronization* subsection to include new Global setting DNPSRC. ➤ Updated to include as many as six DNP sessions. ➤ Updated *Table L.9: DNP Object List*. ➤ Updated *Table L.10: DNP Reference Data Map*. ➤ Updated *Binary Outputs and Control Point Operation in Configurable Data Mapping* subsection to include the operation of new Global settings BOOPPUL and BOOPTCC. ➤ Added *Event Data* subsection to *Analog Inputs*, including new fault locator maximum current analogs, and a description of the handling of 32-bit analogs in 16-bit masters. ➤ Updated Reading Relay Event Data subsection, including operation of new Global setting EVEMODE, and Port settings RPEVTYP, MAXDIST and MINDIST. Appendix N ➤ Added Channel Name column. ➤ Added C37.118 Data Frame table. ➤ Revised Serial Port Bandwidth for Synchrophasors table. ➤ Added description of holdover mode and **TIME Q** command to Configuring *High-Accuracy Timekeeping* subsection. Appendix O ➤ Added output coils for new Remote Bits RB17–RB32. ➤ Updated *Table O.22: Modbus Quantities*. Appendix P ➤ Added *Table P.3: Functional Constraints*. ➤ Added *GOOSE Receive and Transmit Capacity* subsection. ➤ Added MMS capability to access event files and reports. ➤ Updated Transmit Interval in *GOOSE Publication (Transmit) Processing*. ➤ Added *SEL ICD File Versions* subsection. ➤ Updated *Table P.31: MMS Service Supported Conformance*. Appendix Q ➤ Added new *Appendix Q: Cybersecurity Features*.
20110429	Appendix A ➤ Updated for firmware version R510.
20110412	Appendix A ➤ Updated for firmware version R509.
20101206	Section 1 ➤ Updated certification information in *Specifications*.
20101015	Section 1 ➤ Updated certification information in *Specifications*. ➤ Updated Phase Angle Accuracy in *Specifications*.
20100908	Section 8 ➤ In *Station DC Battery Monitor*, changed DCLOP and DCHIP pickup increments from 1 Vdc to 0.02 Vdc. ➤ Expanded *Small Signal Cutoff for Metering* to include description of new Global setting METHRES. Settings Sheets ➤ Added METHRES setting to *Global Settings*. ➤ Added port setting FASTOP when PROTO = PMU. Section 10 ➤ Updated web server screen captures and description. ➤ Updated definition of **COP** command to include copying DNP maps. Also included in Command Summary. ➤ Noted that settings displayed with **MET PM HIS** are present settings. ➤ Changed “close” to “open” in description of **OPE** command.

Table A.4 Instruction Manual Revision History (Sheet 10 of 11)

Date Code	Summary of Revisions
	Appendix A ➤ Updated for firmware version R508. Appendix L ➤ Removed footnote from *Table L.11: DNP3 Reference Data Map*. ➤ Corrected default index range for Object 01, 02 in *Table L.12: DNP3 Default Data Map*. ➤ Clarified description of relay summary event data retrieval using single-event and multi-event modes. Appendix N ➤ Deleted *Table N.4: PM Trigger Reason Bits—IEEE C37.118 Assignments*. ➤ Included setting FASTOP in *Serial Port Settings for IEEE C37.118 Synchrophasors*. ➤ Added subsection *Synchrophasor Protocols and SEL Fast Operate Commands*. Appendix P ➤ Corrected logical node TLEDGGIO13 to properly call out front-panel targets. ➤ Added Relay Word bit documentation for the POTTPSCH1 and DCUBPSCH1 logical nodes in *Table P: 16: Logical Device: PRO (Protection)*.
20100830	Section 1 ➤ Updated certification information in *Specifications*.
20100614	Section 1 ➤ Updated UL certification information in *Specifications*.
20100315	Appendix A ➤ Updated for firmware version R507.
20100119	Section 1 ➤ Updated ratings for UL/CSA compliant installations. Section 2 ➤ Added disconnect requirement to *Power Supply* for UL/CSA compliant installations.
20100105	Section 1 ➤ Added *Harmonic Metering Accuracy* to *Specifications*. ➤ Restated power supply ratings and ranges. Section 2 ➤ Changed “password jumper” to “Access jumper” throughout manual. ➤ Revised OUT/ALARM jumper to JMP10 in *Figure 2.27: Jumper, Connector, and Major Component Locations on the SEL-351 Main Board*. Section 7 ➤ Added Logic Variables LV1–LV32. ➤ Revised OUT/ALARM jumper to JMP10 in *Figure 7.27: Logic Flow for Example Output Contact Operation (All Models)*. Section 8 ➤ Added *Harmonic Metering*. Section 9 ➤ Updated references to USB port, which now inherits EPORT and MAXACC settings from serial Port F. ➤ Clarified reference to IEEE C37.112-1996: IEEE Standard Inverse-Time Characteristic Equations for Overcurrent Relays. ➤ Updated to reflect new functionality of EPORT setting to include Port F (and optional USB port). ➤ Updated to reflect new functionality of MAXACC setting to include an override when the Access Jumper is installed. Section 11 ➤ Added *Harmonic Metering* to *Front-Panel Interface* descriptions. Section 13 ➤ Added steps to *Troubleshooting Procedure* related to settings EPORT and MAXACC, Telnet, HTTP Server, FTP Server, and SNTP configuration.

Table A.4 Instruction Manual Revision History (Sheet 11 of 11)

Date Code	Summary of Revisions
	Appendix A ➤ Updated for firmware version R506. Appendix C ➤ Updated *Table C.6: Relay Word Bits and DNP Indices (Firmware Prior to R500)* with new Relay Word bits. ➤ Corrected *Table C.9: Settings Conversion Rules* entry for setting MFRMT when converting legacy relay EPMU = Y settings. Appendix D ➤ Added new Relay Word bits LV1–LV32 and VB001–VB128. Appendix E ➤ Added new analog quantities related to harmonic metering. Appendix J ➤ Updated Fast Meter and DNA message definitions to include new Relay Word bits. Appendix K ➤ Updated CAS and CEV samples to include new Relay Word bits. Appendix L ➤ Added Ethernet DNP session limit table for relays with IEC 61850. ➤ Added new Relay Word bits and Analog Quantities to DNP Reference Map. ➤ Corrected description of Global setting EVELOCK. Appendix N ➤ Updated Ethernet port synchrophasor settings to include a limit of one session when IEC 61850 is enabled. ➤ Clarified operation of TSOK and TIRIG Relay Word bits in *Configuring High-Accuracy Timekeeping*. Appendix O ➤ Added Modbus TCP session limit table for relays with IEC 61850. ➤ Updated with changes related to new Relay Word bits and Analog Quantities. Appendix P ➤ New appendix describing IEC 61850 functions.
20091103	Appendix A ➤ Updated for firmware version R504.
20090720	Appendix A ➤ Updated for firmware version R503.
20090707	Appendix A ➤ Updated for firmware version R502. Appendix L ➤ Added DNP Binary Output BO_032.
20090602	Appendix A ➤ Updated for firmware version R501.
20090324	➤ Initial version.

APPENDIX B

Firmware Upgrade Instructions for SEL-351 Relays With Ethernet

Overview

⚠CAUTION
Do not install firmware with a lower revision number than the current version. Changing the firmware from R511 or higher to R510 or lower will cause the relay to lose calibration.

From time to time, SEL issues firmware upgrades for this relay. The instructions which follow explain how you can install new firmware in your SEL-351 relay with Ethernet. These instructions are for firmware upgrades only and do not provide complete instructions for part number changes. If a part number change is required (for example, to change an SEL-351-6 to an SEL-351-7), contact SEL for assistance.

This appendix contains the following subsections:

Upgrading to Digitally Signed Firmware Files

NOTE: These instructions are for upgrading a relay with digitally signed firmware files (.zds file extension). Proceed to *Relay Firmware Upgrade Methods* on page B.3 if upgrading to firmware with .s19 file extension.

This device supports digitally signed firmware upgrades for firmware version R511 and higher. These firmware upgrade files are compressed to reduce file transfer times and digitally signed by SEL using a secure hash algorithm. The signature ensures that the file has been provided by SEL and that its contents have not been altered. Once uploaded to the relay, the signature of the firmware is verified with a public key number that is stored on the relay. If the relay cannot verify the signature, it rejects the file.

The name of the digitally signed firmware file is of the form R*xxx*351.zds, where R*xxx* is the firmware revision number, 351 indicates the relay type, and .zds is the file extension reserved for digitally signed files. Firmware files with the .s19 extension are not available for firmware version R511 and higher.

NOTE: Relays with SELBOOT (BFID) version R200 or later only support firmware versions with .zds extensions. Firmware versions with .s19 extensions are not supported.

If you are upgrading a relay from relay firmware version R510 or earlier, follow the *Special Instructions for Upgrading from Firmware Version R510 or Earlier* on page B.2. Otherwise, continue with *Relay Firmware Upgrade Methods* on page B.3.

Special Instructions for Upgrading from Firmware Version R510 or Earlier

The SELBOOT firmware loader in relays shipped with firmware R510 and earlier must be upgraded before digitally signed firmware files can be used. The process for upgrading SELBOOT is similar to Firmware Upgrade Method Two.

To determine if SELBOOT must be updated, do the following:

Step 1. Establish communication between the relay and a personal computer, as described in *C. Establish Communications With the Relay* on page B.10.

NOTE: The CID file may be cleared when upgrading from firmware version R510 or earlier to firmware version R511 or later. Make sure to make a backup copy of the CID file before upgrading firmware.

Step 2. From the computer, type **ID <Enter>**.

The relay responds with the following:

```
"FID=SEL-351-x-Rxxx-V0-Zxxxxxx-Dxxxxxxxx","xxxx"
"BFID=SLBT-3CF1-R102-V0-Zxxxxxx-Dxxxxxxx","xxxxx"
"CID=xxx","xxxx"
"DEVID=xxxxxxx","xxxx"
"DEVCODE=xx","xxxx"
"PARTNO=xxxxxxxxxxxxxxx","xxxx"
"SERIALNO=xxxxxxxxxx","xxxx"
"CONFIG=xxxxxxxx","xxxx"
"SPECIAL=xxxxx","xxxx"
```

Step 3. Locate the Boot Firmware Identification String (BFID).

Step 4. Find the SELBOOT revision number in the BFID (R*xxx*). If the revision number is R102 or earlier, the SELBOOT must be upgraded. If the revision number is R200 or later, follow the instructions under *Relay Firmware Upgrade Methods* on page B.3.

NOTE: If the SELBOOT revision number is R100 or R101, it might be necessary to cycle relay power following the SELBOOT upgrade.

Step 5. To upgrade SELBOOT, contact SEL customer service for the SELBOOT file (R*xxx*3cfl.s19). Follow the instructions under *Method Two: Using a Terminal Emulator* on page B.9. At *G. Upload New Firmware* on page B.17, *Step 1*, replace the **REC** command with **REC BOOT**, and follow the prompts.

Step 6. When the relay prompts:

```
Press any key to begin transfer and then start transfer at the terminal.
```

press **<Enter>** and use *Step 4* on page B.18 to select the SELBOOT file.

Step 7. When the SELBOOT upgrade is successful, the relay prompts:

```
Erasing SELboot.
Writing SELboot.
SELboot upload completed successfully.
Restarting SELboot.
!>
```

Step 8. Type **EXI <Enter>** at the SELBOOT !> prompt to exit SELBOOT. The relay should display the = prompt.

Step 9. If the relay does not return to the SELBOOT !> prompt within two minutes after displaying `Restarting SELboot`, cycle the relay power. The relay should restart and display the = prompt.

Once the SELBOOT upgrade is complete, select a firmware upgrade method as discussed in *Relay Firmware Upgrade Methods* on page B.3. To use Method One, go to *D. Prepare the Relay (Save Relay Settings and Other Data)* on page B.5. To use Method Two, go to *E. Start SELBOOT* on page B.16. It is not necessary to save the relay settings and other data again if you did this before upgrading SELBOOT.

Relay Firmware Upgrade Methods

Introduction

These firmware upgrade instructions apply to SEL-351 relays with at least one Ethernet port.

SEL occasionally offers firmware upgrades to improve the performance of your relay. Changing physical components is unnecessary because the relay stores firmware in Flash memory.

A firmware loader program called SELBOOT resides in the relay. To upgrade firmware, use the SELBOOT program to download an SEL-supplied file from a personal computer to the relay via the USB port or a serial port.

NOTE: SEL strongly recommends that you upgrade firmware at the location of the relay and with a direct connection from the personal computer to the USB port or one of the relay serial ports. Do not load firmware from a remote location; problems can arise that you will not be able to address from a distance. When upgrading at the substation, do not attempt to load the firmware into the relay through an SEL communications processor.

The firmware upgrade can be performed in one of three ways:

- ➤ Method One: Use the Firmware Loader provided within ACSELERATOR QuickSet SEL-5030 Software. The Firmware Loader automates the firmware upgrade process and is the preferred method.
- ➤ Method Two: Connect to the relay in a terminal session and upgrade the firmware by using the steps documented in *Method Two: Using a Terminal Emulator* on page B.9.
- ➤ Method Three: Establish an Ethernet connection and use a web browser to access the embedded Web Server. Upgrade the firmware by using the steps documented in *Method Three: Using a Web Browser* on page B.21. This is the fastest method to complete an upgrade.

The same basic actions are required when using any of these methods:

A. Obtain Firmware File

B. Remove Relay From Service

C. Establish Communications With the Relay

D. Prepare the Relay (Save Relay Settings and Other Data)

E. Start SELBOOT

F. Maximize Port Baud Rate (EIA-232 ports only)

G. Upload New Firmware

H. Check Relay Self-Tests

I. Verify Relay Settings

J. Return Relay to Service

Required Equipment

Gather the following equipment before starting this firmware upgrade:

- ➤ Personal computer
- ➤ To use Method One, QuickSet

- To use Method Two, terminal emulation software that supports 1K Xmodem or Xmodem (these instructions use HyperTerminal from a Microsoft Windows operating system)
- To use Method Three, a CAT5 Ethernet cable with RJ45 connectors, such as SEL cable SEL-C627, can be used. See *Establishing Communications Using an Ethernet Port and Telnet or the Read-Only Web Server* on page 10.6 for detailed instructions.
- Serial communications cable (SEL Cable SEL-C234A, SEL-C662 USB-to-232 converter, or equivalent) or USB cable (SEL-C664 or equivalent)
- Firmware Upgrade Instructions (these instructions)
- Your relay instruction manual

Method One: Using QuickSet Firmware Loader

To use the QuickSet Firmware Loader, you must have QuickSet. See *Appendix C: PC Software* for instructions on how to obtain and install the software. Once the software is installed, perform the firmware upgrade as follows.

A. Obtain Firmware File

To obtain the latest available firmware version, contact SEL customer service. The file name is of the form R*xxx*351.zds, where R*xxx* is the firmware revision number, 351 indicates the relay type, and .zds is the firmware file extension. Copy the firmware file to an easily accessible location on the PC.

NOTE: Firmware versions R510 and earlier revisions have the .s19 file extension.

Firmware is designed to be used with specific relays. A list of relay serial numbers is provided as part of the firmware upgrade package. The firmware provided is for use with the listed relays only. Attempts to upgrade relays not listed might not be successful and can result in relay failure.

B. Remove Relay From Service

Step 1. If the relay is in use, follow your company practices for removing a relay from service. Typically, these include changing settings, or disconnecting external voltage sources or output contact wiring, to disable relay control functions.

Step 2. Apply power to the relay.

Step 3. Connect a communications cable and determine the port speed.

If using the EIA-232 front port to upgrade firmware, determine the port speed as follows:

a. From the relay front panel, press the **SET** pushbutton.

b. Use the arrow pushbuttons to navigate to **PORT**.

c. Press the **SELECT** pushbutton.

d. Use the arrow pushbuttons to navigate to the relay serial port you plan to use (usually the front port).

e. Press the **SELECT** pushbutton.

f. With **SHO** selected, press the **SELECT** pushbutton.

g. Press the down arrow pushbutton to scroll through the port settings; write down the value for each setting.

NOTE: When using the Firmware Loader for upgrading from firmware version R504 or an earlier (lower numbered) version, the relay USB port should not be used. Use one of the available EIA-232 ports instead.

h. Connect an SEL-C234A EIA-232 serial cable, SEL-C662 USB-to-232 converter, or equivalent communications cable to the relay serial port and to the PC.

If using the relay front-panel USB port to upgrade firmware, connect an SEL-C664 cable between the relay and the PC. The USB port appears as a serial connection.

C. Establish Communications With the Relay

NOTE: If upgrading from firmware version R504 or an earlier (lower numbered) version, ensure all serial ports are enabled (EPORT = Y) before continuing with the firmware upgrade procedure. Enable ports as necessary by issuing **SET P n**, where n = 2, 3, F, (and 1 on relays equipped with the optional Port 1) and setting EPORT = Y. You can also use the front-panel **SET** pushbutton as described in *Step 3* on page B.4.

Use the **Communications > Parameters** menu of QuickSet to establish a connection using the communications settings determined in *Step 3* of *B. Remove Relay From Service*. For the USB port, the baud rate does not matter. See *Appendix C: PC Software* for additional information.

D. Prepare the Relay (Save Relay Settings and Other Data)

It is possible for data to be lost during the firmware upgrade process. Follow the steps in this section carefully to ensure that important data are saved.

Step 1. Select **Tools > Firmware Loader** and follow the on-screen prompts.

Step 2. In the Step 1 of 4 window of the Firmware Loader, click the ellipsis button and browse to the location of the firmware file. Select the file and click **Open**. See *Figure B.1*.

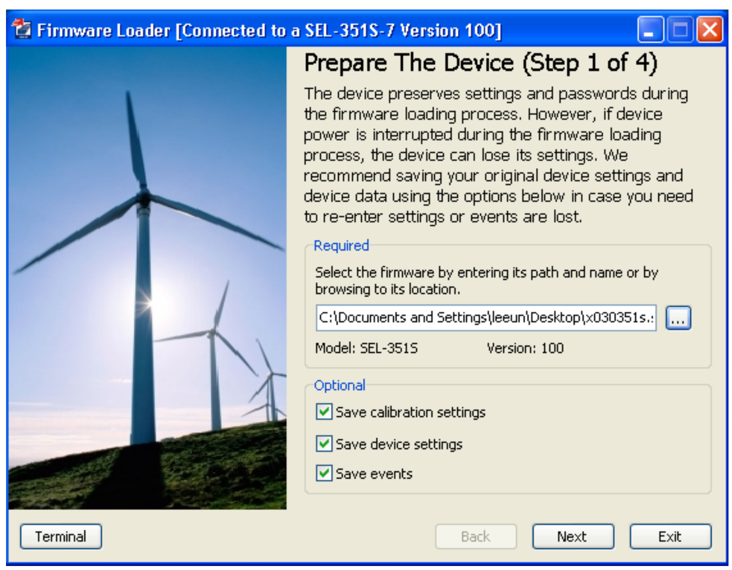

Figure B.1 Prepare the Device (Step 1 of 4)

Step 3. Check the **Save calibration settings** box in the Step 1 of 4 window of the Firmware Loader. These factory settings are required for proper operation of the relay and must be reentered in the unlikely event they are erased during the firmware upgrade process. The Firmware Loader saves the settings in a text file on the PC.

Step 4. Check the **Save device settings** box if you do not have a copy of the relay settings. It is possible for relay settings to be lost during the upgrade process.

Step 5. Check the **Save events** box if there are any event reports that have not been previously saved. It is possible for event reports to be lost during the upgrade process.

Step 6. Click **Next**.

The Firmware Loader reads the calibration settings and saves them in a text file on the PC. Make note of the file name and the location.

If **Save device settings** was selected, the Firmware Loader reads all of the settings from the relay. The software may ask if you want to merge the settings read from the relay with existing design templates on the PC. Click **No, do not merge settings with Design Template**. The Firmware Loader will suggest a name for the settings, but the suggested name can be modified as desired.

If **Save events** was selected, the Event History window will open to allow the events to be saved.

Step 7. If you use the Breaker Wear Monitor, click the **Terminal** button in the lower left portion of the Firmware Loader to open the terminal window. From the Access Level 1 prompt, issue the **BRE** command and record the internal and external trip counters, internal and external trip currents for each phase, and breaker wear percentages for each phase.

Step 8. Enable Terminal Logging capture and issue the following commands to save stored data. It is possible for these data to be lost during the firmware upgrade process. (Some of these features are not available on all relay models.)

a. **MET E**—accumulated energy metering

b. **MET D**—demand and peak demand

c. **MET M**—maximum/minimum metering

d. **COMM A** and **COMM B**—MIRRORED BITS® communications logs

e. **LDP**—Load Profile

f. **SSI**—Voltage sag, swell, interrupt recorder

g. **SER**—Sequential Events Report

E. Start SELBOOT

In the Step 2 of 4 window of the Firmware Loader, click **Next** to disable the relay and enter SELBOOT. See *Figure B.2*.

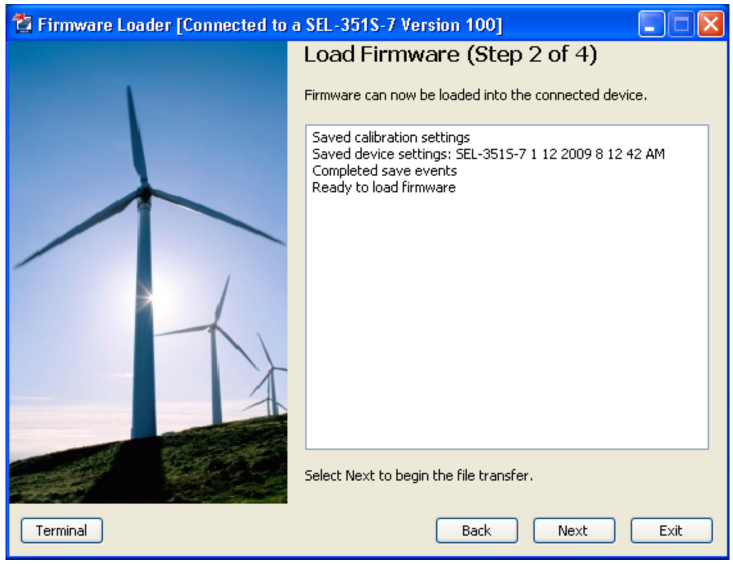

Figure B.2 Load Firmware (Step 2 of 4)

F. Maximize Port Baud Rate

This step is performed automatically by the software.

G. Upload New Firmware

This step is performed automatically by the software. The software will erase the existing firmware and start the file transfer to upload the new firmware. Upload progress will be shown in the **Transfer Status** window.

When the firmware upload is complete, the relay will restart. The Firmware Loader automatically reestablishes communications and issues an **STA** command to the relay.

In cases where the relay does not restart within two minutes of the firmware upload completion (as indicated by the PC application), and no error messages appear on the relay HMI, cycle power to the relay. The firmware loader application should then resume. Answer **Yes** if the Firmware Loader prompts you to continue.

H. Check Relay Self-Tests

The Step 3 of 4 window of the Firmware Loader will indicate that it is checking the device status and when the check is complete (see *Figure B.3*). The software will notify you if any problems are detected. You can view the relay status by opening the terminal using the Terminal button in the lower left portion of the Firmware Loader. If status failures are shown, open the terminal and see *Solving Firmware Upgrade Issues* on page B.25.

Click **Next** to go to the completion step.

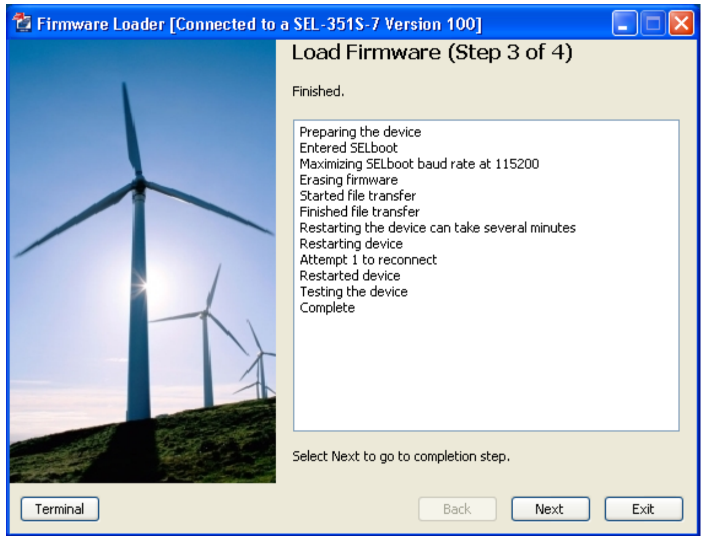

Figure B.3 Load Firmware (Step 3 of 4)

I. Verify Relay Settings

If there are no failures, the relay will enable. In the Step 4 of 4 window (see *Figure B.4*), the Firmware Loader will give you the option to compare the device settings. If any differences are found, the software will provide the opportunity to restore the settings.

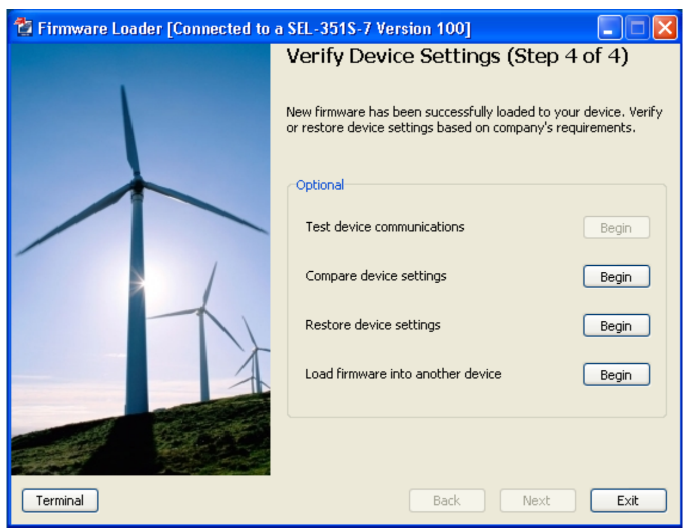

Figure B.4 Verify Device Settings (Step 4 of 4)

J. Return Relay to Service

Step 1. Open the terminal window using the **Terminal** button in the lower left portion of the Firmware Loader.

Step 2. Use the **ACC** command with the associated password to enter Access Level 1.

Step 3. Issue the **ID** command and compare the firmware revision (R*xxx*) displayed in the FID string against the number from the firmware envelope label. If the numbers match, proceed to *Step 5*.

Step 4. For a mismatch between a displayed FID and the firmware envelope label, reattempt the upgrade or contact SEL for assistance.

Step 5. If you use the Breaker Wear Monitor, type **BRE <Enter>** to check the data to see if the relay retained breaker wear data through the upgrade procedure. If the relay did not retain these data, use the **BRE W** command to reload the percent contact wear values recorded in *D. Prepare the Relay (Save Relay Settings and Other Data)* on page B.5.

Step 6. Apply current and voltage signals to the relay.

Step 7. Type **MET <Enter>** or use the QuickSet HMI to verify that the current and voltage signals are correct.

Step 8. Use the **TRI** and **EVE/CEV** commands or **Tools > Events > Get Events** menu in QuickSet to verify that the magnitudes of the current and voltage signals you applied to the relay match those displayed in the event report. If these values do not match, check the relay settings and wiring.

Step 9. Autoconfigure the SEL communications processor port if you have an SEL communications processor connected to the relay. This step reestablishes automatic data collection between the SEL communications processor and the relay. Failure to perform this step can result in automatic data collection failure when cycling communications processor power.

Step 10. Follow your company procedures for returning a relay to service.

Method Two: Using a Terminal Emulator

The instructions for this section use HyperTerminal as a terminal emulator. If HyperTerminal is not used, certain instructions may have to be modified (different menu names used) to execute the step.

A. Obtain Firmware File

NOTE: Firmware versions R510 and earlier revisions have the .s19 file extension.

NOTE: These instructions can also be used to upgrade the SELBOOT firmware loader. See *Upgrading to Digitally Signed Firmware Files* on page B.1 to determine if this is necessary.

To obtain the latest available firmware version, contact SEL customer service. The file name will be of the form R*xxx*351.zds, where R*xxx* is the firmware revision number, 351 indicates the relay type, and .zds is the standard firmware file extension. Copy the firmware file to an easily accessible location on the PC.

Firmware is designed to be used with specific relays. A list of relay serial numbers is provided as part of the firmware upgrade package. The firmware provided is for use with the listed relays only. Attempts to upgrade relays not listed might not be successful and can result in relay failure.

B. Remove Relay From Service

Step 1. If the relay is in use, follow your company practices for removing a relay from service. Typically, these include changing settings, or disconnecting external voltage sources or output contact wiring, to disable relay control functions.

Step 2. Apply power to the relay.

Step 3. Connect a communications cable and determine the port speed.

If using the EIA-232 front port to upgrade firmware, determine the port speed as follows:

a. From the relay front panel, press the **SET** pushbutton.

b. Use the arrow pushbuttons to navigate to PORT.

c. Press the **SELECT** pushbutton.

d. Use the arrow pushbuttons to navigate to the relay serial port you plan to use (usually the front port).

e. Press the **SELECT** pushbutton.

f. With SHO selected, press the **SELECT** pushbutton.

g. Press the down pushbutton to scroll through the port settings; write down the value for each setting.

h. Connect an SEL-C234A EIA-232 serial cable, SEL-C662 USB-to-232 converter, or equivalent communications cable to the relay serial port and to the PC.

If using the relay front-panel USB port to upgrade firmware, connect an SEL-C664 cable between the relay and the PC. The USB port appears as a serial connection.

C. Establish Communications With the Relay

To establish communication between the relay and a personal computer, you must be able to modify the computer serial communications parameters (i.e., data transmission rate, data bits, parity) and set the file transfer protocol to 1K Xmodem or Xmodem protocol.

Step 1. From the computer, open HyperTerminal or other terminal emulation software.

On a personal computer running Windows, you would typically click **Start > Programs > Accessories > Communications**.

NOTE: The terminal window of QuickSet can be used to upgrade firmware.

Step 2. Enter a name, select any icon, and click **OK** (*Figure B.5*).

Figure B.5 Establishing a Connection

Step 3. Select the computer serial port you are using to communicate with the relay (*Figure B.7*) and click **OK**.

If using the relay front-panel USB port, a port driver must be installed on the PC. See *Establishing Communications Using the USB Port* on page 10.2. To see what virtual COM port has been created, launch any communications program that allows selection of a COM port and view all available ports, or go to the Windows Device Manager and inspect the available COM ports as shown in *Figure B.6*. Use Device Manager to verify which virtual COM port is associated with a particular physical USB port. Device Manager updates the available COM ports each time a cable is inserted or removed.

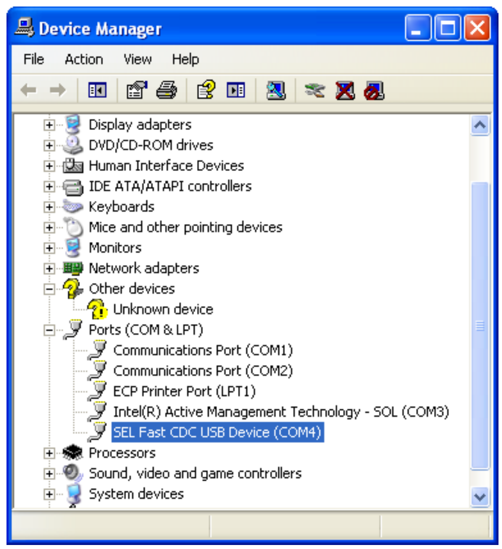

Figure B.6 Inspect Available COM Ports

Figure B.7 Determining the Computer Serial Port

Step 4. Establish serial port communications parameters.

If using the EIA-232 front port to upgrade firmware, the settings for the computer (*Figure B.8*) must match the relay settings you recorded earlier.

a. Enter the serial port communications parameters (*Figure B.8*) that correspond to the relay settings you recorded in *B. Remove Relay From Service* on page B.9.

b. Click **OK**.

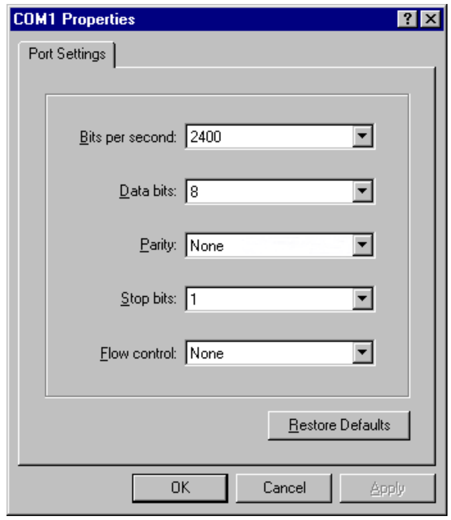

Figure B.8 Determining Communications Parameters for the Computer

If using the relay front-panel USB port, the relay will accept any baud rate. SEL suggests the use of the following parameters:

- ➢ Bits per second: 57600
- ➢ Data bits: 8
- ➢ Parity: None
- ➢ Stop bits: 1
- ➢ Flow control: XON/OFF

Step 5. Set the terminal emulation to VT100:

a. From the **File** menu, choose **Properties**.

b. Select the **Settings** tab in the **Properties** dialog box (*Figure B.9*).

c. Select **VT100** from the **Emulation** list box and click **OK**.

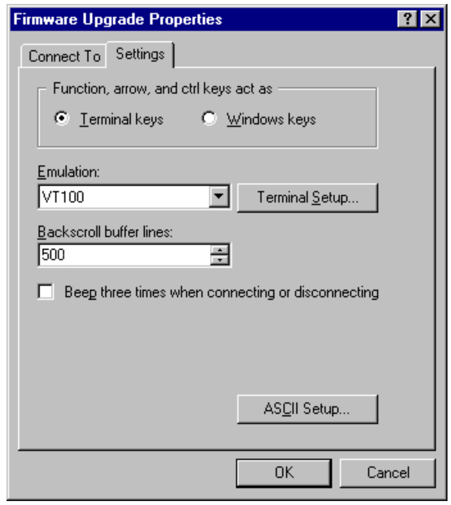

Figure B.9 Setting Terminal Emulation

Step 6. Confirm serial communication.

Press **<Enter>**. In the terminal emulation window, you should see the Access Level 0 = prompt, similar to that in *Figure B.10*.

If this is successful, proceed to *D. Prepare the Relay (Save Relay Settings and Other Data)* on page B.15.

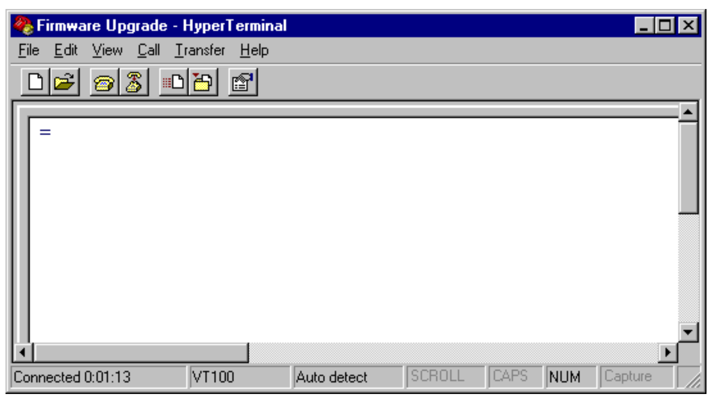

Figure B.10 Terminal Emulation Startup Prompt

Failure to Connect

If you do not see the Access Level 0 = prompt, press **<Enter>** again. If you still do not see the Access Level 0 = prompt, you have either selected the incorrect serial communications port on the computer, or the computer speed setting does not match the data transmission rate of the relay. Perform the following steps to reattempt a connection:

Step 7. From the **Call** menu, choose **Disconnect** to terminate communication.

Step 8. Correct the port setting:

a. From the **File** menu, choose **Properties**.

You should see a dialog box similar to *Figure B.11*.

b. Select a different port in the **Connect using** list box.

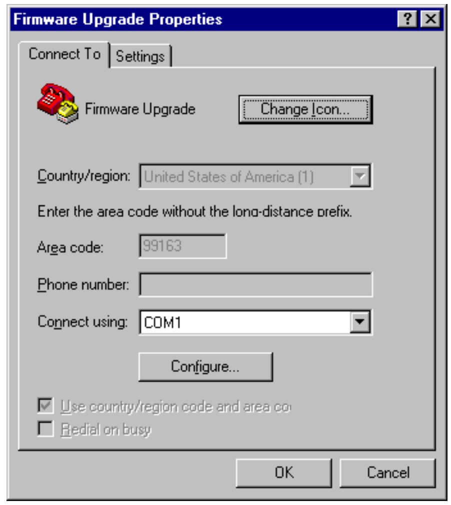

Figure B.11 Correcting the Port Setting

Step 9. Correct the communications parameters:

a. From the filename **Properties** dialog box shown in *Figure B.11*, click **Configure**.

You will see a dialog box similar to *Figure B.12*.

b. Change the settings in the appropriate list boxes to match the settings you recorded in *B. Remove Relay From Service* on page B.9 and click **OK** twice to return to the terminal emulation window.

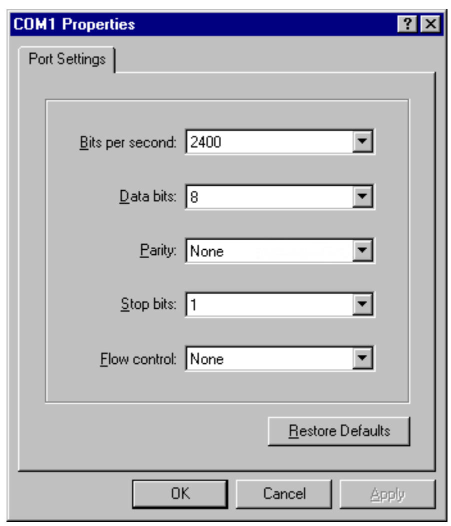

Figure B.12 Correcting the Communications Parameters

Step 10. Press **<Enter>**. In the terminal emulation window, you should see the Access Level 0 = prompt, similar to that in *Figure B.10*.

If using the relay front-panel USB port, see *Troubleshooting Procedure* on page 13.10 for additional troubleshooting tips.

D. Prepare the Relay (Save Relay Settings and Other Data)

It is possible for data to be lost during the firmware upgrade process. Follow the steps in this section carefully to ensure that important data are saved.

Before upgrading firmware, retrieve and record any History (**HIS**) or Event (**EVE**) data that you want to retain (see *Section 10: Communications* for an explanation of the commands). During this process, you may find it helpful to use the Capture Text feature of HyperTerminal, which is available in the **Transfer** menu. See additional instructions for using Capture Text in *Backup Relay Settings and Other Data* on page B.15.

Enter Access Level 2

NOTE: If the relay does not prompt you for Access Level 1 and Access Level 2 passwords, check whether the relay Access jumper is in place. With this jumper in place, the relay is unprotected from unauthorized access (see *Section 2: Installation*).

Step 1. Type **ACC <Enter>** at the Access Level 0 = prompt.

Step 2. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 3. Type **2AC <Enter>**.

Step 4. Type the Access Level 2 password and press **<Enter>**.

You will see the Access Level 2 =>> prompt.

Backup Relay Settings and Other Data

The relay preserves settings and passwords during the firmware upgrade process. However, interruption of relay power during the upgrade process can cause the relay to lose settings. Make a copy of the original relay settings in case you need to reenter the settings. Use either the SEL-5010 Relay Assistant software or QuickSet to record the existing relay settings and proceed to *E. Start SELBOOT* on page B.16. Otherwise, perform the following steps:

Step 1. From the **Transfer** menu in **HyperTerminal**, select **Capture Text**.

Step 2. Enter a directory and filename for a text file where you will record the existing relay settings.

Step 3. Click **Start**.

The **Capture Text** command copies all the information you retrieve and all the keystrokes you type until you send the command to stop capturing text. The terminal emulation program stores these data in the text file.

Step 4. Execute the Show Calibration (**SHO C**) command to retrieve the relay calibration settings.

Use the following Show commands to retrieve the relay settings: **SHO G**, **SHO 1**, **SHO L 1**, **SHO 2**, **SHO L 2**, **SHO 3**, **SHO L 3**, **SHO 4**, **SHO L 4**, **SHO 5**, **SHO L 5**, **SHO 6**, **SHO L 6**, **SHO P 1**, **SHO P 2**, **SHO P 3**, **SHO P F**, **SHO R**, **SHO T**, **SHO D 1**, **SHO D 2**, **SHO D 3**, and **SHO M**.

Step 5. Issue the following commands to save stored data. It is possible for these data to be lost during the firmware upgrade process. (Some of these features are not available on all relay models.)

a. **MET E**—accumulated energy metering

b. **MET D—**demand and peak demand

c. **MET M**—maximum/minimum metering

d. **COMM A** and **COMM B**—MIRRORED BITS communications logs

e. **LDP**—Load Profile

f. **SSI**—Voltage sag, swell, interrupt recorder

g. **SER**—Sequential Events Report

h. **BRE**—Breaker Wear Monitor data

Step 6. From the **Transfer** menu in **HyperTerminal**, select **Capture Text** and click **Stop**.

NOTE: If upgrading an SEL-351 from firmware version R504 or an earlier (lower-numbered) version, ensure all serial ports are enabled (EPORT = Y) before continuing with the firmware upgrade procedure. Enable ports as necessary by issuing **SET P n**, where n = 2, 3, F, (and 1 on relays equipped with the optional Port 1) and setting EPORT = Y.

Step 7. The computer saves the text file you created to the directory you specified in *Step 2*.

Step 8. Write down the present relay data transmission setting (SPEED) for the port to be used for the firmware upgrade.

The SPEED setting is included in the **SHO P** relay settings output. The SPEED value should be the same as the value you recorded in *B. Remove Relay From Service* on page B.9.

E. Start SELBOOT

Step 1. From the computer, start the SELBOOT program:

a. From the Access Level 2 =>> prompt, type **L_D <Enter>**.

The relay responds with the following:

```
Disable relay to send or receive firmware
(Y/N)?
```

b. Type **Y <Enter>**.

The relay responds with the following:

```
Are you sure (Y/N)?
```

c. Type **Y <Enter>**.

The relay responds with the following:

```
Relay Disabled
```

Step 2. Wait for the SELBOOT program to load.

The front-panel LCD screen displays `SELboot`. The computer displays the SELBOOT `!>` prompt after SELBOOT loads.

Step 3. Press **<Enter>** to confirm that the relay is in SELBOOT.

You will see another SELBOOT `!>` prompt.

Commands Available in SELBOOT

For a listing of commands available in SELBOOT, type **HELP <Enter>**. You should see a screen similar to *Figure B.13*.

```
!>HELP <Enter>
BFID=SLBT-3CF1-R100-V0-Z100100-D20081222
USBID=FID string not found.


Baud             - Set to a standard baud rate from 300 to 115200 bps.
Erase            - Erase the existing firmware.
Exit             - Exit this program and restart the device.
FID              - Display the firmware identification (FID).
Receive [BOOT]   - Receive new firmware for the device using Xmodem.
Help             - Print this help list.

Program Memory Size: 01000000
Firmware Checksum = 1935  OK
```

Figure B.13 List of Commands Available in SELBOOT

F. Maximize Port Baud Rate for EIA-232 Ports

Step 1. Type **BAU 115200 <Enter>** at the SELBOOT !> prompt.

Step 2. From the **Call** menu, choose **Disconnect** to terminate communication.

Step 3. Correct the communications parameters:

> **NOTE:** The USB port speed is fixed. If you are using the USB port for the firmware upgrade, continue to *G. Upload New Firmware* on page B.17.

a. From the **File** menu, choose **Properties**.

b. Choose **Configure**.

c. Change the computer communications speed to match the new data transmission rate in the relay (*Figure B.14*).

d. Click **OK** twice.

Step 4. Press **<Enter>** to check for the SELBOOT !> prompt indicating that serial communication is successful.

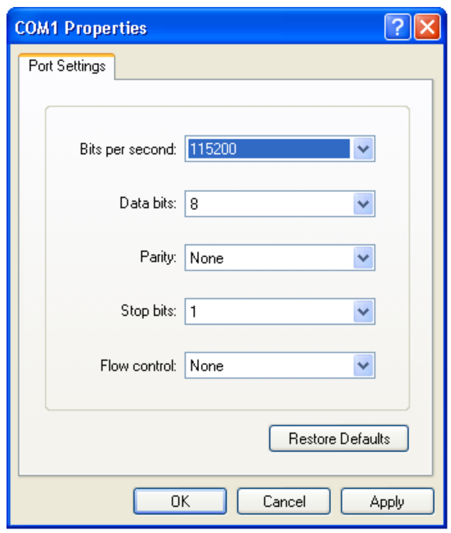

Figure B.14 Matching Computer to Relay Parameters

G. Upload New Firmware

Step 1. Type **REC <Enter>** at the SELBOOT !> prompt to command the relay to receive new firmware.

```
!>REC <Enter>

Caution! This command erases the firmware.

If you erase the firmware then new firmware
must be loaded before returning the IED to service.
Are you sure you want to erase the existing firmware (Y/N)?
```

> **NOTE:** When upgrading SELBOOT, type **REC BOOT <Enter>** at the SELBOOT !> prompt in *Step 1* to command the relay to receive new SELBOOT firmware.

The relay asks whether you want to erase the existing firmware.

```
Are you sure you wish to erase the existing firmware? (Y/N) Y
```

Step 2. Type **Y** to erase the existing firmware and load new firmware.

The relay responds with the following:

```
Erasing firmware.

Erase successful
Press any key to begin transfer then start transfer at the terminal <Enter>
```

Step 3. Press **<Enter>** to start the file transfer routine.

NOTE: If you are using the QuickSet terminal window to upgrade firmware, right-click in the terminal window, select **Send File**, **Xmodem**, and browse to select the new firmware file.

Step 4. Send new firmware to the relay.

a. From the **Transfer** menu in HyperTerminal, choose **Send File** (*Figure B.15*).

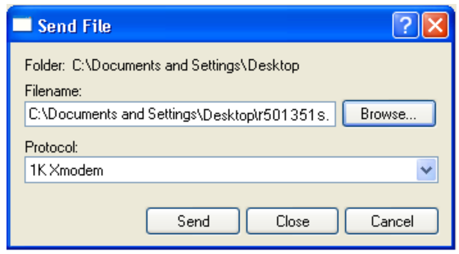

Figure B.15 Selecting New Firmware to Send to the Relay

NOTE: When upgrading SELBOOT, select the SELBOOT filename in *Step b*.

b. In the **Filename** text box, type the location and filename of the new firmware or use the **Browse** button to select the firmware file.

c. In the **Protocol** text box, select **1K Xmodem** if this protocol is available.

If the computer does not have **1K Xmodem**, select **Xmodem**.

d. Click **Send** to send the file containing the new firmware.

NOTE: The relay restarts in SELBOOT if relay power fails while receiving new firmware. Upon power-up, the relay serial port will be at the default 9600 baud. Perform the steps beginning in *C. Establish Communications With the Relay* on page B.10 to increase the serial connection data speed. Then resume the firmware upgrade process at *G. Upload New Firmware* on page B.17.

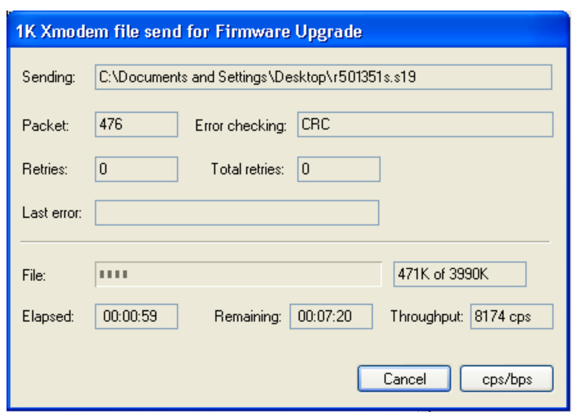

Figure B.16 Transferring New Firmware to the Relay

You should see a dialog box similar to *Figure B.16*. Incrementing numbers in the **Packet** box and a bar advancing from left to right in the **File** box indicate that a transfer is in progress.

If you see no indication of a transfer in progress within a few minutes after clicking **Send**, use the **REC** command again and reattempt the transfer.

Step 5. Wait for the transfer to be completed.

a. If you are using an EIA-232 port, the relay displays the following:

```
Upload completed successfully. Attempting a restart.
```

b. If you are using the front-panel USB port, the relay displays the following after the transfer is completed:

```
Upload completed successfully. Press any key to restart.
```

After a key is pressed, the relay displays:

NOTE: Unsuccessful uploads can result from Xmodem time-out, a power failure, loss of communication between the relay and the computer, or voluntary cancelation. Check connections, reestablish communication, and start again at *Step 1* on page B.17.

```
Close the USB port and remove the USB cable.
Attempting a restart in 5 seconds.
```

From the **Call** menu of HyperTerminal, choose **Disconnect** and remove the USB cable from the front of the relay.

Step 6. Wait for relay to restart.

A successful restart sequence can take as long as two minutes, after which time the relay leaves SELBOOT. You will see no display on your PC to indicate a successful restart. A successful restart is indicated when the **ENABLED** LED illuminates. This LED is labeled either **EN** or **ENABLED**, depending on the relay model.

In cases where the relay does not restart within two minutes of the firmware upload completion (as indicated by the PC terminal emulator), and no error messages appear on the relay HMI, cycle power to the relay. Re-establish your connection in HyperTerminal, and then continue with *Step 7*.

In some cases, the **ENABLED** LED might not illuminate, and a `FAIL` message will be displayed on the relay LCD screen, if equipped.

Step 7. Press **<Enter>** and confirm that the Access Level 0 = prompt appears on the computer screen.

If you are using the relay front-panel USB port, you will need to reestablish the connection.

a. Reinstall the cable.

b. From the **Call** menu of Hyperterminal, choose **Call** and press **<Enter>** several times, until you see the Access Level 0 = prompt.

Step 8. If you see the Access Level 0 = prompt, proceed to *H. Check Relay Self-Tests* on page B.20.

No Access Level 0 = Prompt

If no Access Level 0 = prompt appears in the terminal emulation window, one of several things could have occurred. Refer to *Table B.1* to determine the best solution:

Table B.1 Troubleshooting New Firmware Upload

Problemth	Solution
The restart was successful, but the relay data transmission rate reverted to the rate at which the relay was operating prior to entering SELBOOT (the rate you recorded in *B. Remove Relay From Service* on page B.9).	Change the computer terminal speed to match the relay data transmission rate you recorded in *B. Remove Relay From Service* on page B.9. Step 1. From the **Call** menu, choose **Disconnect** to terminate relay communication. Step 2. Change the communications software settings to the values you recorded in *B. Remove Relay From Service* on page B.9. Step 3. From the **Call** menu, choose **Call** to reestablish communication. Step 4. Press **<Enter>** to check for the Access Level 0 = prompt indicating that serial communication is successful.
The restart was successful, but the relay data transmission rate reverted to 9600 bps (the settings have been reset to default).	Match the computer terminal speed to a relay data transmission rate of 9600 bps. Step 1. From the **Call** menu, choose **Disconnect** to terminate relay communication. Step 2. Change the communications software settings to 9600 bps, 8 data bits, no parity, and 1 stop bit (see *F. Maximize Port Baud Rate for EIA-232 Ports* on page B.17). Step 3. From the **Call** menu, choose **Call** to reestablish communication. Step 4. Press **<Enter>** to check for the Access Level 0 = prompt indicating successful serial communication.
The restart was unsuccessful, in which case the relay is in SELBOOT, indicated by a SELBOOT !> prompt.	If you see a SELBOOT !> prompt, type **EXI <Enter>** to exit SELBOOT. Check for the Access Level 0 = prompt. If you see the Access Level 0 = prompt, proceed to *H. Check Relay Self-Tests* on page B.20. If the relay will not exit SELBOOT, reattempt to upload the new firmware (beginning at *Step 1* under *G. Upload New Firmware* on page B.17) or contact the factory for assistance.
Cannot communicate with relay via front-panel USB port.	From the **Call** menu of HyperTerminal, choose Disconnect and remove the USB cable from the front of the relay. Reinstall the cable and see *C. Establish Communications With the Relay* on page B.10. See *Troubleshooting Procedure* on page 13.10 for additional troubleshooting tips.

H. Check Relay Self-Tests

The relay can display various self-test fail status messages. The troubleshooting procedures that follow depend upon the status message the relay displays.

Step 1. Type **ACC <Enter>**.

Step 2. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 3. Enter the **STATUS** command (**STA <Enter>**) to view relay status messages.

If the relay displays no fail status message, proceed to *I. Verify Relay Settings* on page B.21.

If failures are displayed in the status message, proceed to *Solving Firmware Upgrade Issues* on page B.25.

I. Verify Relay Settings

Step 1. Use the **ACC** and **2AC** commands with the associated passwords to enter Access Level 2.

Step 2. Use the **SHO** command to view the relay settings and verify that these match the settings you saved earlier (see *Backup Relay Settings and Other Data* on page B.15).

If the settings do not match, reenter the settings you saved earlier.

J. Return the Relay to Service

Step 1. Open the terminal window.

Step 2. Use the **ACC** command with the associated password to enter Access Level 1.

Step 3. Issue the **ID** command and compare the firmware revision (R*xxx*) displayed in the FID string against the number from the firmware envelope label. If the numbers match, proceed to *Step 5*.

Step 4. For a mismatch between a displayed FID and the firmware envelope label, reattempt the upgrade or contact SEL for assistance.

Step 5. If you use the Breaker Wear Monitor, type **BRE <Enter>** to check the data and see if the relay retained breaker wear data through the upgrade procedure. If the relay did not retain these data, use the **BRE W** command to reload the percent contact wear values recorded in *D. Prepare the Relay (Save Relay Settings and Other Data)* on page B.5.

Step 6. Apply current and voltage signals to the relay.

Step 7. Type **MET <Enter>** to verify that the current and voltage signals are correct.

Step 8. Use the **TRI** and **EVE/CEV** commands to verify that the magnitudes of the current and voltage signals you applied to the relay match those displayed in the event report. If these values do not match, check the relay settings and wiring.

Step 9. Autoconfigure the SEL communications processor port if you have an SEL communications processor connected to the relay. This step reestablishes automatic data collection between the SEL communications processor and the relay. Failure to perform this step can result in automatic data collection failure when cycling communications processor power.

Step 10. Follow your company procedures for returning a relay to service.

Method Three: Using a Web Browser

A. Set Port 5 Setting HTTPACC to 2

To upgrade firmware by using the Web Browser, the Port 5 setting HTTPACC must be set to 2. If this setting is set to 2, the FWFPC setting becomes available. FWFPC determines whether front-panel confirmation is required for firmware upgrades and defaults to Y. If FWFPC is set to N, the firmware upgrade process takes place without the need for front-panel confirmation. See *F. Upload New Firmware* on page B.22 for details on the front-panel confirmation process.

B. Obtain Firmware File

Follow instructions under *A. Obtain Firmware File* on page B.4.

C. Remove Relay From Service

Step 1. If the relay is in use, follow your company practices for removing a relay from service. Typically, these include changing settings, or disconnecting external voltage sources or output contact wiring, to disable relay control functions.

Step 2. Apply power to the relay.

Step 3. Establish an Ethernet connection to the device. See *Section 10: Communications* for more detailed instructions.

D. Establish Communications With the Relay

Establish communication between your personal computer and the relay by using a web browser. See *Section 10: Communications* for more information. Establish a Telnet session with HyperTerminal (or an equivalent) using the TCP/IP connection, with the Host address and Port number set to match the Port 5 settings IPADDR (e.g., 192.168.1.2) and TPORT (e.g., 23), respectively.

E. Prepare the Relay (Save Relay Settings and Other Data)

Using the Telnet session, follow *D. Prepare the Relay (Save Relay Settings and Other Data)* on page B.15.

F. Upload New Firmware

Step 1. To upload new firmware, log in to Access Level 2 of the web server. Select **2AC** from the Access Level drop-down box. Enter the respective **ACC** and **2AC** passwords and click the **Login** button.

NOTE: Access Level passwords are not encrypted in any way by the Web Server when logging in.

Step 2. Once logged in verify communication with the correct relay by checking the Relay Identifier (RID setting) and Terminal Identifier (TID setting). Choose **System > Firmware Upgrade** from the left pane, which brings up the page shown in *Figure B.17*. This page also displays feedback from the previous firmware upgrades. If the prior firmware upgrade was successful, the page displays `Previous firmware upgrade successful. Date:  mm/dd/yy  Time: hh:mm:ss`. If the prior firmware upgrade failed, the page displays `Previous firmware upgrade failed. Date: mm/dd/yy Time: hh:mm:ss`, with an error message below. See *Solving Firmware Upgrade Issues* on page B.25 for possible error messages and their descriptions. If no prior firmware upgrade has occurred (which is the case for a new unit from the factory), the page displays the message shown in *Figure B.17*.

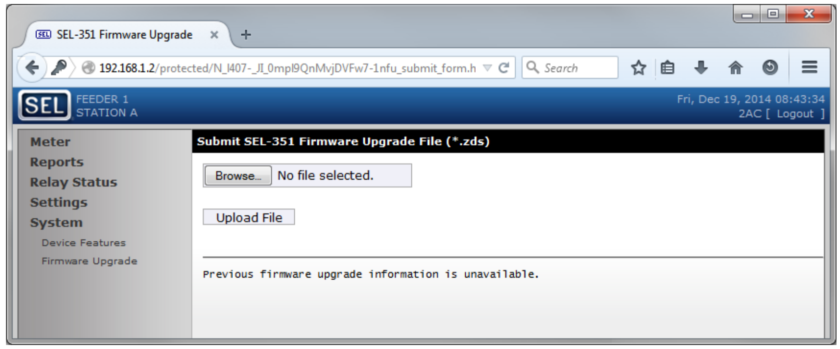

Figure B.17 Firmware Upload File Selection Page

Step 3. To search for your firmware file, click on the **Browse** button. The format of this file must be .zds.

Step 4. To submit, click **Upload File**. Once the upload has started, it cannot be canceled. During the upload process the relay remains enabled and continues normal operation.

Step 5. Once the firmware file is transferred to the device, the relay attempts to restart using the new firmware. This process completes in as few as 45 seconds.

Step 6. If front-panel confirmation is enabled (setting FWFPC = Y) and the file upload is complete, the Web Server displays the message shown in *Figure B.18* and the following message is displayed on the relay's LCD:

```
CONFIRM UPGRADE?
SELECT=Y; EXIT=N
```

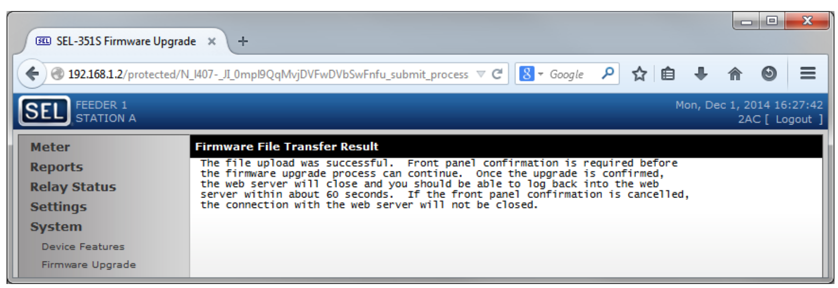

Figure B.18 Firmware Upgrade With Front-Panel Confirmation Required

a. Press the **SELECT** button to confirm the firmware upgrade. Once front-panel confirmation is given, the HTTP session closes and the firmware upgrade takes place.

b. If front-panel confirmation is not given within 60 seconds, the message shown in *Figure B.19* is displayed by the Web Server at the Firmware Upgrade page. The HTTP session remains open and the firmware upgrade does not take place.

c. The relay remains enabled and in normal operation until the upgrade is confirmed via the front panel. If confirmation times out, the relay stays enabled and continues normal operation.

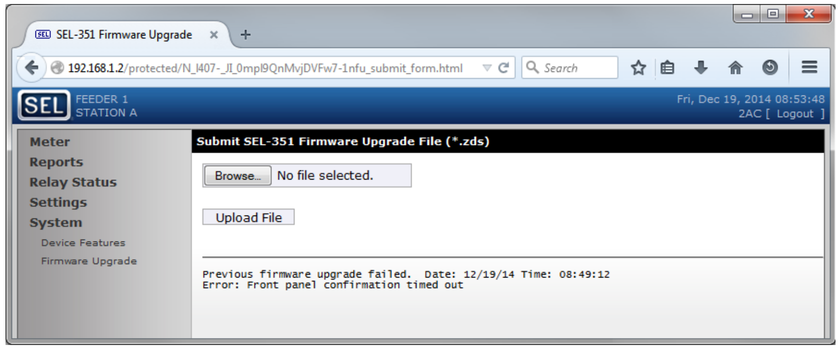

Figure B.19 Front-Panel Confirmation Time Out Message

Step 7. If front-panel confirmation is not enabled (FWFPC = N), the message shown in *Figure B.20* is displayed by the Web Server. The HTTP session closes after the upload is complete and the firmware upgrade takes place.

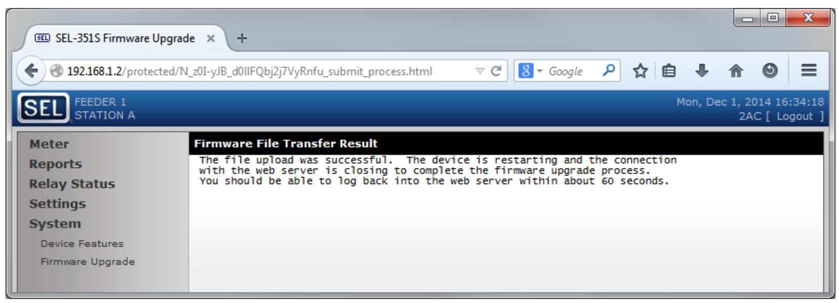

Figure B.20 Firmware Upgrade Without Front-Panel Confirmation Required

G. Check Relay Self-Tests

After the firmware upgrade is completed and once you have logged back into Access Level 1 of the Web Server, you can check the relay self-tests by clicking on **Relay Status > Self Tests** in the left pane. If the relay displays no fail status message, proceed to *I. Verify Relay Settings* on page B.21. If failures are displayed in the status message, proceed to *Solving Firmware Upgrade Issues* on page B.25.

H. Verify Relay Settings

To verify the settings are correct for your relay, choose **Show Settings** in the left pane. Verify that these match the settings saved earlier (see *Backup Relay Settings and Other Data* on page B.15). Note that Calibration settings are not viewable via the Web Server, a terminal connection is needed to verify these settings. If the settings do not match, reenter the settings saved earlier.

I. Return Relay to Service

Step 1. Begin a Telnet session by opening the terminal window. Type **telnet IPADDR**, where IPADDR is the Port 5 setting IPADDR (e.g., 192.168.1.2).

Step 2. Follow *Step 2* on page B.21–*Step 10* on page B.21 under *J. Return the Relay to Service* on page B.21.

Solving Firmware Upgrade Issues

⚠**CAUTION**
Step 6 will cause the loss of settings and other important data. Be sure to retain relay settings and other data downloaded from the relay at the start of the firmware upgrade process

If a `FAIL` message is returned in response to the **STA** command, perform the following steps.

Step 1. Use the **ACC** and **2AC** commands with the associated passwords to enter Access Level 2.

Step 2. Type **STA C <Enter>**. Answer **Y <Enter>** to the `Reboot the relay and clear status` prompt. The relay will respond with `Rebooting the relay`. Wait for about 30 seconds, then press **<Enter>** until you see the Access Level 0 = prompt.

Step 3. Use the **ACC** command with the associated password to enter Access Level 1.

Step 4. Type **STA <Enter>**.

If there are no fail messages and you are using Method One, click **Next** in Step 3 of 4 of the Firmware Loader and go to *I. Verify Relay Settings* on page B.8.

If there are no fail messages and you are using Method Two, go to *I. Verify Relay Settings* on page B.21.

If there are fail messages, continue with *Step 5*.

Step 5. Use the **2AC** command with the associated password to enter Access Level 2.

Step 6. Type **R_S <Enter>** to restore factory-default settings in the relay.

The relay asks whether to restore default settings. If the relay does not accept the **R_S** command, contact SEL for assistance.

Step 7. Type **Y <Enter>**.

The relay can take as long as two minutes to restore default settings. The relay then reinitializes, and the **ENABLED** LED illuminates. This LED is labeled either **EN** or **ENABLED**, depending on the relay model. Contact SEL for assistance if the relay does not enable.

Step 8. Press **<Enter>** to check for the Access Level 0 = prompt indicating that serial communication is successful.

Step 9. Use the **ACC** and **2AC** commands and type the corresponding passwords to reenter Access Level 2.

Step 10. Type **SHO C <Enter>** to verify the relay calibration settings.

If using Method One and the settings do not match the settings contained in the text file you recorded in *D. Prepare the Relay (Save Relay Settings and Other Data)* on page B.5, contact SEL for assistance.

If using Method Two and the settings do not match the settings contained in the text file you recorded in *D. Prepare the Relay (Save Relay Settings and Other Data)* on page B.15, contact SEL for assistance.

Step 11. Use the **PAS** command to set the relay passwords.

Step 12. Restore the relay settings:

a. If you have the SEL-5010 or QuickSet, restore the original settings by following the instructions for the respective software.

b. If you do not have the SEL-5010 or QuickSet, restore the original settings by issuing the necessary **SET *n*** commands.

Step 13. If any failure status messages still appear on the relay display, see *Section 13: Testing and Troubleshooting* or contact SEL for assistance.

If the firmware upgrade process fails, the firmware upgrade page of the web server displays one of the error messages in *Table B.2*.

Table B.2 Error Messages

Error Message	Description
Invalid digital signature	The digital signature verification failed.
Invalid firmware file	The firmware file failed one of many possible integrity checks.
Front-panel confirmation canceled	The user canceled the front-panel confirmation process.
Front-panel confirmation timed out	The user did not confirm or cancel the firmware upgrade process before the time-out period expired.

APPENDIX C

PC Software

Overview

NOTE: PC software is updated more frequently than relay firmware. As a result, the descriptions in this section may differ slightly from the software. Select **Help** in the PC software for information.

SEL provides many PC software solutions (applications) that support SEL devices. These software solutions are listed in *Table C.1*.

Visit selinc.com to obtain the latest versions of the software listed in *Table C.1*.

Table C.1 SEL Software Solutions

Product Name	Description
SEL Compass	This application provides an interface for web-based notification of product updates and automatic software updating.
ACSELERATOR QuickSet SEL-5030 Software	QuickSet is a powerful setting, event analysis, and measurement tool that aids in applying and using the relay. See the *ACSELERATOR QuickSet SEL-5030 Software Instruction Manual* for information about the various QuickSet applications.[a]
ACSELERATOR Architect SEL-5032 Software	Use this application to design and commission SEL IEDs in IEC 61850 substations, create and map GOOSE messages, utilize predefined reports, create and edit data sets, and read in SCD, ICD, and CID files.
ACSELERATOR TEAM SEL-5045 Software	The TEAM system provides custom data collection and movement of a wide variety of device information. The system provides tools for device communication, automatic collection of data, and creation of reports, warnings, and alarms. See *ACSELERATOR Team SEL-5045 Software Instruction Manual* for information about the various ACSELERATOR TEAM applications.
SEL-5601-2SYNCHROWAVE Event Software	Converts SEL Compressed ASCII and COMTRADE event report files to oscillography
Cable Selector SEL-5801 Software	Selects the proper SEL cables for your application.

[a] The SEL-351 does not support the freeform logic described in the SEL-5030 Instruction Manual.

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APPENDIX D

Relay Word Bits

Relay Word bits show the status of functions within the relay. The bits are available via communications protocols and the front panel.

Relay Word bits are used in SELOGIC control equation settings. Numerous SELOGIC control equation settings examples are given in *Section 3: Overcurrent, Harmonic Blocking, Voltage, Synchronism Check, Frequency, and Power Elements* through *Section 8: Breaker Monitor, Metering, and Load Profile Functions*. SELOGIC control equation settings can also be *set directly* to 1 (logical 1) or 0 (logical 0). *Appendix F: Setting SELOGIC Control Equations* gives SELOGIC control equation details, examples, and limitations.

The Relay Word bit row numbers correspond to the row numbers used in the **TAR** command (see ***TAR*** *(Display Relay Element Status)* on page 10.80). Rows 0 and 1 are reserved for the display of the two front-panel target LED rows (see *Table 10.23*).

Table D.2 provides an alphanumeric listing of the Relay Word bits that includes a description of each bit.

Table D.1 and *Table D.2* include cross-reference information for most Relay Word bits. *Table D.3* describes Relay Word bits that are not described elsewhere in the manual.

Relay Word

Table D.1 Relay Word Bit Mapping (Sheet 1 of 6)

Row	Relay Word Bits[a]							
Target LED Bits (see *Section 5: Trip and Target Logic*)								
0[b]	EN	TRIP	INST	COMM	SOTF	50	51	81
1[b]	A	B	C	G	N	RS	CY	LO
Instantaneous, Definite-Time, and Inverse-Time Overcurrent Elements (see *Section 3: Overcurrent, Harmonic Blocking, Voltage, Synchronism Check, Frequency, and Power Elements*)								
2	50A1	50B1	50C1	50A2	50B2	50C2	50A3	50B3
3	50C3	50A4	50B4	50C4	50AB1	50BC1	50CA1	50AB2
4	50BC2	50CA2	50AB3	50BC3	50CA3	50AB4	50BC4	50CA4
5	50A	50B	50C	51A	51AT	51AR	51B	51BT
6	51BR	51C	51CT	51CR	51P	51PT	51PR	51N
7	51NT	51NR	51G	51GT	51GR	51Q	51QT	51QR
8	50P1	50P2	50P3	50P4	50N1	50N2	50N3	50N4

Table D.1 Relay Word Bit Mapping (Sheet 2 of 6)

Row	Relay Word Bits[a]							
9	67P1	67P2	67P3	67P4	67N1	67N2	67N3	67N4
10	67P1T	67P2T	67P3T	67P4T	67N1T	67N2T	67N3T	67N4T
11	50G1	50G2	50G3	50G4	50Q1	50Q2	50Q3	50Q4
12	67G1	67G2	67G3	67G4	67Q1	67Q2	67Q3	67Q4
13	67G1T	67G2T	67G3T	67G4T	67Q1T	67Q2T	67Q3T	67Q4T
14	50P5	50P6	50N5	50N6	50G5	50G6	50Q5	50Q6
Directional Control (see *Section 4: Loss-of-Potential, Load-Encroachment, and Directional Element Logic*)								
15	50QF	50QR	50GF	50GR	32VE	32QGE	32IE	32QE
16	F32P	R32P	F32Q	R32Q	F32QG	R32QG	F32V	R32V
17	F32I	R32I	32PF	32PR	32QF	32QR	32GF	32GR
Voltage Elements and Synchronism-Check Elements (see *Section 3: Overcurrent, Harmonic Blocking, Voltage, Synchronism Check, Frequency, and Power Elements*)								
18	27A1	27B1	27C1	27A2	27B2	27C2	59A1	59B1
19	59C1	59A2	59B2	59C2	27AB	27BC	27CA	59AB
20	59BC	59CA	59N1	59N2	59Q	59V1	27S	59S1
21	59S2	59VP	59VS	SF	25A1	25A2	3P27	3P59
Frequency Elements (see *Section 3: Overcurrent, Harmonic Blocking, Voltage, Synchronism Check, Frequency, and Power Elements*), Three-Pole Open Logic (see *Section 5: Trip and Target Logic*), Directional Control and Loss-of-Potential Logic (see *Section 4: Loss-of-Potential, Load-Encroachment, and Directional Element Logic*)								
22	81D1	81D2	81D3	81D4	81D5	81D6	27B81	50L
23	81D1T	81D2T	81D3T	81D4T	81D5T	81D6T	VPOLV	LOP
Synchronism-Check Elements (see *Section 3: Overcurrent, Harmonic Blocking, Voltage, Synchronism Check, Frequency, and Power Elements*), Optoisolated Inputs (see *Section 7: Inputs, Outputs, Timers, and Other Control Logic*)								
24	SFAST	SSLOW	IN106	IN105	IN104	IN103	IN102	IN101
Local Bits, Remote Bits, and Latch Bits (see *Section 7: Inputs, Outputs, Timers, and Other Control Logic*)								
25	LB1	LB2	LB3	LB4	LB5	LB6	LB7	LB8
26	LB9	LB10	LB11	LB12	LB13	LB14	LB15	LB16
27	RB1	RB2	RB3	RB4	RB5	RB6	RB7	RB8
28	RB9	RB10	RB11	RB12	RB13	RB14	RB15	RB16
29	LT1	LT2	LT3	LT4	LT5	LT6	LT7	LT8
30	LT9	LT10	LT11	LT12	LT13	LT14	LT15	LT16
SELOGIC Control Equation Variables/Timers (see *Section 7: Inputs, Outputs, Timers, and Other Control Logic*)								
31	SV1	SV2	SV3	SV4	SV1T	SV2T	SV3T	SV4T
32	SV5	SV6	SV7	SV8	SV5T	SV6T	SV7T	SV8T
33	SV9	SV10	SV11	SV12	SV9T	SV10T	SV11T	SV12T
34	SV13	SV14	SV15	SV16	SV13T	SV14T	SV15T	SV16T

Table D.1 Relay Word Bit Mapping (Sheet 3 of 6)

Row	Relay Word Bits[a]							
Close Logic and Reclosing Relay (see *Section 6: Close and Reclose Logic*), Fault Identification (see *Section 5: Trip and Target Logic*)								
35	79RS	79CY	79LO	SH0	SH1	SH2	SH3	SH4
36	CLOSE	CF	RCSF	OPTMN	RSTMN	FSA	FSB	FSC
Breaker Monitor (see *Section 8: Breaker Monitor, Metering, and Load Profile Functions*), Directional Control (see *Section 4: Loss-of-Potential, Load-Encroachment, and Directional Element Logic*), Synchronism-Check Elements (see *Section 3: Overcurrent, Harmonic Blocking, Voltage, Synchronism Check, Frequency, and Power Elements*), Breaker Status (see *Section 6: Close and Reclose Logic*)								
37	BCW	50P32	*	59VA	TRGTR	52A	*	*
Setting Group Bits (see *Section 7: Inputs, Outputs, Timers, and Other Control Logic*), Load Encroachment (see *Section 4: Loss-of-Potential, Load-Encroachment, and Directional Element Logic*)								
38	SG1	SG2	SG3	SG4	SG5	SG6	ZLOUT	ZLIN
Load Encroachment (see *Section 4: Loss-of-Potential, Load-Encroachment, and Directional Element Logic*), Breaker Monitor (see *Section 8: Breaker Monitor, Metering, and Load Profile Functions*)								
39	ZLOAD	BCWA	BCWB	BCWC	*	51G2	51G2T	51G2R
Output Contacts (see *Section 7: Inputs, Outputs, Timers, and Other Control Logic*)								
40[c]	ALARM	OUT107	OUT106	OUT105	OUT104	OUT103	OUT102	OUT101
Switch-Onto-Fault Trip Logic and Communications-Assisted Trip Logic (see *Section 5: Trip and Target Logic*)								
41	3PO	SOTFE	Z3RB	KEY	EKEY	ECTT	WFC	PT
42	PTRX2	PTRX	PTRX1	UBB1	UBB2	UBB	Z3XT	DSTRT
Communications-Assisted Trip Logic (see *Section 5: Trip and Target Logic*), OPEN and CLOSE Command (see *Section 10: Communications*), Station DC Battery Monitor (see *Section 8: Breaker Monitor, Metering, and Load Profile Functions*)								
43	NSTRT	STOP	BTX	TRIP	OC	CC	DCHI	DCLO
Communications-Assisted Trip Logic (see *Section 5: Trip and Target Logic*), Demand Current Logic Outputs (see *Section 8: Breaker Monitor, Metering, and Load Profile Functions*)								
44	67P2S	67N2S	67G2S	67Q2S	PDEM	NDEM	GDEM	QDEM
Extra I/O Board Output Contacts (see *Section 7: Inputs, Outputs, Timers, and Other Control Logic*)								
45[c,d,e]	OUT201	OUT202	OUT203	OUT204	OUT205	OUT206	OUT207	OUT208
46[c,d]	OUT209	OUT210	OUT211	OUT212	*	*	*	*
Extra I/O Board Optoisolated Inputs (see *Section 7: Inputs, Outputs, Timers, and Other Control Logic*)								
47[d,e]	IN208	IN207	IN206	IN205	IN204	IN203	IN202	IN201
48[e]	IN216	IN215	IN214	IN213	IN212	IN211	IN210	IN209
MIRRORED BITS (see *Appendix H: MIRRORED BITS Communications (in Firmware Versions 6 and 7)*)								
49[f]	RMB8A	RMB7A	RMB6A	RMB5A	RMB4A	RMB3A	RMB2A	RMB1A
50[f]	TMB8A	TMB7A	TMB6A	TMB5A	TMB4A	TMB3A	TMB2A	TMB1A
51[f]	RMB8B	RMB7B	RMB6B	RMB5B	RMB4B	RMB3B	RMB2B	RMB1B
52[f]	TMB8B	TMB7B	TMB6B	TMB5B	TMB4B	TMB3B	TMB2B	TMB1B
53[f]	LBOKB	CBADB	RBADB	ROKB	LBOKA	CBADA	RBADA	ROKA

Table D.1 Relay Word Bit Mapping (Sheet 4 of 6)

Row	Relay Word Bits[a]							
Power Elements and Voltage Sag/Swell/Interruption Elements (see *Section 3: Overcurrent, Harmonic Blocking, Voltage, Synchronism Check, Frequency, and Power Elements*), IRIG-B Status (see *Appendix N: Synchrophasors*)								
54[g]	PWRA1	PWRB1	PWRC1	PWRA2	PWRB2	PWRC2	INTC	INT3P
55[g]	PWRA3	PWRB3	PWRC3	PWRA4	PWRB4	PWRC4	INTA	INTB
56[g]	SAGA	SAGB	SAGC	SAG3P	SWA	SWB	SWC	SW3P
57	SAGAB[g]	SAGBC[g]	SAGCA[g]	SWAB[g]	SWBC[g]	SWCA[g]	TSOK	TIRIG
58[g]	3PWR1	3PWR2	3PWR3	3PWR4	INTAB	INTBC	INTCA	*
Extra Voltage Elements for Open-Delta Connection (see *Section 3: Overcurrent, Harmonic Blocking, Voltage, Synchronism Check, Frequency, and Power Elements*), VSCONN Indication (see *Section 9: Setting the Relay*)								
59	27AB2	27BC2	27CA2	59AB2	59BC2	59CA2	59Q2	3V0
Loss-of-Potential (see *Section 4: Loss-of-Potential, Load-Encroachment, and Directional Element Logic*), Analog Scaling (see *Analog Scaling and Frequency Indicators* on page D.18)								
60	V1GOOD	*	*	V0GAIN	INMET	ICMET	IBMET	IAMET
Directional Control (see *Section 4: Loss-of-Potential, Load-Encroachment, and Directional Element Logic*), Phasor Measurement Status (see *Appendix N: Synchrophasors*), Fault Identification (see *Section 5: Trip and Target Logic*)								
61	GNDSW[h]	50NF[h]	50NR[h]	32NE[h]	F32N[h]	R32N[h]	32NF	32NR
62	PMDOK	F32W[h]	R32W[h]	F32C[h]	R32C[h]	NSA[h]	NSB[h]	NSC[h]
PTCONN Indication (see *Section 9: Setting the Relay*), TEST DB Indication (see *Section 10: Communications*), Frequency Source (see *Analog Scaling and Frequency Indicators* on page D.18)								
63	DELTA	WYE	SINGLE	TESTDB	27B81A	FRQ81OK	FRQ81FZ	FREQOK
IRIG Time Quality Information (see *Appendix N: Synchrophasors*)								
64	DST	DSTP	LPSEC	LPSECP	TQUAL4	TQUAL3	TQUAL2	TQUAL1
Target Reset Control (see *Section 5: Trip and Target Logic*), Metering Reset Control (see *Section 8: Breaker Monitor, Metering, and Load Profile Functions*)								
65	RSTTRGT	RST_MML	RST_ENE	RST_HIS	RST_BK	RST_PDM	RST_DEM	RST_HAL
Phasor Measurement Unit Trigger Status (see *Appendix N: Synchrophasors*)								
66	*	*	*	PMTRIG	TREA4	TREA3	TREA2	TREA1
Ethernet Status (see *Section 10: Communications*)								
67	LINK5[i]	LINK5A[j]	LINK5B[j]	LNKFAIL	P5ASEL[j]	P5BSEL[j]	TSNTPP	TSNTPB
Remote Bits (see *Section 7: Inputs, Outputs, Timers, and Other Control Logic*)								
68	RB17	RB18	RB19	RB20	RB21	RB22	RB23	RB24
69	RB25	RB26	RB27	RB28	RB29	RB30	RB31	RB32
Logic Variables (see *Section 7: Inputs, Outputs, Timers, and Other Control Logic*)								
70	LV1	LV2	LV3	LV4	LV5	LV6	LV7	LV8
71	LV9	LV10	LV11	LV12	LV13	LV14	LV15	LV16
72	LV17	LV18	LV19	LV20	LV21	LV22	LV23	LV24
73	LV25	LV26	LV27	LV28	LV29	LV30	LV31	LV32

Table D.1 Relay Word Bit Mapping (Sheet 5 of 6)

Row	Relay Word Bits[a]							
74	*	*	*	*	*	*	*	*
75	*	*	*	*	*	*	*	*
76	*	*	*	*	*	*	*	*
77	*	*	*	*	*	*	*	*
Virtual Bits (see *Appendix P: IEC 61850*)								
78[k]	VB001	VB002	VB003	VB004	VB005	VB006	VB007	VB008
79[k]	VB009	VB010	VB011	VB012	VB013	VB014	VB015	VB016
80[k]	VB017	VB018	VB019	VB020	VB021	VB022	VB023	VB024
81[k]	VB025	VB026	VB027	VB028	VB029	VB030	VB031	VB032
82[k]	VB033	VB034	VB035	VB036	VB037	VB038	VB039	VB040
83[k]	VB041	VB042	VB043	VB044	VB045	VB046	VB047	VB048
84[k]	VB049	VB050	VB051	VB052	VB053	VB054	VB055	VB056
85[k]	VB057	VB058	VB059	VB060	VB061	VB062	VB063	VB064
86[k]	VB065	VB066	VB067	VB068	VB069	VB070	VB071	VB072
87[k]	VB073	VB074	VB075	VB076	VB077	VB078	VB079	VB080
88[k]	VB081	VB082	VB083	VB084	VB085	VB086	VB087	VB088
89[k]	VB089	VB090	VB091	VB092	VB093	VB094	VB095	VB096
90[k]	VB097	VB098	VB099	VB100	VB101	VB102	VB103	VB104
91[k]	VB105	VB106	VB107	VB108	VB109	VB110	VB111	VB112
92[k]	VB113	VB114	VB115	VB116	VB117	VB118	VB119	VB120
93[k]	VB121	VB122	VB123	VB124	VB125	VB126	VB127	VB128
Loss-of-Potential Elements and Alarm and Security Bits (see *Section 4: Loss-of-Potential, Load-Encroachment, and Directional Element Logic*, *Section 7: Inputs, Outputs, Timers, and Other Control Logic*, *Section 13: Testing and Troubleshooting*, and *Appendix Q: Cybersecurity Features*)								
94	SALARM	ACCESS	ALRMOUT	*	HALARMA	HALARMP	HALARML	HALARM
95	*	*	PASNVAL	ACCESSP	GRPSW	SETCHG	CHGPASS	BADPASS
96	DD	LOPRST	LOPBLK	LOP2	LOP3	*	*	*
Mechanical and Electrical Operate Timer Alarms and Second Harmonic Blocking Elements (see *Section 3: Overcurrent, Harmonic Blocking, Voltage, Synchronism Check, Frequency, and Power Elements* and *Section 8: Breaker Monitor, Metering, and Load Profile Functions*)								
97	ESTRA	ESTRB	ESTRC	ESCLA	ESCLB	ESCLC	ESOAL	MSOAL
98	*	*	HBL2T	HBL2AT	HBL2BT	HBL2CT	MSTR	MSCL
Rate-of-Change-of-Frequency Elements, Breaker Failure Elements, and DNP Event Register Reset Equation (see *Section 3: Overcurrent, Harmonic Blocking, Voltage, Synchronism Check, Frequency, and Power Elements*, *Section 5: Trip and Target Logic*, and *Appendix L: DNP3 Communications*)								
99	*	*	*	81R4T	81R3T	81R2T	81R1T	81RT
100	*	50BFA	50BFB	50BFC	50BFT	RT	BFT	BFTRIP

Table D.1 Relay Word Bit Mapping (Sheet 6 of 6)

Row	Relay Word Bits[a]							
101	*	*	*	*	*	*	*	RSTDNPE
102	*	*	*	*	*	*	*	*

[a] "*" indicates not used.
[b] Target LED bits EN–LO cannot be used in SELogic control equations or the Sequential Events Recorder (SER). Row 0 and Row 1 can be displayed by using the **TAR n** (Target) command or via the front-panel HMI. See *Front-Panel Target LEDs* on page 5.34 and *TAR (Display Relay Element Status)* on page 10.80.
[c] All output contacts can be "a" or "b" type contacts. See *Output Contacts* on page 7.33 for details.
[d] OUT201–OUT212 and IN201–IN208 available when extra I/O board options 2 or 6 are present.
[e] OUT201–OUT204 and IN201–IN216 available when extra I/O board option 4 is present.
[f] Mirrored Bits elements only valid in Firmware Versions 6 or 7 (rows 49–53).
[g] Indicated Power Elements and Sag/Swell/Interruption elements only valid in Firmware Version 7 (rows 54–58).
[h] Indicated Relay Word bits are only valid in Relays with 0.2 A nominal neutral channel (rows 61–62).
[i] LINK5 is replaced by "*" when dual Ethernet connectors are present.
[j] Relay Word bits (for Ethernet ports) are replaced by "*" when a single Ethernet connector is present.
[k] Virtual bits VB001–VB128 are only present in relays ordered with IEC 61850 protocol.

Table D.2 Alphabetic List of Relay Word Bits (Sheet 1 of 13)

Name	Description	Usage	Row (*Table D.1*)
25A1, 25A2	Synchronism-check elements 1 and 2 (see *Figure 3.30*)	Control	21
27A1	A-Phase instantaneous undervoltage element (A-Phase voltage below pickup setting 27P1P; see *Figure 3.23*)	Control	18
27A2	A-Phase instantaneous undervoltage element (A-Phase voltage below pickup setting 27P2P; see *Figure 3.23*)	Control	18
27AB	AB-phase-to-phase instantaneous undervoltage element (AB-phase-to-phase voltage below pickup setting 27PP; see *Figure 3.24* and *Figure 3.25*)	Control	19
27AB2	AB-phase-to-phase instantaneous undervoltage element (AB-phase-to-phase voltage below pickup setting 27PP2P; see *Figure 3.25*)	Control	59
27B1	B-Phase instantaneous undervoltage element (B-Phase voltage below pickup setting 27P1P; see *Figure 3.23*)	Control	18
27B2	B-Phase instantaneous undervoltage element (B-Phase voltage below pickup setting 27P2P; see *Figure 3.23*)	Control	18
27B81	Undervoltage element for frequency element blocking (voltage below pickup setting 27B81P; see *Figure 3.35* and *Figure 3.36*)	Testing	22
27B81A	Undervoltage element for frequency element blocking (voltage below pickup setting 27B81P; see *Figure 3.37* and *Figure 3.39*)	Testing	63
27BC	BC-phase-to-phase instantaneous undervoltage element (BC-phase-to-phase voltage below pickup setting 27PP; see *Figure 3.24* and *Figure 3.25*)	Control	19
27BC2	BC-phase-to-phase instantaneous undervoltage element (BC-phase-to-phase voltage below pickup setting 27PP2P; see *Figure 3.25*)	Control	59
27C1	C-Phase instantaneous undervoltage element (C-Phase voltage below pickup setting 27P1P; see *Figure 3.23*)	Control	18
27C2	C-Phase instantaneous undervoltage element (C-Phase voltage below pickup setting 27P2P; see *Figure 3.23*)	Control	18
27CA	CA-phase-to-phase instantaneous undervoltage element (CA-phase-to-phase voltage below pickup setting 27PP; see *Figure 3.24* and *Figure 3.25*)	Control	19
27CA2	CA-phase-to-phase instantaneous undervoltage element (CA-phase-to-phase voltage below pickup setting 27PP2P; see *Figure 3.25*)	Control	59
27S	Channel VS instantaneous undervoltage element (channel VS voltage below pickup setting 27SP; see *Figure 3.27*)	Control	20

Table D.2 Alphabetic List of Relay Word Bits (Sheet 2 of 13)

Name	Description	Usage	Row (*Table D.1*)
32GF, 32GR	Forward or Reverse directional control routed to residual ground overcurrent elements (see *Figure 4.8* and *Figure 4.20*)	Testing, Special directional control schemes	17
32IE	Internal enable for channel IN current-polarized directional element (see *Figure 4.8* and *Figure 4.12*)	Testing	15
32NE	Internal enable for directional elements for low-impedance grounded, Petersen Coil grounded, or ungrounded/high-impedance grounded systems (see *Figure 4.13*)	Testing	61
32NF, 32NR	Forward or Reverse directional control routed to neutral-ground overcurrent elements (see *Figure 4.21* and *Figure 4.23*)	Testing, Special directional control schemes	61
32PF, 32PR	Forward or Reverse directional control routed to phase overcurrent elements (see *Figure 4.24* and *Figure 4.27*)	Testing, Special directional control schemes	17
32QE	Internal enable for negative-sequence voltage-polarized directional element (see *Figure 4.11*, and *Figure 4.24*)	Testing	15
32QF	Forward directional control routed to negative-sequence overcurrent elements (see *Figure 4.24* and *Figure 4.27*)	Testing, Special directional control schemes	17
32QGE	Internal enable for negative-sequence voltage-polarized directional element (for ground; see *Figure 4.8* and *Figure 4.11*)	Testing	15
32QR	Reverse directional control routed to negative-sequence overcurrent elements (see *Figure 4.24* and *Figure 4.27*)	Testing, Special directional control schemes	17
32VE	Internal enable for zero-sequence voltage-polarized directional element (see *Figure 4.8* and *Figure 4.12*)	Testing	15
3P27	= 27A1 * 27B1 * 27C1 (see *Figure 3.23* and *Figure 3.25*)	Control	21
3P59	= 59A1 * 59B1 * 59C1 (see *Figure 3.23* and *Figure 3.25*)	Control	21
3PO	Three-pole open condition (see *Figure 5.3*)	Testing	41
3PWR1–3PWR4	Three-phase power elements, 1 through 4 (see *Figure 3.47*)	Tripping, Control (only operable in Firmware Version 7)	58
3V0	3V0 configuration element (asserts when Global setting VSCONN = 3V0; see *Figure 9.11*)	Indication	59
50A	= 50A1 + 50A2 + 50A3 + 50A4 (see *Figure 3.4*)	Tripping, Control	5
50A1–50A4	Level 1 through Level 4 A-Phase instantaneous overcurrent elements (see *Figure 3.1*)	Tripping, Control	2, 3
50AB1–50AB4	Level 1 through Level 4 AB-phase-to-phase instantaneous overcurrent elements (see *Figure 3.7*)	Tripping, Control	3, 4
50B	= 50B1 + 50B2 + 50B3 + 50B4 (see *Figure 3.4*)	Tripping, Control	5
50B1–50B4	Level 1 through Level 4 B-Phase instantaneous overcurrent elements (see *Figure 3.1*)	Tripping, Control	2, 3
50BC1–50BC4	Level 1 through Level 4 BC-phase-to-phase instantaneous overcurrent elements (see *Figure 3.7*)	Tripping, Control	3, 4
50BFA	A-Phase breaker failure current threshold exceeded	Indication	100
50BFB	B-Phase breaker failure current threshold exceeded	Indication	100
50BFC	C-Phase breaker failure current threshold exceeded	Indication	100
50BFT	Any phase breaker failure current threshold exceeded	Tripping, Control	100

Table D.2 Alphabetic List of Relay Word Bits (Sheet 3 of 13)

Name	Description	Usage	Row (*Table D.1*)
50C	= 50C1 + 50C2 + 50C3 + 50C4 (see *Figure 3.4*)	Tripping, Control	5
50C1–50C4	Level 1 through Level 4 C-Phase instantaneous overcurrent elements (see *Figure 3.1*)	Tripping, Control	2, 3
50CA1–50CA4	Level 1 through Level 4 CA-phase-to-phase instantaneous overcurrent elements (see *Figure 3.7*)	Tripping, Control	3, 4
50G1–50G4	Level 1 through Level 4 residual ground instantaneous overcurrent elements (see *Figure 3.10*)	Tripping, Testing, Control	11
50G5, 50G6	Level 5 and Level 6 residual ground instantaneous overcurrent elements (see *Figure 3.11*)	Tripping, Control	14
50GF, 50GR	Forward or Reverse direction residual ground overcurrent threshold exceeded (see *Figure 4.8* and *Figure 4.12*)	Testing	15
50L	Phase instantaneous overcurrent element for load detection (maximum phase current above pickup setting 50LP; see *Figure 5.3*)	Testing	22
50N1–50N4	Level 1 through Level 4 neutral ground instantaneous overcurrent elements (see *Figure 3.8*)	Tripping, Testing, Control	8
50N5, 50N6	Level 5 and Level 6 neutral ground instantaneous overcurrent elements (see *Figure 3.9*)	Tripping, Control	14
50NF, 50NR	Forward or Reverse direction neutral-ground overcurrent threshold exceeded (see *Figure 4.13*)	Testing	61
50P1–50P4	Level 1 through Level 4 phase instantaneous overcurrent elements (see *Figure 3.1*)	Tripping, Testing, Control	8
50P32	Three-phase directional element overcurrent threshold exceeded (see *Figure 4.26*)	Testing	37
50P5, 50P6	Level 5 and Level 6 phase instantaneous overcurrent elements (see *Figure 3.2*)	Tripping, Control	14
50Q1–50Q4	Level 1 through Level 4 negative-sequence instantaneous overcurrent elements (see *Figure 3.12*)	Testing, Control	11
50Q5, 50Q6	Level 5 and Level 6 negative-sequence instantaneous overcurrent elements (see *Figure 3.13*)	Control	14
50QF, 50QR	Forward or Reverse direction negative-sequence overcurrent threshold exceeded (see *Figure 4.8*, *Figure 4.11*, and *Figure 4.24*)	Testing	15
51A	A-Phase current above pickup setting 51AP for A phase time-overcurrent element 51AT (see *Figure 3.15*)	Testing, Control	5
51AR	A-Phase time-overcurrent element 51AT reset (see *Figure 3.15*)	Testing	5
51AT	A-Phase time-overcurrent element 51AT timed out (see *Figure 3.15*)	Tripping	5
51B	B-Phase current above pickup setting 51BP for B phase time-overcurrent element 51BT (see *Figure 3.16*)	Testing, Control	5
51BR	B-Phase time-overcurrent element 51BT reset (see *Figure 3.16*)	Testing	6
51BT	B-Phase time-overcurrent element 51BT timed out (see *Figure 3.16*)	Tripping	5
51C	C-Phase current above pickup setting 51CP for C phase time-overcurrent element 51CT (see *Figure 3.17*)	Testing, Control	6
51CR	C-Phase time-overcurrent element 51CT reset (see *Figure 3.17*)	Testing	6
51CT	C-Phase time-overcurrent element 51CT timed out (see *Figure 3.17*)	Tripping	6
51G	Residual ground current above pickup setting 51GP for residual ground time-overcurrent element 51GT (see *Figure 3.19*)	Testing, Control	7
51GR	Residual ground time-overcurrent element 51GT reset (see *Figure 3.19*)	Testing	7
51GT	Residual ground time-overcurrent element 51GT timed out (see *Figure 3.19*)	Tripping	7

Table D.2 Alphabetic List of Relay Word Bits (Sheet 4 of 13)

Name	Description	Usage	Row (*Table D.1*)
51G2	Residual ground current above pickup setting 51G2P for residual ground time-overcurrent element 51G2T (see *Figure 3.20*)	Testing, Control	39
51G2R	Residual ground time-overcurrent element 51G2T reset (see *Figure 3.20*)	Testing	39
51G2T	Residual ground time-overcurrent element 51G2T timed out (see *Figure 3.20*)	Tripping	39
51N	Neutral ground current (channel IN) above pickup setting 51NP for neutral ground time-overcurrent element 51NT (see *Figure 3.18*)	Testing, Control	6
51NR	Neutral ground time-overcurrent element 51NT reset (see *Figure 3.18*)	Testing	7
51NT	Neutral ground time-overcurrent element 51NT timed out (see *Figure 3.18*)	Tripping	7
51P	Maximum phase current above pickup setting 51PP for phase time-overcurrent element 51PT (see *Figure 3.14*)	Testing, Control	6
51PR	Phase time-overcurrent element 51PT reset (see *Figure 3.14*)	Testing	6
51PT	Phase time-overcurrent element 51PT timed out (see *Figure 3.14*)	Tripping	6
51Q	Negative-sequence current above pickup setting 51QP for negative-sequence time-overcurrent element 51QT (see *Figure 3.21*)	Testing, Control	7
51QR	Negative-sequence time-overcurrent element 51QT reset (see *Figure 3.21*)	Testing	7
51QT	Negative-sequence time-overcurrent element 51QT timed out (see *Figure 3.21*)	Tripping	7
52A	Circuit breaker status (asserts to logical 1 when circuit breaker is closed; see *Circuit Breaker Status* on page 6.5)	Indication	37
59A1	A-Phase instantaneous overvoltage element (A-Phase voltage above pickup setting 59P1P; see *Figure 3.23*)	Control	18
59A2	A-Phase instantaneous overvoltage element (A-Phase voltage above pickup setting 59P2P; see *Figure 3.23*)	Control	19
59AB	AB-phase-to-phase instantaneous overvoltage element (AB-phase-to-phase voltage above pickup setting 59PP; see *Figure 3.24* and *Figure 3.25*)	Control	19
59AB2	AB-phase-to-phase instantaneous overvoltage element (AB-phase-to-phase voltage above pickup setting 59PP2P; see *Figure 3.25*)	Control	59
59B1	B-Phase instantaneous overvoltage element (B-Phase voltage above pickup setting 59P1P; see *Figure 3.23*)	Control	18
59B2	B-Phase instantaneous overvoltage element (B-Phase voltage above pickup setting 59P2P; see *Figure 3.23*)	Control	19
59BC	BC-phase-to-phase instantaneous overvoltage element (BC-phase-to-phase voltage above pickup setting 59PP; see *Figure 3.24* and *Figure 3.25*)	Control	20
59BC2	BC-phase-to-phase instantaneous overvoltage element (BC-phase-to-phase voltage above pickup setting 59PP2P; see *Figure 3.25*)	Control	59
59C1	C-Phase instantaneous overvoltage element (C-Phase voltage above pickup setting 59P1P; see *Figure 3.23*)	Control	19
59C2	C-Phase instantaneous overvoltage element (C-Phase voltage above pickup setting 59P2P; see *Figure 3.23*)	Control	19
59CA	CA-phase-to-phase instantaneous overvoltage element (CA-phase-to-phase voltage above pickup setting 59PP; see *Figure 3.24* and *Figure 3.25*)	Control	20
59CA2	CA-phase-to-phase instantaneous overvoltage element (CA-phase-to-phase voltage above pickup setting 59PP2P; see *Figure 3.25*)	Control	59
59N1	Zero-sequence instantaneous overvoltage element (zero-sequence voltage above pickup setting 59N1P; see *Figure 3.24*)	Control	20
59N2	Zero-sequence instantaneous overvoltage element (zero-sequence voltage above pickup setting 59N2P; see *Figure 3.24*)	Control	20

Table D.2 Alphabetic List of Relay Word Bits (Sheet 5 of 13)

Name	Description	Usage	Row (*Table D.1*)
59Q	Negative-sequence instantaneous overvoltage element (negative-sequence voltage above pickup setting 59QP; see *Figure 3.24* and *Figure 3.26*)	Control	20
59Q2	Negative-sequence instantaneous overvoltage element (negative-sequence voltage above pickup setting 59Q2P; see *Figure 3.26*)	Control	59
59S1	Channel VS instantaneous overvoltage element (channel VS voltage above pickup setting 59S1P; see *Figure 3.27*)	Control	20
59S2	Channel VS instantaneous overvoltage element (channel VS voltage above pickup setting 59S2P; see *Figure 3.27*)	Control	21
59V1	Positive-sequence instantaneous overvoltage element (positive-sequence voltage above pickup setting 59V1P; see *Figure 3.24* and *Figure 3.26*)	Control	20
59VA	Channel VA voltage window element (channel VA voltage between threshold settings 25VLO and 25VHI; see *Figure 3.29*)	Testing	37
59VP	Phase voltage window element (selected phase voltage [VP] between threshold settings 25VLO and 25VHI; see *Figure 3.29*)	Testing	21
59VS	Channel VS voltage window element (channel VS voltage between threshold settings 25VLO and 25VHI; see *Figure 3.29*)	Testing	21
67G1–67G4	Level 1 through Level 4 residual ground instantaneous overcurrent elements with directional control option (derived from 50G1–50G4; see *Figure 3.10*)	Tripping, Testing, Control	12
67G1T–67G4T	Level 1 through Level 4 residual ground definite-time overcurrent elements (derived from 67G1–67G4; see *Figure 3.10*)	Tripping	13
67G2S	Level 2 directional residual ground definite-time (short delay) overcurrent element 67G2S timed out (derived from 67G2; see *Figure 3.10* and *Figure 5.14*)	Tripping in DCB schemes	44
67N1–67N4	Level 1 through Level 4 neutral ground instantaneous overcurrent elements with directional control option (derived from 50N1–50N4; see *Figure 3.8*)	Tripping, Testing, Control	9
67N1T–67N4T	Level 1 through Level 4 neutral ground definite-time overcurrent elements (derived from 67N1–67N4; see *Figure 3.8*)	Tripping	10
67N2S	Level 2 directional neutral ground definite-time (short delay) overcurrent element 67N2S timed out (derived from 67N2; see *Figure 3.8* and *Figure 5.14*)	Tripping in DCB schemes	44
67P1–67P4	Level 1 through Level 4 phase instantaneous overcurrent elements with directional control option (derived from 50P1–50P4; see *Figure 3.3*)	Tripping, Testing, Control	9
67P1T–67P4T	Level 1 through Level 4 phase definite-time overcurrent elements (derived from 67P1–67P4; see *Figure 3.3*)	Tripping	10
67P2S	Level 2 directional phase definite-time (short delay) overcurrent element 67P2S timed out (derived from 67P2; see *Figure 3.3* and *Figure 5.14*)	Tripping in DCB schemes	44
67Q1–67Q4	Level 1 through Level 4 negative-sequence instantaneous overcurrent elements with directional control option (derived from 50Q1–50Q4; see *Figure 3.12*)	Testing, Control	12
67Q1T–67Q4T	Level 1 through Level 4 negative-sequence definite-time overcurrent elements (derived from 67Q1–67Q4; see *Figure 3.12*)	Tripping	13
67Q2S	Level 2 directional negative-sequence definite-time (short delay) overcurrent element 67Q2S timed out (derived from 67Q2; see *Figure 3.12* and *Figure 5.14*)	Tripping in DCB schemes	44
79CY	Reclosing relay in the Reclose Cycle State (see *Figure 6.6* and *Table 6.1*)	Control	35
79LO	Reclosing relay in the Lockout State (see *Figure 6.6* and *Table 6.1*)	Control	35
79RS	Reclosing relay in the Reset State (see *Figure 6.6* and *Table 6.1*)	Control	35
81D1–81D6	Level 1 through Level 6 instantaneous frequency elements (see *Figure 3.40*)	Testing	22
81D1T–81D6T	Level 1 through Level 6 definite-time frequency elements (derived from 81D1–81D6; see *Figure 3.40*)	Tripping, Control	23
81R1T	Rate-of-change-of-frequency element 81R1T timed out	Tripping, Control	99

Table D.2 Alphabetic List of Relay Word Bits (Sheet 6 of 13)

Name	Description	Usage	Row (*Table D.1*)
81R2T	Rate-of-change-of-frequency element 81R2T timed out	Tripping, Control	99
81R3T	Rate-of-change-of-frequency element 81R3T timed out	Tripping, Control	99
81R4T	Rate-of-change-of-frequency element 81R4T timed out	Tripping, Control	99
81RT	81R1T + 81R2T + 81R3T + 81R4T	Tripping, Control	99
ACCESS	Asserted while any user is logged in at Access Level B or higher	Indication	94
ACCESSP	Pulses for approximately one second when any user increases their access level to B or higher	Indication	95
ALARM	ALARM condition (ALRMOUT deasserted, **PULSE ALARM**, or **PULSE ALRMOUT** command executed—see *Figure 7.28*)	Indication	40
ALRMOUT	ALARM output contact coil energized	Indication	94
BADPASS	Pulses for approximately one second whenever a user enters three successive bad passwords in an SEL ASCII terminal session or web session	Indication	95
BCW	= BCWA + BCWB + BCWC	Indication	37
BCWA	A-Phase breaker contact wear has reached 100% wear level (see *Breaker Monitor* on page 8.1)	Indication	39
BCWB	B-Phase breaker contact wear has reached 100% wear level (see *Breaker Monitor* on page 8.1)	Indication	39
BCWC	C-Phase breaker contact wear has reached 100% wear level (see *Breaker Monitor* on page 8.1)	Indication	39
BFT	Circuit breaker failure	Tripping, Control	100
BFTRIP	Circuit breaker failure trip	Tripping, Control	100
BTX	Block trip input extension (see *Figure 5.14*)	Testing	43
CBADA, CBADB	MIRRORED BITS channel unavailability over threshold, Channels A and B	Indication (only operable in Firmware Versions 6, 7)	53
CC	Asserts 1/4 cycle for **CLOSE** command execution (see *Factory Settings Example* on page 6.4)	Testing, Control	43
CF	Close Failure condition (asserts for 1/4 cycle; see *Figure 6.2*)	Indication	36
CHGPASS	Pulses for approximately one second whenever a password changes	Indication	95
CLOSE	Close logic output asserted (see *Figure 6.2*)	Output contact assignment	36
DCHI	Station dc battery instantaneous overvoltage element (see *Figure 8.11*)	Indication	43
DCLO	Station dc battery instantaneous undervoltage element (see *Figure 8.11*)	Indication	43
DD	Disturbance detector	Indication	96
DELTA	Delta-connected configuration element (asserts when Global setting PTCONN = DELTA; see *Figure 9.11*)	Indication	63
DST	Daylight-saving time active.	Indication	64
DSTP	Daylight-saving time change Pending. Asserts as long as a minute before daylight-saving time change.	Indication	64
DSTRT	Directional carrier start (see *Figure 5.14*)	Testing	42
ECTT	Echo conversion to trip condition (see *Figure 5.6*)	Testing	41
EKEY	Echo key (see *Figure 5.6*)	Testing	41
ESCLA	Circuit breaker electrical close operating time alarm, A-Phase	Indication	97
ESCLB	Circuit breaker electrical close operating time alarm, B-Phase	Indication	97

Table D.2 Alphabetic List of Relay Word Bits (Sheet 7 of 13)

Name	Description	Usage	Row (*Table D.1*)
ESCLC	Circuit breaker electrical close operating time alarm, C-Phase	Indication	97
ESOAL	Circuit breaker electrical operating time alarm	Indication	97
ESTRA	Circuit breaker electrical trip operating time alarm, A-Phase	Indication	97
ESTRB	Circuit breaker electrical trip operating time alarm, B-Phase	Indication	97
ESTRC	Circuit breaker electrical trip operating time alarm, C-Phase	Indication	97
F32C	Forward directional element for Petersen Coil Incremental Conductance Element (see *Figure 4.18*)	Control, Indication	62
F32I	Forward channel IN current-polarized directional element (see *Figure 4.8* and *Figure 4.16*)	Testing, Special directional control schemes	17
F32N	Forward directional element for low-impedance grounded (*Figure 4.17*), Petersen Coil grounded (Wattmetric element only—see F32W in *Figure 4.18*), or ungrounded/high-impedance grounded systems (*Figure 4.19*)	Testing, Special directional control schemes	61
F32P	Forward positive-sequence voltage-polarized directional element (see *Figure 4.24* and *Figure 4.26*)	Testing, Special directional control schemes	16
F32Q	Forward negative-sequence voltage-polarized directional element (see *Figure 4.24* and *Figure 4.25*)	Testing, Special directional control schemes	16
F32QG	Forward negative-sequence voltage-polarized directional element (for ground; see *Figure 4.8* and *Figure 4.14*)	Testing, Special directional control schemes	16
F32V	Forward zero-sequence voltage-polarized directional element (see *Figure 4.8* and *Figure 4.15*)	Testing, Special directional control schemes	16
F32W	Forward directional output for Petersen Coil Wattmetric element (an input to F32N logic). See *Figure 4.18*.	Control, Indication	62
FREQOK	System frequency and tracking frequency valid. See *Analog Scaling and Frequency Indicators* on page D.18.	Indication, Testing	63
FRQ81OK	System frequency estimation is valid for 81 and 81R element operation	Indication	63
FRQ81FZ	Frequency estimation logic is frozen on the last healthy frequency estimation value	Indication	63
FSA, FSB, FSC	Fault identification logic outputs used in targeting (see *Front-Panel Target LEDs* on page 5.34)	Control	36
GDEM	Residual ground demand current above pickup setting GDEMP (see *Figure 8.17*)	Indication	44
GNDSW	Directional element for low-impedance grounded or ungrounded/high-impedance grounded systems is operating on neutral channel (IN) current IN; if GNDSW = logical 0, then directional element is operating on residual ground current IG instead (see *Internal Enables* on page 4.19)	Testing	61
GRPSW	Pulses for approximately one second whenever groups are switched	Indication	95
HALARM	Indicates a hardware diagnostic failure or warning	Indication	94
HALARMA	Pulses for five seconds per minute until reset when a hardware diagnostic warning occurs	Indication	94
HALARML	Latches for relay hardware diagnostic failures	Indication	94
HALARMP	Pulses for five seconds when a hardware warning diagnostic condition occurs	Indication	94
HBL2AT	Phase A second harmonic block timed out	Indication	98
HBL2BT	Phase B second harmonic block timed out	Indication	98

Table D.2 Alphabetic List of Relay Word Bits (Sheet 8 of 13)

Name	Description	Usage	Row (*Table D.1*)
HBL2CT	Phase C second harmonic block timed out	Indication	98
HBL2T	Combined-phase second harmonic block timed out	Indication, Control	98
IAMET	Channel IA high-gain mode active. See *Analog Scaling and Frequency Indicators* on page D.18.	Event Report	60
IBMET	Channel IB high-gain mode active. See *Analog Scaling and Frequency Indicators* on page D.18.	Event Report	60
ICMET	Channel IC high-gain mode active. See *Analog Scaling and Frequency Indicators* on page D.18.	Event Report	60
IN101–IN106	Optoisolated inputs IN101 through IN106, asserted (see *Figure 7.1*)	Status sensing or control via optoisolated inputs	24
IN201–IN208	Optoisolated inputs IN201 through IN208, asserted (see *Figure 7.2*)	Status sensing or control via optoisolated inputs (only operable if optional I/O board installed)	47
IN209–IN216	Optoisolated inputs IN209 through IN216, asserted (see *Figure 7.2*)	Status sensing or control via optoisolated inputs (only operable if extra I/O board option 4 installed)	48
INMET	Channel IN high-gain mode active. See *Analog Scaling and Frequency Indicators* on page D.18.	Event Report	60
INT3P	Three-phase voltage interruption element	Sag/Swell/Int reporting (only operable in Firmware Version 7)	54
INTA, INTB, INTC	A, B, or C-Phase voltage interruption elements (see *Figure 3.44*)	Sag/Swell/Int reporting (only operable in Firmware Version 7)	54, 55
INTAB, INTBC, INTCA	Phase-to-phase AB, BC, or CA voltage interruption elements (see *Figure 3.44*)	Sag/Swell/Int reporting (only operable in Firmware Version 7)	58
KEY	Key permissive trip signal start (see *Figure 5.6*)	Testing	41
LB1–LB16	Local Bits 1 through 16 asserted (see *Figure 7.4*)	Control via front panel—replacing traditional panel-mounted control switches	25, 26
LBOKA, LBOKB	MIRRORED BITS channel looped back OK, Channels A and B (see *Appendix H: MIRRORED BITS Communications (in Firmware Versions 6 and 7)*)	Control (only operable in Firmware Versions 6, 7)	53
LINK5	Asserted when a valid link is detected on port 5 (see *Section 10: Communications*) (only on relays with a single Ethernet connector)	Indication, Testing	67
LINK5A, LINK5B	Asserted when a valid Ethernet link is detected on port 5A or 5B (see *Section 10: Communications*) (only on relays with dual Ethernet connectors)	Indication, Testing	67
LNKFAIL	Asserted when a valid link is not detected on the active port(s) (see *Section 10: Communications*)	Indication, Testing	67
LOP	Loss-of-potential (see *Figure 4.1*)	Testing, Special directional control schemes	23
LOP2	Change in voltage without change in current	Testing	96

Table D.2 Alphabetic List of Relay Word Bits (Sheet 9 of 13)

Name	Description	Usage	Row (*Table D.1*)
LOP3	LOP latched	Testing	96
LOPBLK	SELOGIC control equation LOPBLK asserted	Control	96
LOPRST	LOP reset condition	Indication, Testing	96
LPSEC	Leap Second direction. Add second if deasserted, delete if asserted. Only available when Global setting IRIGC = C37.118 and a proper IRIG signal is decoded.	Indication	64
LPSECP	Leap Second Pending. Asserts as long as a minute prior to leap second insertion.	Indication	64
LT1–LT16	Latch Bits 1 through 16, asserted (see *Figure 7.12*)	Control—replacing traditional latching relays	29, 30
LV1–LV32	Logic Variables 1 through 32. Logic variables follow the states of SELOGIC settings with the same name, as shown in *Figure 7.27*.	Testing, Seal-in functions, etc.	70–73
MSCL	Circuit breaker mechanical close operating time alarm	Indication	98
MSOAL	Circuit breaker mechanical operating time alarm	Indication	97
MSTR	Circuit breaker mechanical trip operating time alarm	Indication	98
NDEM	Neutral ground demand current above pickup setting NDEMP (see *Figure 8.17*)	Indication	44
NSA, NSB, NSC	A, B, or C-Phase fault identification logic output. Used in fault-type target logic for Petersen Coil grounded and ungrounded/high-impedance grounded systems (see *Front-Panel Target LEDs* on page 5.34)	Control, Indication	62
NSTRT	Nondirectional carrier start (see *Figure 5.14*)	Testing	43
OC	Asserts 1/4 cycle for **OPEN** command execution (see *Settings Example (Using Settings TR and TRQUAL)* on page 5.6)	Testing, Control	43
OPTMN	Open interval timer is timing (see *Reclosing Relay* on page 6.12)	Testing	36
OUT101–OUT107	Output contacts OUT101 through OUT107, asserted (see *Figure 7.28*)	Indication	40
OUT201–OUT212	Output contacts OUT201 through OUT212, asserted (see *Figure 7.29*)	Indication (only operable if optional I/O board installed)	45, 46
P5ASEL	Asserted when port 5A is active (see *Section 10: Communications*) (only on relays with dual Ethernet connectors)	Indication, Testing	67
P5BSEL	Asserted when port 5B is active (see *Section 10: Communications*) (only on relays with dual Ethernet connectors)	Indication, Testing	67
PASNVAL	Pulses for approximately one second when an incorrect password is entered when attempting to access Level B or higher, or when changing passwords	Indication	95
PDEM	Phase demand current above pickup setting PDEMP (see *Figure 8.17*)	Indication	44
PMDOK	Phasor measurement data OK (see *Synchrophasor Relay Word Bits* on page N.17)	Synchrophasors	62
PMTRIG	Phasor Measurement Unit SELOGIC control equation trigger (see *Appendix N: Synchrophasors*). Sent with C37.118 synchrophasor message.	Indication, Synchrophasors	66
PT	Permissive trip signal to POTT logic (see *Figure 5.5*)	Testing	41
PTRX	Permissive trip signal to Trip logic (see *Figure 5.7*)	Testing	42
PTRX1, PTRX2	Permissive trip signals 1 or 2 from DCUB logic (see *Figure 5.10*)	Testing	42
PWRA1–PWRA4	A-Phase power elements 1 through 4 (see *Figure 3.46*)	Tripping, Control (only operable in Firmware Version 7)	54, 55

Table D.2 Alphabetic List of Relay Word Bits (Sheet 10 of 13)

Name	Description	Usage	Row (*Table D.1*)
PWRB1–PWRB4	B-Phase power elements 1 through 4 (see *Figure 3.46*)	Tripping, Control (only operable in Firmware Version 7)	54, 55
PWRC1–PWRC4	C-Phase power elements 1 through 4 (see *Figure 3.46*)	Tripping, Control (only operable in Firmware Version 7)	54, 55
QDEM	Negative-sequence demand current above pickup setting QDEMP (see *Figure 8.17*)	Indication	44
R32C	Reverse directional element for Petersen Coil Incremental Conductance Element (see *Figure 4.18*)	Control, Indication	62
R32I	Reverse channel IN current-polarized directional element (see *Figure 4.8* and *Figure 4.16*)	Testing, Special directional control schemes	17
R32N	Reverse directional element for low-impedance grounded (*Figure 4.17*), Petersen Coil grounded (Wattmetric element only—see R32W in *Figure 4.18*), or ungrounded/high-impedance grounded systems (*Figure 4.19*)	Testing, Special directional control schemes	61
R32P	Reverse positive-sequence voltage-polarized directional element (see *Figure 4.24* and *Figure 4.26*)	Testing, Special directional control schemes	16
R32Q	Reverse negative-sequence voltage-polarized directional element (see *Figure 4.24* and *Figure 4.25*)	Testing, Special directional control schemes	16
R32QG	Reverse negative-sequence voltage-polarized directional element (for ground; see *Figure 4.8* and *Figure 4.14*)	Testing, Special directional control schemes	16
R32V	Reverse zero-sequence voltage-polarized directional element (see *Figure 4.8* and *Figure 4.15*)	Testing, Special directional control schemes	16
R32W	Reverse directional output for Petersen Coil Wattmetric element (an input to R32N logic). See *Figure 4.18*.	Control, Indication	62
RB1–RB32	Remote Bits 1 through 32, asserted (see *Figure 7.10*)	Control via serial port	27, 28, 68, 69
RBADA, RBADB	MIRRORED BITS outage duration over threshold, Channels A and B. See *Appendix H: MIRRORED BITS Communications (in Firmware Versions 6 and 7)*.	Indication (only operable in Firmware Versions 6, 7)	53
RCSF	Reclose supervision failure (asserts for 1/4 cycle; see *Figure 6.3*)	Indication	36
RMB1A–RMB8A	Received MIRRORED BITS 1 through 8, channel A (see *Appendix H: MIRRORED BITS Communications (in Firmware Versions 6 and 7)*)	Control (only operable in Firmware Versions 6, 7)	49
RMB1B–RMB8B	Received MIRRORED BITS 1 through 8, channel B (see *Appendix H: MIRRORED BITS Communications (in Firmware Versions 6 and 7)*)	Control (only operable in Firmware Versions 6, 7)	51
ROKA, ROKB	MIRRORED BITS received data OK, Channels A and B (see *Appendix H: MIRRORED BITS Communications (in Firmware Versions 6 and 7)*)	Control (only operable in Firmware Versions 6, 7)	53
RST_BK	Reset Breaker Monitor SELOGIC control equation (see *Section 8: Breaker Monitor, Metering, and Load Profile Functions*). The relay resets the breaker monitor accumulators when a rising edge is detected on RST_BK.	Indication, Control	65

Table D.2 Alphabetic List of Relay Word Bits (Sheet 11 of 13)

Name	Description	Usage	Row (*Table D.1*)
RST_DEM	Reset Demand Metering SELOGIC control equation (see *Section 8: Breaker Monitor, Metering, and Load Profile Functions*). The relay resets the demand metering registers when a rising edge is detected on RST_DEM.	Indication, Control	65
RST_ENE	Reset Energy Metering SELOGIC control equation (see *Section 8: Breaker Monitor, Metering, and Load Profile Functions*). The relay resets the energy metering registers when a rising edge is detected on RST_ENE.	Indication, Control	65
RST_HAL	Reset hardware alarm SELOGIC control equation asserted	Indication, Control	65
RST_HIS	Reset Event History SELOGIC control equation (see *Section 8: Breaker Monitor, Metering, and Load Profile Functions*). The relay clears the event history archive when a rising edge is detected on RST_HIS.	Indication, Control	65
RST_MML	Reset Max/Min Metering SELOGIC control equation (see *Section 8: Breaker Monitor, Metering, and Load Profile Functions*). The relay resets the max/min metering registers when a rising edge is detected on RST_MML.	Indication, Control	65
RST_PDM	Reset Peak Demand Metering SELOGIC control equation (see *Section 8: Breaker Monitor, Metering, and Load Profile Functions*). The relay resets the peak demand metering registers when a rising edge is detected on RST_PDM.	Indication, Control	65
RSTDNPE	Reset DNP event registers	Indication, Control	101
RSTMN	Recloser reset timer is timing (see *Reclosing Relay* on page 6.12).	Testing	36
RSTTRGT	Reset Target SELOGIC control equation (see *SELOGIC Control Equation Setting RSTTRGT* on page 5.39). The relay resets the front panel target LEDs when a rising edge is detected on RSTTRGT.	Indication, Control	65
RT	Breaker failure retrip	Tripping, Control	100
SAG3P	Three-phase voltage sag element	Sag/Swell/Int reporting (only operable in Firmware Version 7)	56
SAGA, SAGB, SAGC	A, B, or C-Phase voltage sag elements (see *Figure 3.42*)	Sag/Swell/Int reporting (only operable in Firmware Version 7)	56
SAGAB, SAGBC, SAGCA	Phase-to-phase AB, BC, or CA voltage sag elements (see *Figure 3.42*)	Sag/Swell/Int reporting (only operable in Firmware Version 7)	57
SALARM	Indicates software or user activity	Indication	94
SETCHG	Pulses for approximately one second when settings are changed	Indication	95
SF	Synchronism-check element, slip frequency less than setting 25SF (see *Figure 3.29*)	Testing	21
SFAST	Synchronism-check element, frequency VP > frequency VS (see *Figure 3.29* and *Table 3.15*)	Special control schemes	24
SG1–SG6	Setting group indication, Group 1 through 6, asserted for active group (see *Table 7.3*)	Indication	38
SH0–SH4	Reclosing relay shot counter = 0, 1, 2, 3, or 4 (see *Table 6.3*)	Control	35
SINGLE	Single-phase configuration element (asserts when Global setting PTCONN = SINGLE; see *Figure 9.11*)	Indication	63
SOTFE	Switch-onto-fault logic enable (see *Figure 5.3*)	Testing	41
SSLOW	Synchronism-check element, frequency VP < frequency VS (see *Figure 3.29* and *Table 3.15*)	Special control schemes	24
STOP	Carrier stop (see *Figure 5.14*)	Testing	43
SV1–SV16	SELOGIC variables 1 through 16. Associated timers (below) are picked up when variable is asserted (see *Figure 7.24* and *Figure 7.25*)	Testing, Seal-in functions, etc. (see *Figure 7.28*)	31–34

Table D.2 Alphabetic List of Relay Word Bits (Sheet 12 of 13)

Name	Description	Usage	Row (*Table D.1*)
SV1T–SV16T	SELOGIC timers 1 through 16, timed-out when asserted (see *Figure 7.24* and *Figure 7.25*)	Testing, Seal-in functions, etc. (see *Figure 7.28*)	31–34
SW3P	Three-phase voltage swell element	Sag/Swell/Int reporting (only operable in Firmware Version 7)	56
SWA, SWB, SWC	A, B, or C-Phase voltage swell elements (see *Figure 3.43*)	Sag/Swell/Int reporting (only operable in Firmware Version 7)	56
SWAB, SWBC, SWCA	Phase-to-phase AB, BC, or CA voltage swell elements (see *Figure 3.43*)	Sag/Swell/Int reporting (only operable in Firmware Version 7)	57
TESTDB	Test DataBase command active. Asserts when analog and digital values reported via DNP, Modbus, IEC 61850, or Fast Meter protocol may be overridden (see *Section 10: Communications*).	Testing	63
TIRIG	Relay Time is based on IRIG-B time source (see *Synchrophasor Relay Word Bits* on page N.17)	Synchrophasors	57
TMB1A–TMB8A	Transmit MIRRORED BITS 1 through 8, channel A (see *Appendix H: MIRRORED BITS Communications (in Firmware Versions 6 and 7)*)	Control (only operable in Firmware Versions 6, 7)	50
TMB1B–TMB8B	Transmit MIRRORED BITS 1 through 8, channel B (see *Appendix H: MIRRORED BITS Communications (in Firmware Versions 6 and 7)*)	Control (only operable in Firmware Versions 6, 7)	52
TQUAL1–TQUAL4	Encoded IRIG time quality bits 1 through 4. Only available when Global setting IRIGC = C37.118 and a proper IRIG signal is decoded.	Indication	64
TREA1–TREA4	Trigger Reason bits 1 through 4 (follow SELOGIC control equations of same name—see *Appendix N: Synchrophasors*. Sent with C37.118 synchrophasor message.	Indication, Synchrophasors	66
TRGTR	Target Reset. TRGTR pulses to logical 1 for one processing interval when either the TARGET RESET pushbutton is pushed or the **TAR R** (Target Reset) serial port command is executed (see *Figure 5.1* and *TARGET RESET/LAMP TEST Front-Panel Pushbutton* on page 5.38)	Control	37
TRIP	Trip logic output asserted (see *Figure 5.1*)	Output contact assignment	43
TSNTPB	Asserted when relay time is based on Simple Network Time Protocol (SNTP) backup server.	Indication	67
TSNTPP	Asserted when relay time is based on Simple Network Time Protocol (SNTP) primary server.	Indication	67
TSOK	Time synchronization OK (see *Synchrophasor Relay Word Bits* on page N.17)	Synchrophasors	57
UBB	Unblocking block to Trip logic (see *Figure 5.11*)	Testing	42
UBB1, UBB2	Unblocking block 1 and 2 from DCUB logic (see *Figure 5.10*)	Testing	42
V0GAIN	3V0 high-gain mode active (see *Analog Scaling and Frequency Indicators* on page D.18)	Testing	60
V1GOOD	Positive-sequence overvoltage element (positive-sequence voltage greater than setting VNOM • 0.75 (wye-connected) or VNOM • 0.43 (delta-connected); see *Figure 4.1*)	Testing	60
VB001–VB128	Virtual bits 001 through 128. Virtual bit configuration is controlled by loaded CID file (IEC 61850 relay models only). Virtual bits can be configured to follow received GOOSE messages (see *Appendix P: IEC 61850*).	Control	78–93

Table D.2 Alphabetic List of Relay Word Bits (Sheet 13 of 13)

Name	Description	Usage	Row (*Table D.1*)
VPOLV	Positive-sequence polarization voltage valid (see *Figure 4.26*)	Testing	23
WFC	Weak-infeed condition (see *Figure 5.6*)	Testing	41
WYE	Wye-connected configuration element (asserts when Global setting PTCONN = WYE; see *Figure 9.11*)	Indication	63
Z3RB	Zone (level) 3 reverse block (see *Figure 5.6*)	Testing	41
Z3XT	Logic output from zone (level) 3 extension timer (see *Figure 5.14*)	Testing	42
ZLIN	Load-encroachment “load in” element (see *Figure 4.6*)	Special phase overcurrent element control	38
ZLOAD	= ZLOUT + ZLIN (see *Figure 4.6*)	Special phase overcurrent element control	39
ZLOUT	Load-encroachment “load out” element (see *Figure 4.6*)	Special phase overcurrent element control	38

Analog Scaling and Frequency Indicators

The SEL-351 uses the Relay Word bits listed in *Table D.3* for internal operations, such as event report preparation and phasor measurement. The operating criteria for these elements is not exact, so they should not be included in commissioning tests.

Table D.3 Analog Scaling and Frequency Indicators

Relay Word Bit	Description	Asserts When:
V0GAIN	3V0 high-gain mode active	Zero-sequence voltage $3V_0$ is less than approximately 80 V sec.
INMET	Channel IN high-gain mode active	Channel IN current signal is less than the nominal current rating (5 A, 1 A, 0.2 A, or 0.05 A sec)
ICMET	Channel IC high-gain mode active	Channel IC current signal is less than the nominal current rating (5 A or 1 A sec)
IBMET	Channel IB high-gain mode active	Channel IB current signal is less than the nominal current rating (5 A or 1 A sec)
IAMET	Channel IA high-gain mode active	Channel IA current signal is less than the nominal current rating (5 A or 1 A sec)
FREQOK	System frequency and tracking frequency valid	System frequency measurement source is healthy[a], the frequency is between 40 Hz and 65 Hz, and the rate-of-change-of-frequency is less than 20 Hz/s

[a] The preferred source is the voltage measured on terminal **VA-N**, which must be > 10 V secondary. If the preferred source is unavailable for more than one second, the relay will qualify a backup source from terminals VB-N or VC-N, depending on the PT configuration, as discussed in *Potential Transformer Inputs* on page 2.11.

APPENDIX E

Analog Quantities

Overview

The SEL-351 Relay contains several analog quantities that can be used for more than one function.

Analog quantities are typically generated and used by a primary function, such as metering, and selected analog quantities are made available for one or more supplemental functions, such as the load profile recorder.

SEL-351 analog quantities are generated by the following:

- Metering functions (see *Section 8: Breaker Monitor, Metering, and Load Profile Functions*)
- Breaker monitor (see *Section 8: Breaker Monitor, Metering, and Load Profile Functions*)
- Self-test diagnostics (see *Section 13: Testing and Troubleshooting*)
- Modbus (see *Appendix O: Modbus RTU and TCP Communications*)
- Relay settings (see *Section 9: Setting the Relay*)
- Event history (see *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*)
- System date and time (see *Section 10: Communications*)
- Reclosing relay logic (see *Section 6: Close and Reclose Logic*)

Table E.1 provides a complete list of analog quantities that can be used in the following interfaces (when marked with an "x"):

- Display points (see *Rotating Display* on page 7.37)
- Load profile recorder (see *Load Profile Report (Available in Firmware Versions 6 and 7)* on page 8.45)
- DNP3 (see *Appendix L: DNP3 Communications*)
- Modbus (see *Appendix O: Modbus RTU and TCP Communications*)
- SEL Fast Meter protocol (see *Appendix J: Configuration, Fast Meter, and Fast Operate Commands*)
- IEC 61850 protocol (see *Appendix P: IEC 61850*)

Analog Quantities Table

Table E.1 SEL-351 Analog Quantities (Sheet 1 of 10)

Label	Description	Units	Display Points[a]	Load Profile	DNP3	Modbus	Fast Meter	IEC 61850
Instantaneous Metering								
IA, IB, IC	Phase (A, B, C) Current Magnitudes	A pri	x	x	x	x	x	x
IAFA, IBFA, ICFA	Phase (A, B, C) Current Angles	degrees	[b]		x	x	x	x
IN	Neutral (channel IN) Current Magnitude	A pri	x	x	x	x	x	x
INFA	Neutral (channel IN) Current Angle	degrees	[b]		x	x	x	x
IG	Residual Ground ($3I_0$) Current Magnitude	A pri	x	x	x	x		x
IGFA	Residual Ground ($3I_0$) Current Angle	degrees	[b]		x	x		x
I1	Positive-Sequence (I_1) Current Magnitude	A pri	x	x	x	x	[c]	x
I1FA	Positive-Sequence (I_1) Current Angle	degrees	[b]		x	x	[c]	x
3I2	Negative-Sequence ($3I_2$) Current Magnitude	A pri	x	x	x	x	[c]	x
3I2FA	Negative-Sequence ($3I_2$) Current Angle	degrees	[b]		x	x	[c]	x
3I0	Zero-Sequence ($3I_0$) Current Magnitude	A pri	x		x	x	[c]	x
3I0FA	Zero-Sequence ($3I_0$) Current Angle	degrees	[b]		x	x	[c]	x
VA, VB, VC	Phase (A, B, C) Voltage Magnitudes	kV pri	x[d]	x[d]	x[e]			x[e]
VA, VB, VC	Phase (A, B, C) Voltage Magnitudes	V pri				x[e]	x[e]	
VAFA, VBFA, VCFA	Phase (A, B, C) Voltage Angles	degrees	[b, d]		x[e]	x[e]	x[e]	x[e]
VS	Channel VS Voltage Magnitude	kV pri	x	x	x			x
VS	Channel VS Voltage Magnitude	V pri				x	x	
VSFA	Channel VS Voltage Angle	degrees	[b]		x	x	x	x
VAB, VBC, VCA	Phase-to-Phase (AB, BC, CA) Voltage Magnitudes	kV pri	x	x[e]				x[e]
VAB, VBC, VCA	Phase-to-Phase (AB, BC, CA) Voltage Magnitudes	V pri				x[e]	x[c,e]	
VABFA, VBCFA, VCAFA	Phase-to-Phase (AB, BC, CA) Voltage Angles	degrees	[b]		x[e]	x[e]	x[c,e]	x[e]
V1[f]	Positive-Sequence (V_1) Voltage Magnitude	kV pri	x	x	x			x
V1[f]	Positive-Sequence (V_1) Voltage Magnitude	V pri				x	[c]	

Table E.1 SEL-351 Analog Quantities (Sheet 2 of 10)

Label	Description	Units	Display Points[a]	Load Profile	DNP3	Modbus	Fast Meter	IEC 61850
V1FA[f]	Positive-Sequence (V_1) Voltage Angle	degrees	[b]		x	x	[c]	x
V2[f]	Negative-Sequence (V_2) Voltage Magnitude	kV pri	x	x	x			x
V2[f]	Negative -Sequence (V_2) Voltage Magnitude	V pri				x	[c]	
V2FA[f]	Negative -Sequence (V_2) Voltage Angle	degrees	[b]		x	x	[c]	x
3V0[f, g]	Zero-Sequence ($3V_0$) Voltage Magnitude	kV pri	x	x				
3V0_MAG[f, g]	Zero-Sequence ($3V_0$) Voltage Magnitude	kV pri			x			x
3V0_MAG[f, g]	Zero-Sequence ($3V_0$) Voltage Magnitude	V pri				x	[c]	
3V0FA[f, g]	Zero-Sequence ($3V_0$) Voltage Angle	degrees	[b]		x	x	[c]	x
MWA, MWB, MWC[g, h]	Phase (A, B, C) Real Power	MW	x	x	x		[c]	
KWA, KWB, KWC[g, h]	Phase (A, B, C) Real Power	kW				x		x
MW3[h]	Three-Phase Real Power	MW	x	x	x		[c]	
KW3[h]	Three-Phase Real Power	kW				x		x
MVARA, MVARB, MVARC[g, h]	Phase (A, B, C) Reactive Power	MVAr	x	x	x		[c]	
KVARA, KVARB, KVARC[g, h]	Phase (A, B, C) Reactive Power	kVAr				x		x
MVAR3[h]	Three-Phase Reactive Power	MVAr	x	x	x		[c]	
kVAR3[h]	Three-Phase Reactive Power	kVAr				x		x
PFA, PFB, PFC[g, h]	Phase (A, B, C) Power Factor	per unit	x	x	x	x		x
PF3[h]	Three-Phase Power Factor	per unit	x	x	x	x		x
LDPFA, LDPFB, LDP-FC[g, h]	Phase (A, B, C) Power Factor Leading (1 indicates leading PF)	0 or 1	[i]	x	x	x		
LDPF3[h]	Three-Phase Power Factor Leading (1 indicates leading PF)	0 or 1	[i]	x	x	x		
VDC	Station DC Battery Voltage	V	x	x	x	x	x	x
FREQ	System Frequency	Hz	x	x	x	x	x	x
Demand Metering								
IADEM, IBDEM, ICDEM	Phase (A, B, C) Demand Current	A pri	x	x	x	x	x	x
INDEM	Neutral (channel IN) Demand Cur-rent	A pri	x	x	x	x	x	x

Table E.1 SEL-351 Analog Quantities (Sheet 3 of 10)

Label	Description	Units	Display Points[a]	Load Profile	DNP3	Modbus	Fast Meter	IEC 61850
IGDEM	Residual Ground ($3I_0$) Demand Current	A pri	x	x	x	x	x	x
3I2DEM	Negative-Sequence ($3I_2$) Demand Current	A pri	x	x	x	x	x	x
MWADI, MWBDI, MWCDI[g, h]	Phase (A, B, C) Real Power Demand—IN	MW	x	x	x		x	
KWADI, KWBDI, KWCDI[g, h]	Phase (A, B, C) Real Power Demand—IN	kW				x		
MW3DI[h]	Three-Phase Real Power Demand—IN	MW	x	x	x		x	
KW3DI[h]	Three-Phase Real Power Demand—IN	kW				x		
MWADO, MWBDO, MWCDO[g, h]	Phase (A, B, C) Real Power Demand—OUT	MW	x	x	x		x	
KWADO, KWBDO, KWCDO[g, h]	Phase (A, B, C) Real Power Demand—OUT	kW				x		
MW3DO[h]	Three-Phase Real Power Demand—OUT	MW	x	x	x		x	
KW3DO[h]	Three-Phase Real Power Demand—OUT	kW				x		
MVRADI, MVRBDI, MVRCDI[g, h]	Phase (A, B, C) Reactive Power Demand—IN	MVAr	x	x	x		x	
KVRADI, KVRBDI, KVRCDI[g, h]	Phase (A, B, C) Reactive Power Demand—IN	kVAr				x		
MVR3DI[h]	Three-Phase Reactive Power Demand—IN	MVAr	x	x	x		x	
KVR3DI[h]	Three-Phase Reactive Power Demand—IN	kVAr				x		
MVRADO, MVRBDO, MVRCDO[g, h]	Phase (A, B, C) Reactive Power Demand—OUT	MVAr	x	x	x		x	
KVRADO, KVRBDO, KVRCDO[g, h]	Phase (A, B, C) Reactive Power Demand—OUT	kVAr				x		
MVR3DO[h]	Three-Phase Reactive Power Demand—OUT	MVAr	x	x	x		x	
KVR3DO[h]	Three-Phase Reactive Power Demand—OUT	kVAr				x		
Peak (Demand) Metering								
IAPK, IBPK, ICPK	Phase (A, B, C) Peak Demand Current	A pri	x		x	x	x	x
INPK	Neutral (channel IN) Peak Demand Current	A pri	x		x	x	x	x
IGPK	Residual Ground ($3I_0$) Peak Demand Current	A pri	x		x	x	x	x

Table E.1 SEL-351 Analog Quantities (Sheet 4 of 10)

Label	Description	Units	Display Points[a]	Load Profile	DNP3	Modbus	Fast Meter	IEC 61850
3I2PK	Negative-Sequence ($3I_2$) Peak Demand Current	A pri	x		x	x	x	x
MWAPI, MWBPI, MWCPI[g, h]	Phase (A, B, C) Real Power Peak Demand—IN	MW	x		x		x	
KWAPI, KWBPI, KWCPI[g, h]	Phase (A, B, C) Real Power Peak Demand—IN	kW				x		
MW3PI[h]	Three-Phase Real Power Peak Demand—IN	MW	x		x		x	
KW3PI[h]	Three-Phase Real Power Peak Demand—IN	kW				x		
MWAPO, MWBPO, MWCPO[g, h]	Phase (A, B, C) Real Power Peak Demand—OUT	MW	x		x		x	
KWAPO, KWBPO, KWCPO[g, h]	Phase (A, B, C) Real Power Peak Demand—OUT	kW				x		
MW3PO[h]	Three-Phase Real Power Peak Demand—OUT	MW	x		x		x	
KW3PO[h]	Three-Phase Real Power Peak Demand—OUT	kW				x		
MVRAPI, MVRBPI, MVRCPI[g, h]	Phase (A, B, C) Reactive Power Peak Demand—IN	MVAr	x		x		x	
KVRAPI, KVRBPI, KVRCPI[g, h]	Phase (A, B, C) Reactive Power Peak Demand—IN	kVAr				x		
MVR3PI[h]	Three-Phase Reactive Power Peak Demand—IN	MVAr	x		x		x	
KVR3PI[h]	Three-Phase Reactive Power Peak Demand—IN	kVAr				x		
MVRAPO, MVRBPO, MVRCPO[g, h]	Phase (A, B, C) Reactive Power Peak Demand—OUT	MVAr	x		x		x	
KVRAPO, KVRBPO, KVRCPO[g, h]	Phase (A, B, C) Reactive Power Peak Demand—OUT	kVAr				x		
MVR3PO[h]	Three-Phase Reactive Power Peak Demand—OUT	MVAr	x		x		x	
KVR3PO[h]	Three-Phase Reactive Power Peak Demand—OUT	kVAr				x		
Energy Metering[h]								
MWHAI, MWHBI, MWHCI[g]	Phase (A, B, C) Real Energy—IN	MWh	x	x	x	x		
MWH3I	Three-Phase Real Energy—IN	MWh	x	x	x	x		x
MWHAO, MWHBO, MWHCO[g]	Phase (A, B, C) Real Energy—OUT	MWh	x	x	x	x		
MWH3O	Three-Phase Real Energy—OUT	MWh	x	x	x	x		x

Table E.1 SEL-351 Analog Quantities (Sheet 5 of 10)

Label	Description	Units	Display Points[a]	Load Profile	DNP3	Modbus	Fast Meter	IEC 61850
MVRHAI, MVRHBI, MVRHCI[g]	Phase (A, B, C) Reactive Energy—IN	MVArh	x	x	x	x		
MVRH3I	Three-Phase Reactive Energy—IN	MVArh	x	x	x	x		x
MVRHAO, MVRHBO, MVRHCO[g]	Phase (A, B, C) Reactive Energy—OUT	MVArh	x	x	x	x		
MVRH3O	Three-Phase Reactive Energy—OUT	MVArh	x	x	x	x		x
Harmonic Metering—Currents								
IAHT, IBHT, ICHT	Phase (A, B, C) Current Total Harmonic Distortion (THD)	%	x	x	x	x		
INHT	Neutral (channel IN) Current Total Harmonic Distortion (THD)	%	x	x	x	x		
IAHR, IBHR, ICHR	Phase (A, B, C) Current RMS Magnitude	A pri	x	x	x	x		
INHR	Neutral (channel IN) Current RMS Magnitude	A pri	x	x	x	x		
IAH01, IBH01, ICH01[j]	Phase (A, B, C) Current Fundamental Magnitude (harmonic metering)	A pri	x	x	x	x		
INH01[j]	Neutral (channel IN) Current Fundamental Magnitude (harmonic metering)	A pri	x	x	x	x		
IAH*nn*, IBH*nn*, ICH*nn*[k]	Phase (A, B, C) Current Harmonic *nn* (*nn* = 02–16)	%						
INH*nn*[k]	Neutral (channel IN) Current Harmonic *nn* (*nn* = 02–16)	%						
Harmonic Metering—Voltages (when Global setting PTCONN = WYE or SINGLE)								
VAHT, VBHT, VCHT	Phase (A, B, C) Voltage Total Harmonic Distortion (THD)	%	x	x	x	x		
VSHT	Channel VS Voltage Total Harmonic Distortion (THD)	%	x	x	x	x		
VAHR, VBHR, VCHR	Phase (A, B, C) Voltage RMS Magnitude	kV pri	x	x	x			
VAHR, VBHR, VCHR	Phase (A, B, C) Voltage RMS Magnitude	V pri				x		
VSHR	Channel VS Voltage RMS Magnitude	kV pri	x	x	x			
VSHR	Channel VS Voltage RMS Magnitude	V pri				x		
VAH01, VBH01, VCH01[j]	Phase (A, B, C) Voltage Fundamental Magnitude (harmonic metering)	kV pri	x	x	x			
VAH01, VBH01, VCH01[j]	Phase (A, B, C) Voltage Fundamental Magnitude (harmonic metering)	V pri				x		
VSH01[j]	Channel VS Voltage Fundamental Magnitude (harmonic metering)	kV pri	x	x	x			

Table E.1 SEL-351 Analog Quantities (Sheet 6 of 10)

Label	Description	Units	Display Points[a]	Load Profile	DNP3	Modbus	Fast Meter	IEC 61850
VSH01[j]	Channel VS Voltage Fundamental Magnitude (harmonic metering)	V pri				x		
VAH*nn*, VBH*nn*, VCH*nn*[k]	Phase (A, B, C) Voltage Harmonic *nn* (*nn* = 02–16)	%						
VSH*nn*[k]	Channel VS Voltage Harmonic *nn* (*nn* = 02–16)	%						
Harmonic Metering—Voltages (when Global setting PTCONN = DELTA)								
VAHT	Phase-to-Phase AB Voltage Total Harmonic Distortion (THD)	%	x	x	x	x		
VCHT	Phase-to-Phase BC Voltage Total Harmonic Distortion (THD)	%	x	x	x	x		
VSHT	Channel VS Voltage Total Harmonic Distortion (THD)	%	x	x	x	x		
VAHR	Phase-to-Phase AB Voltage RMS Magnitude	kV pri	x	x	x			
VAHR	Phase-to-Phase AB Voltage RMS Magnitude	V pri				x		
VCHR	Phase-to-Phase BC Voltage RMS Magnitude	kV pri	x	x	x			
VCHR	Phase-to-Phase BC Voltage RMS Magnitude	V pri				x		
VSHR	Channel VS Voltage RMS Magnitude	kV pri	x	x	x			
VSHR	Channel VS Voltage RMS Magnitude	V pri				x		
VAH01[j]	Phase-to-Phase AB Voltage Fundamental Magnitude (harmonic metering)	kV pri	x	x	x			
VAH01[j]	Phase-to-Phase AB Voltage Fundamental Magnitude (harmonic metering)	V pri				x		
VCH01[j]	Phase-to-Phase BC Voltage Fundamental Magnitude (harmonic metering)	kV pri	x	x	x			
VCH01[j]	Phase-to-Phase BC Voltage Fundamental Magnitude (harmonic metering)	V pri				x		
VSH01[j]	Channel VS Voltage Fundamental Magnitude (harmonic metering)	kV pri	x	x	x			
VSH01[j]	Channel VS Voltage Fundamental Magnitude (harmonic metering)	V pri				x		
VAH*nn*[k]	Phase-to-Phase AB Voltage Harmonic *nn* (*nn* = 02–16)	%						
VCH*nn*[k]	Phase-to-Phase BC Voltage Harmonic *nn* (*nn* = 02–16)	%						
VSH*nn*[k]	Channel VS Voltage Harmonic *nn* (*nn* = 02–16)	%						

Table E.1 SEL-351 Analog Quantities (Sheet 7 of 10)

Label	Description	Units	Display Points[a]	Load Profile	DNP3	Modbus	Fast Meter	IEC 61850
Breaker Monitor								
BRKDAT	Last Reset Date	date	x					
BRKTIM	Last Reset Time	time	x					
INTTR	Internal Trip Counter	count	x		x[1]	x		x
OPSCTR	Combined Operations Counter = (INTTR + EXTTR)	count	x					
INTIA, INTIB, INTIC	Accumulated current—internal trips, A-, B-, and C-phase	kA	x					
EXTTR	External Trip Counter	count	x		x[1]	x		x
EXTIA, EXTIB, EXTIC	Accumulated current—external trips, A-, B-, and C-phase	kA	x					
WEARA, WEARB, WEARC	Breaker Wear %—A-, B-, and C-phase	percent	x		x	x		x
MAXWEAR	Greatest wear of WEARA, WEARB, or WEARC	percent	x		x	x		x
EOTTRAAV	Average electrical trip operating time, A-phase	ms			x	x		x
EOTTRBAV	Average electrical trip operating time, B-phase	ms			x	x		x
EOTTRCAV	Average electrical trip operating time, C-phase	ms			x	x		x
EOTCLAAV	Average electrical close operating time, A-phase	ms			x	x		x
EOTCLBAV	Average electrical close operating time, B-phase	ms			x	x		x
EOTCLCAV	Average electrical close operating time, C-phase	ms			x	x		x
MOTTRAV	Average mechanical trip operating time	ms			x	x		x
MOTCLAV	Average mechanical close operating time	ms			x	x		x
ESOALCNT	Electrical operation alarm counter	counts			x	x		x
MSOALCNT	Mechanical operation alarm counter	counts			x	x		x
Event History								
NUMEVE	Event History Number	count				x		
EVESEL	Selected History Number	count				x		
FDATE_Y	Fault date—Year portion	year				x		
FDATE_M	Fault date—Month portion	month				x		
FDATE_D	Fault date—Day portion	day				x		
FTIME_H	Fault time—Hour portion	hour				x		
FTIME_M	Fault time—Minute portion	minute				x		
FTIME_S	Fault time—Second portion	second				x		
FTIMEH	Fault date/time stamp—High word	binary			x			

Table E.1 SEL-351 Analog Quantities (Sheet 8 of 10)

Label	Description	Units	Display Points[a]	Load Profile	DNP3	Modbus	Fast Meter	IEC 61850
FTIMEH16	Fault date/time stamp—High word formatted as a 16-bit signed value	binary			x			
FTIMEM	Fault date/time stamp—Middle word	binary			x			
FTIMEM16	Fault date/time stamp—Middle word formatted as a 16-bit signed value	binary			x			
FTIMEL	Fault date/time stamp—Low word	binary			x			
FTIMEL16	Fault date/time stamp—Low word formatted as a 16-bit signed value	binary			x			
FTYPE[m]	Fault Type				x			
FTYPE16[m]	Fault Type formatted as a 16-bit signed value				x			
EVE_TYPE[m]	Event Type					x		
FI[n]	Highest Phase Fault Current (maximum of FIA, FIB, and FIC)	A pri			x	x		x
FIA, FIB, FIC[n]	Phase (A, B, C) Fault Current from maximum current event report row	A pri			x	x		x
FIG[n]	Ground Fault Current from maximum current event report row	A pri			x	x		x
FIN[n]	Neutral Fault Current from maximum current event report row	A pri			x	x		x
FIQ[n]	Negative Sequence Fault Current from maximum current event report row	A pri			x	x		x
FLI	Highest Phase Fault Locator Current (from maximum of FLIA, FLIB, and FLIC)	A pri			x			
FLIA, FLIB, FLIC	Fault Locator Phase (A, B, C) Fault Current	A pri			x			
FLIG	Fault Locator Ground Fault Current	A pri			x			
FLIN	Fault Locator Neutral Fault Current	A pri			x			
FLIQ	Fault Locator Negative-Sequence Fault Current	A pri			x			
FFREQ	Event Frequency	Hz			x	x		
FGRP	Setting group active at event trigger	count			x	x		
FSHO	Reclosing relay Shot Counter at event trigger	count			x	x		
FUNR	Number of Unread faults	count			x			
Fault Location								
FLOC[o,p]	Fault Location	LL units			x	x		x
FZ[o]	Fault Impedance Magnitude	Ω sec			x	x		x
FZFA[o]	Fault Impedance Angle	degrees			x	x		x

Table E.1 SEL-351 Analog Quantities (Sheet 9 of 10)

Label	Description	Units	Display Points[a]	Load Profile	DNP3	Modbus	Fast Meter	IEC 61850
Time-Overcurrent Element (TOC) Pickup Settings								
51AP, 51BP, 51CP	Pickup for A-, B-, or C-Phase TOC elements	A pri	x[q]		x			
51PP	Pickup for maximum-phase TOC element 51PT	A pri	x[q]		x			
51NP	Pickup for neutral TOC element 51NT	A pri	x[q]		x			
51GP	Pickup for residual ground (IG = $3I_0$) TOC element 51GT	A pri	x[q]		x			
51G2P	Pickup for residual ground (IG = $3I_0$) TOC element 51G2T	A pri	x[q]		x			
51QP	Pickup for negative-sequence ($3I_2$) TOC element 51QT	A pri	x[q]		x			
Setting Group, Date, Time, and Internal Temperature								
ACTGRP	Active Settings Group	count			x[r]	x		
DATE	Present Date from relay clock	date					x	
TIME	Present Time from relay clock	time					x	
DATE_Y	Present date—Year portion	year				x		
DATE_M	Present date—Month portion	month				x		
DATE_D	Present date—Day portion	day				x		
TIME_H	Present time—Hour portion	hour				x		
TIME_M	Present time—Minute portion	minute				x		
TIME_S	Present time—Second portion	second				x		
	Combined Date/Time (DNP Object 50). No label required.	binary			x			
TEMP	Relay internal temperature	degrees C			x	x		
Modbus Communications Counters								
MSGRCD	Number of Messages Received	count				x		
MSGOID	Number of Messages to Other devices (Other ID)	count				x		
ILLADDR	Illegal Address count	count				x		
BADCRC	Bad CRC count	count				x		
UARTER	Uart Error count	count				x		
ILLFUNC	Illegal Function count	count				x		
ILLREG	Illegal Register count	count				x		
ILLDATA	Illegal Data count	count				x		
BADPF	Bad Packet Format count	count				x		
BADPL	Bad Packet Length count	count				x		
Relay Information								
FWREV	Relay Firmware Revision				x	x		x
SNUMBL	Relay Serial Number, Lowest Four Digits				x	x		x

Table E.1 SEL-351 Analog Quantities (Sheet 10 of 10)

Label	Description	Units	Display Points[a]	Load Profile	DNP3	Modbus	Fast Meter	IEC 61850
SNUMBM	Relay Serial Number, Middle Four Digits				x	x		x
SNUMBH	Relay Serial Number, High Four Digits				x	x		x

[a] Display points analog quantities must be preceded by "::" in the DPn_0 and DPn_1 text settings (n = 1–16).

[b] Angles are automatically included in Display Points when the corresponding magnitude is selected. For example, Setting "DP1_0 = ::IB" will display `IB= 256.2A-121°` as display point 1 when DP1 = logical 0.

[c] Quantity calculated from other Fast Meter data in SEL Communications Processor 20METER data region. The label used in the 20METER data region may differ.

[d] Per-phase voltage values are not available when PTCONN = DELTA.

[e] When PTCONN = DELTA, the relay returns phase-to-phase values for voltage labels VA, VB, VC, VAFA, VBFA, VCFA for DNP3, Modbus, and IEC 61850 protocols. i.e., VA returns VAB, VB returns VBC, and VC returns VCA. Phase-to-phase voltage labels VAB, VBC, VCA, VABFA, VBCFA, and VCAFB are available for DNP, Modbus, and IEC 61850 protocols when PTCONN = WYE or DELTA. The Fast Meter protocol automatically changes the label in the configuration message to indicate phase-to-phase values when PTCONN = DELTA.

[f] Voltage symmetrical component metering values forced to 0.00 when Global setting PTCONN = SINGLE.

[g] Zero-sequence voltage, and per-phase power, power factor, demand power, peak demand power, and energy values are not available when PTCONN = DELTA. DNP and Modbus maps may contain these labels, and the relay will return values of 0.00, except for power factors which will be reported as 1.00.

[h] Power factors forced to 1.00 lagging, metering power, energy, and related demand values forced to 0.00 when Global settings PTCONN = SINGLE and PHANTV = OFF.

[i] Lag or lead is automatically included in Display Points for power factor. For example, Setting "DP2_0 = ::PF3" will display `PF 3P = 0.76 LAG` as display point 2 when DP2 = logical 0.

[j] The first harmonic (01) is also called the "fundamental" component and comes from the harmonic metering subsystem. This quantity may be different than the quantity from the fundamental metering subsystem because the relay calculates the two numbers using different methods. For example, VBH01 may not exactly match VB (from Fundamental Metering).

[k] Individual harmonics nn = 02 to 16, expressed as a percentage of the fundamental (IxH01 or VxH01) quantity for the same signal, are only available via serial port **MET H** command or front-panel METER display.

[l] Available in DNP as a counter input.

[m] Refer to *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER* for definitions of FTYPE and EVE_TYPE values.

[n] For Modbus and IEC 61850, current used is controlled by Global Setting FLTDISP. See *Appendix O: Modbus RTU and TCP Communications* and *Appendix P: IEC 61850* for more details.

[o] When fault location is undefined, for IEC-61850, the relay will report –999.9 for FLOC, and FZ, and 0 for FZFA. For DNP, the relay will report –9999 for FLOC, –99990 for FZ, and 0 for FZFA after default scaling. For Modbus, the relay will report 32767 for FLOC, 65535 for FZ, and 18000 for FZFA.

[p] Fault location is a unitless quantity and depends upon the units used for Group setting LL. IEC61850 assumes the units are km.

[q] See *Additional Format for Displaying Time-Overcurrent Elements on the Rotating Display* on page 7.48 for full display point formatting options.

[r] Available in DNP as both a counter input and analog output.

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APPENDIX F

Setting SELOGIC Control Equations

Overview

SELOGIC control equations combine relay protection and control elements with logic operators to create custom protection and control schemes. This appendix shows how to set the protection and control elements (Relay Word bits) in the SELOGIC control equations.

Additional SELOGIC control equation setting details are available in *Section 9: Setting the Relay* (see also *SELOGIC Control Equation Settings (Serial Port Command SET L)* on page SET.23). See the ***SHO*** *(Show/View Settings)* on page 10.68 for a list of the factory default settings.

Relay Word Bits

Most of the protection and control element *logic outputs* shown in the various figures in *Section 3* through *Section 8* are Relay Word bits (labeled as such in the figures). Each Relay Word bit has a label name and can be in either of the following states:

- 1 (logical 1)
- or 0 (logical 0)

Logical 1 represents an element being picked up, timed out, or otherwise asserted.

Logical 0 represents an element being dropped out or otherwise deasserted.

A complete listing of Relay Word bits and their descriptions is referenced in *Table D.1* and *Table D.2*.

Relay Word Bit Operation Example—Phase Time-Overcurrent Element 51PT

As an example of protection element operation via the logic output of Relay Word bits, a phase time-overcurrent element is examined. Refer to phase time-overcurrent element 51PT in *Figure 3.14*. Read the text that accompanies *Figure 3.14* (*Table 3.3* and following text).

The following Relay Word bits are the logic outputs of the phase time-overcurrent element:

Table F.1 Logic Outputs of the Phase Time-Overcurrent Element

Logic Output	Description
51P	indication that the maximum phase current magnitude is above the level of the phase time-overcurrent pickup setting 51PP
51PT	indication that the phase time-overcurrent element has timed out on its curve
51PR	indication that the phase time-overcurrent element is fully reset

Phase Time-Overcurrent Element 51PT Pickup Indication

If the maximum phase current is *at or below* the level of the phase time-overcurrent pickup setting 51PP, Relay Word bit 51P is in the following state:

51P = 0 (logical 0)

If the maximum phase current is *above* the level of the phase time-overcurrent pickup setting 51PP, Relay Word bit 51P is in the following state:

51P = 1 (logical 1)

If the maximum phase current is *above* the level of the phase time-overcurrent pickup setting 51PP, phase time-overcurrent element 51PT is either timing on its curve or is already timed out.

Phase Time-Overcurrent Element 51PT Time-Out Indication

If phase time-overcurrent element 51PT is *not timed out* on its curve, Relay Word bit 51PT is in the following state:

51PT = 0 (logical 0)

If phase time-overcurrent element 51PT is *timed out* on its curve, Relay Word bit 51PT is in the following state:

51PT = 1 (logical 1)

Phase Time-Overcurrent Element 51PT Reset Indication

If phase time-overcurrent element 51PT is *not fully reset*, Relay Word bit 51PR is in the following state:

51PR = 0 (logical 0)

If phase time-overcurrent element is *fully reset*, Relay Word bit 51PR is in the following state:

51PR = 1 (logical 1)

If phase time-overcurrent element 51PT is *not fully reset*, the element is either:

- ➤ Timing on its curve
- ➤ Already timed out
- ➤ Is timing to reset (one-cycle reset or electromechanical emulation—see setting 51PRS)

Relay Word Bit Application Examples—Phase Time-Overcurrent Element 51PT

Table F.2 describes common uses for Relay Word bits 51P, 51PT, and 51PR:

Table F.2 Common uses for Relay Word bits 51P, 51PT, and 51PR

Relay Word Bit	Common Uses
51P	testing (e.g., assign to an output contact for pickup testing) trip unlatch logic (see *Example of NOT Operator ! Applied to Multiple Elements (Within Parentheses)* on page F.7)
51PT	trip logic (see *SELOGIC Control Equation Operation Example—Tripping* on page F.7)
51PR	used in testing (e.g., assign to an output contact for reset indication)

Other Relay Word Bits

The preceding example was for a phase time-overcurrent element, demonstrating Relay Word bit operation for pickup, time-out, and reset conditions. Other Relay Word bits (e.g., those for definite-time overcurrent elements, voltage elements, frequency elements) behave similarly in their assertion or deassertion to logical 1 or logical 0, respectively. The time-overcurrent elements (like the preceding phase time-overcurrent element example) are rather unique because they have a Relay Word bit (e.g., 51PR) that asserts for the reset state of the element.

Relay Word bits are used in SELOGIC control equations, which are explained in the following subsection.

SELOGIC Control Equations

Many of the protection and control element *logic inputs* shown in the various figures in *Section 3* through *Section 8* are SELOGIC control equations (labeled "SELOGIC Settings" in most of the figures). SELOGIC control equations are set with combinations of Relay Word bits to accomplish such functions as:

- ➤ Tripping circuit breakers
- ➤ Assigning functions to optoisolated inputs
- ➤ Operating output contacts
- ➤ Torque-controlling overcurrent elements
- ➤ Switching active setting groups
- ➤ Enabling/disabling reclosing

Traditional or advanced custom schemes can be created with SELOGIC control equations.

SELOGIC Control Equation Operators

SELOGIC control equation settings use logic similar to Boolean algebra logic, combining Relay Word bits together using one or more of the six SELOGIC control equation operators listed in *Table F.3*.

Table F.3 SELOGIC Control Equation Operators (Listed in Processing Order)

Operator	Logic Function
/	rising-edge detect
\	falling-edge detect
()	parentheses
!	NOT
*	AND
+	OR

Operators in a SELOGIC control equation setting are processed in the order shown in *Table F.3*.

SELOGIC Control Equation Rising-Edge Operator /

The rising-edge operator / is applied to individual Relay Word bits only—not to groups of elements within parentheses. For example, the SELOGIC control equation event report generation setting uses rising-edge operators:

ER = **/51P + /51G + /OUT103**

The Relay Word bits in this factory setting example are:

Relay Word Bit	Description
51P	Maximum phase current above pickup setting 51PP for phase time-overcurrent element 51PT (see *Figure 3.14*)
51G	Residual ground current above pickup setting 51GP for residual ground time-overcurrent element 51GT (see *Figure 3.19*)
OUT103	Output contact **OUT103** is set as a breaker failure trip output (see *Output Contacts* on page 7.33)

When setting ER sees a logical 0 to logical 1 transition, it generates an event report (if the relay is not already generating a report that encompasses the new transition). The rising-edge operators in the above factory setting example allow setting ER to see each transition individually.

Suppose a ground fault occurs and a breaker failure condition finally results. *Figure F.1* demonstrates the action of the rising-edge operator / on the individual elements in setting ER.

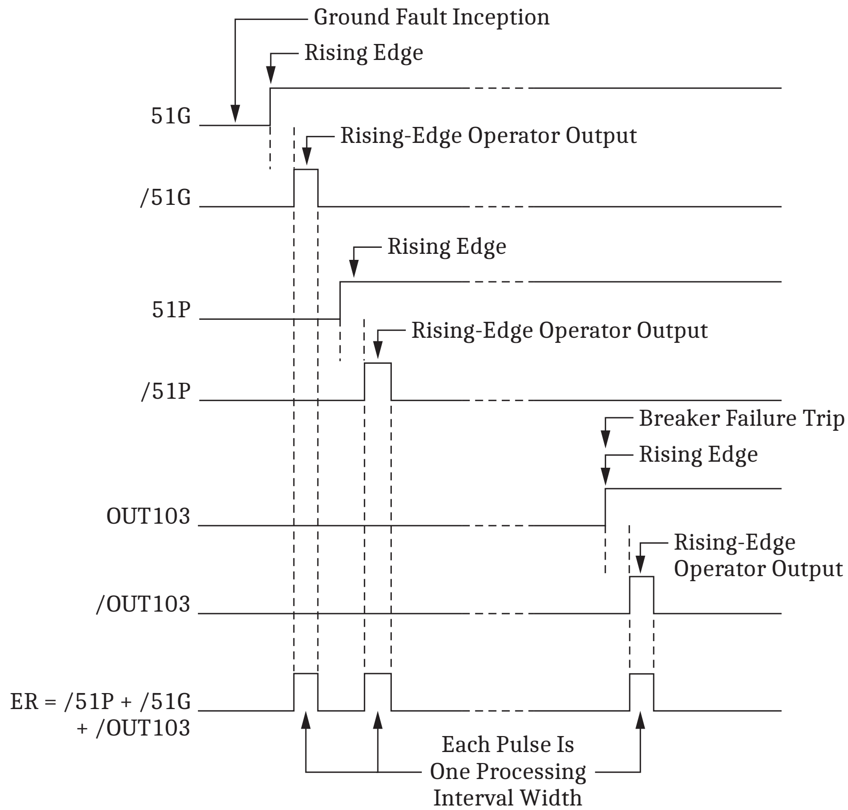


Figure F.1 Result of Rising-Edge Operators on Individual Elements in Setting ER

Note in *Figure F.1* that setting ER sees three separate rising edges, because of the application of rising-edge operators /. The rising-edge operator / in front of a Relay Word bit sees this logical 0 to logical 1 transition as a "rising edge" and the resultant asserts to logical 1 for one processing interval. The assertions of 51G and 51P are close enough that they will be on the same event report (generated by 51G asserting first). The assertion of OUT103 for a breaker failure condition is some appreciable time later and will generate another event report, if the first event report capture has ended when OUT103 asserts.

If the rising-edge operators / were not applied and setting ER was:

ER = **51P + 51G + OUT103**

the ER setting would not see the assertion of OUT103, because 51G and 51P would continue to be asserted at logical 1, as shown in *Figure F.1*.

SELOGIC Control Equation Falling-Edge Operator \

The falling-edge operator \ is applied to individual Relay Word bits only—not to groups of elements within parentheses. The falling-edge operator \ operates similar to the rising-edge operator, but looks for Relay Word bit deassertion (element going from logical 1 to logical 0). The falling-edge operator \ in front of a Relay Word bit sees this logical 1 to logical 0 transition as a "falling edge" and asserts to logical 1 for one processing interval.

For example, suppose the SELOGIC control equation event report generation setting is set with the detection of the falling edge of an underfrequency element:

ER = **... + \81D1T**

When frequency goes above the corresponding pickup level 81D1P, Relay Word bit 81D1T deasserts and an event report is generated (if the relay is not already generating a report that encompasses the new transition). This allows a recovery from an underfrequency condition to be observed. See *Figure 3.40* and *Table 3.17*. *Figure F.2* demonstrates the action of the falling-edge operator \ on the underfrequency element in setting ER.

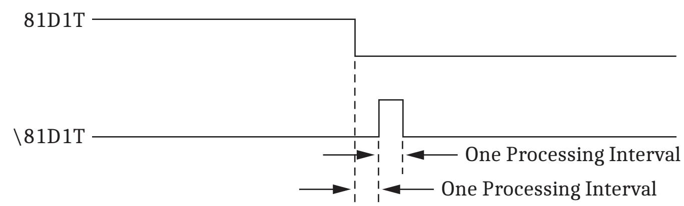


Figure F.2 Result of Falling-Edge Operator on a Deasserting Underfrequency Element

SELOGIC Control Equation Parentheses Operator ( )

More than one set of parentheses ( ) can be used in a SELOGIC control equation setting. For example, the following SELOGIC control equation setting has two sets of parentheses:

SV7 = **(SV7 + IN101) * (50P1 + 50N1)**

In the above example, the logic within the parentheses is processed first and then the two parentheses resultants are ANDed together. The above example is from *Figure 7.28*. Parentheses cannot be "nested" (parentheses within parentheses) in an SEL-351 SELOGIC control equation setting.

SELOGIC Control Equation NOT Operator !

The NOT operator ! is applied to a single Relay Word bit and also to multiple elements (within parentheses). Following are examples of both.

Example of NOT Operator ! Applied to Single Element

The internal circuit breaker status logic in the SEL-351 operates on 52a circuit breaker auxiliary contact logic. The SELOGIC control equation circuit breaker status setting is labeled 52A. See *Optoisolated Inputs* on page 7.1 and *Close Logic* on page 6.2 for more information on SELOGIC control equation circuit breaker status setting 52A.

When a circuit breaker is closed, the 52a circuit breaker auxiliary contact is closed. When a circuit breaker is open, the 52a contact is open.

The opposite is true for a 52b circuit breaker auxiliary contact. When a circuit breaker is closed, the 52b circuit breaker auxiliary contact is open. When the circuit breaker is open, the 52b contact is closed.

If a 52a contact is connected to optoisolated input **IN101**, the SELOGIC control equation circuit breaker status setting 52A is set:

52A = **IN101**

Conversely, if a 52b contact is connected to optoisolated input **IN101**, the SELOGIC control equation circuit breaker status setting 52A is set:

52A = **!IN101** [=NOT(IN101)]

With a 52b contact connected, if the circuit breaker is closed, the 52b contact is open and input **IN101** is de-energized [IN101 = 0 (logical 0)]:

52A = **!IN101** = NOT(IN101) = NOT(0) = 1

Thus, the SELOGIC control equation circuit breaker status setting 52A sees a closed circuit breaker.

With a 52b contact connected, if the circuit breaker is open, the 52b contact is closed and input **IN101** is energized [IN101 = 1 (logical 1)]:

52A = **!IN101** = NOT(IN101) = NOT(1) = 0

Thus, the SELOGIC control equation circuit breaker status setting 52A sees an open circuit breaker.

Example of NOT Operator ! Applied to Multiple Elements (Within Parentheses)

The SELOGIC control equation trip unlatch setting is set as follows:

ULTR = **!(51P + 51G)**

Refer also to *Trip Logic* on page 5.1.

In this factory setting example, the unlatch condition comes true only when *both* the 51P (phase time-overcurrent element pickup indication) and 51G (residual ground time-overcurrent element pickup indication) Relay Word bits deassert:

ULTR = **!(51P + 51G)** = NOT(51P + 51G)

As stated previously, the logic within the parentheses is performed first. In this example, the states of Relay Word bits 51P and 51G are ORed together. Then the NOT operator is applied to the logic resultant from the parentheses.

If either one of 51P or 51G is still asserted [e.g., 51G = 1 (logical 1)], the unlatch condition is not true:

ULTR = **NOT(51P + 51G)** = NOT(0 + 1) = NOT(1) = 0

If *both* 51P and 51G are deasserted [i.e., 51P = 0 and 51G = 0 (logical 0)], the unlatch condition is true:

ULTR = **NOT(51P + 51G)** = NOT(0 + 0) = NOT(0) = 1

and the trip condition can unlatch, subject to other conditions in the trip logic (see *Figure 5.1*).

SELOGIC Control Equation Operation Example—Tripping

If tripping does not involve communications-assisted or switch-onto-fault trip logic, the SELOGIC control equation trip settings TR and TRQUAL are the only trip settings needed. Refer to *Trip Logic* on page 5.1.

Note that *Figure 5.1* appears quite complex. But because tripping does not involve communications-assisted or switch-onto-fault trip logic in this example, respective SELOGIC control equation trip settings TRCOMM and TRSOTF are not used. The only effective input into logic gate OR-1 in *Figure 5.1* is SELOGIC control equation trip settings TR and TRQUAL. The following example is intended to illustrate the use of various SELOGIC control equation operators and not to recommend trip logic for any particular application.

TR = **51PT + 51GT + 50P1 * SH0** (fuse saving example)

TRQUAL = **0**

TRCOMM = **0** (not used—set directly to logical 0)

TRSOTF = **0** (not used—set directly to logical 0)

ULTR = **!(51P + 51G)** (discussed in preceding subsection)

Analysis of SELogic Control Equation Trip Setting TR

Again, the example trip equation is:

TR = **51PT + 51GT + 50P1 * SH0**

The Relay Word bit definitions are:

Relay Word Bit	Description
51PT	Phase time-overcurrent element timed out
51GT	Residual ground time-overcurrent element timed out
50P1	Phase instantaneous overcurrent element asserted
SH0	Reclosing relay shot counter at shot = 0

In the trip equation, the AND operator * is executed before the OR operators +, as shown in *Table F.3*:

50P1 * SH0

Element 50P1 can only cause a trip if the reclosing relay shot counter is at shot = 0. When the reclosing relay shot counter is at shot = 0 (see *Table 6.3*), Relay Word bit SH0 is in the following state:

SH0 = **1** (logical 1)

If maximum phase current is *above* the phase instantaneous overcurrent element pickup setting 50P1P (see *Figure 3.1*), Relay Word bit 50P1 is in the following state:

50P1 = **1** (logical 1)

With SH0 = 1 and 50P1 = 1, the ANDed combination results in:

50P1 * SH0 = **1 * 1 = 1** (logical 1)

and an instantaneous trip results. This logic is commonly used in fuse saving schemes for distribution feeders.

If the reclosing relay shot counter advances to shot = 1 for the reclose that follows the trip, Relay Word bit SH0 is in the following state:

SH0 = **0** (logical 0)

If maximum phase current is *above* the phase instantaneous overcurrent element pickup setting 50P1P for the reoccurring fault, Relay Word bit 50P1 is in the following state:

50P1 = **1** (logical 1)

With SH0 = 0 and 50P1 = 1, the ANDed combination results in:

50P1 * SH0 = **1 * 0 = 0** (logical 0)

and no trip results from phase instantaneous overcurrent element 50P1.

A trip will eventually result if time-overcurrent element 51PT or 51GT times out. If residual ground time-overcurrent element 51GT times out, Relay Word bit 51GT is in the following state:

51GT = **1** (logical 1)

When shot = 1, SH0 = 0 and the result is:

TR = **51PT + 51GT + 50P1 * SH0** = 0 + 1 + 1 * 0 = 0 + 1 + 0 = 1

and a time-delayed trip results from residual ground time-overcurrent element 51GT.

Set an Output Contact for Tripping

To assert output contact **OUT101** to trip a circuit breaker, make the following SELogic control equation output contact setting (see *Output Contacts* on page 7.33):

OUT101 = **TRIP**

All SELogic Control Equations Must Be Set

All SELogic control equations must be set in one of the following ways (they cannot be "blank"):

- Single Relay Word bit (e.g., 52A = IN101)
- Combination of Relay Word bits (e.g., TR = 51PT + 51GT + 50P1 * SH0)
- Directly to logical 1 (e.g., 67P1TC = 1)
- Directly to logical 0 (e.g., TRCOMM = 0)

Set SELogic Control Equations Directly to 1 or 0

NOTE: SELogic control equation torque-control settings (e.g., 67P1TC, 51PTC) cannot be set directly to logical 0.

SELogic control equations can be set directly to:

1 (logical 1) or 0 (logical 0)

instead of with Relay Word bits. If a SELogic control equation setting is set directly to 1, it is always "asserted/on/enabled." If a SELogic control equation setting is set equal to 0, it is always "deasserted/off/disabled."

Under the ***SHO*** *(Show/View Settings)* on page 10.68, note that a number of the factory SELogic control equation settings are set directly to 1 or 0.

The individual SELogic control equation settings explanations (referenced in *SELogic Control Equation Settings (Serial Port Command SET L)* on page SET.23) discuss whether it makes logical sense to set the given SELogic control equation setting to 0 or 1 for certain criteria.

Set SELogic Control Equations Directly to 1 or 0 (Example)

Of special concern are the SELogic control equation torque-control settings 67P1TC–51QTC for the overcurrent elements. In the default factory settings, these are all set directly to logical 1. See these factory settings in ***SHO*** *(Show/View Settings)* on page 10.68.

If one of these torque-control settings is set directly to logical 1,e.g.,

51PTC = **1** (set directly to logical 1) then the corresponding overcurrent element (e.g., phase time-overcurrent element 51PT) is subject only to the directional control. See *Figure 3.14* for phase time-overcurrent element 51PT logic.

If the directional control enable setting E32 = N (and 51PTC = 1), then time-overcurrent element 51PT is enabled (assuming pickup setting 51PP is made) and nondirectional.

Use Logic Variables to Create a Seal-In Function

In some applications, a transient condition should be sealed-in until intentionally reset. One method of doing this is to use a logic variable Relay Word bit LV*n* in its own equation.

In this example system, the protection designer wants an output contact to be closed only after the relay trips for a ground fault. If the relay trips for another reason, the output contact should remain open, even if the ground overcurrent element picks up shortly after. The output should remain asserted until a TARGET RESET is performed (e.g., the pushbutton is pressed, or relay processes an appropriate reset command).

Example Settings

TR = other trip settings + 67P1T + LV11

LV11 = 67G1T * LT1

LV12 = LV11 * !TRIP + LV12 * !TRGTR

OUT105 = LT12

These settings are also shown in a logic diagram in *Figure F.3*. The dashed lines and circled numbers represent the processing order of the SELogic control equations, as defined in *Table F.4*,

1. LV11
2. LV12
3. TR
4. OUT105

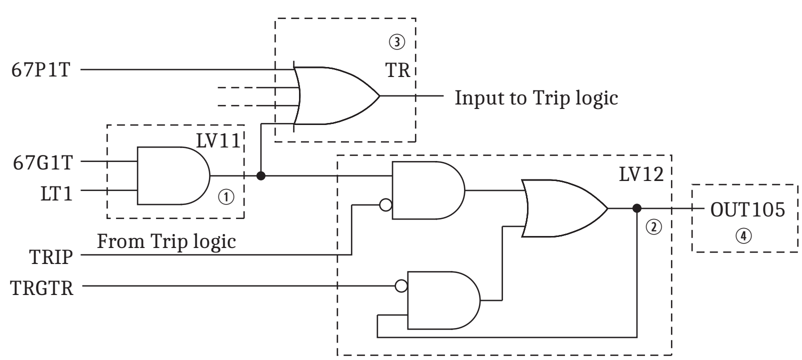
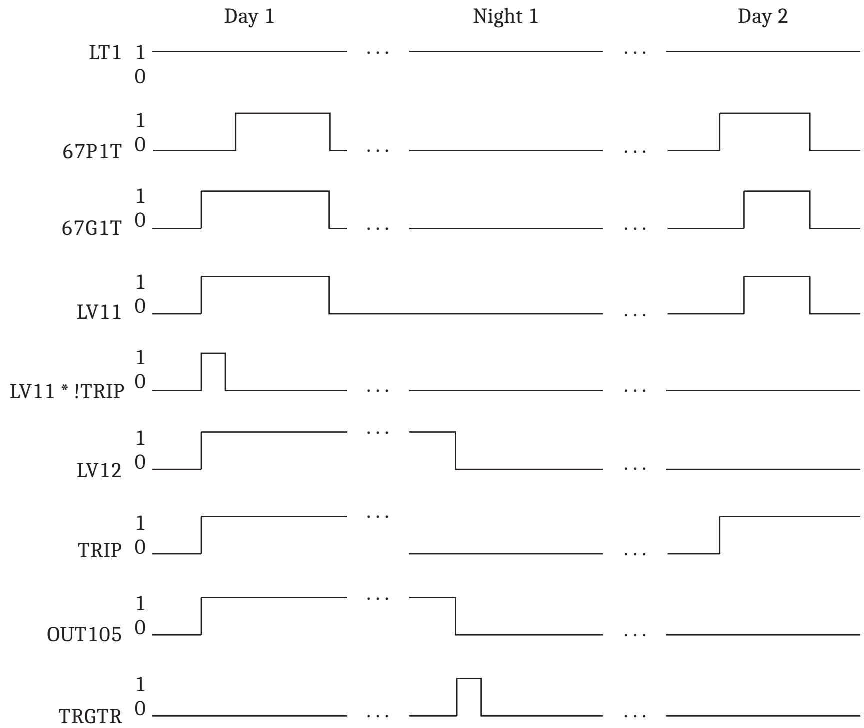


Figure F.3 Logic Diagram of LV12 Seal-In Example

Figure F.4 shows a timing diagram of this logic. On Day 1, a ground fault trips the relay, and the phase element asserts soon after. During Night 1, the **TARGET RESET** button is pressed. On Day 2, a phase fault trips the relay, and the ground element asserts soon after.



Listed in order of processing, from top to bottom.

Figure F.4 Timing Diagram of LV12 Seal-In Example

This example contains a few details that are not apparent at first inspection:

- Although the SELOGIC control equation setting TR appears first in the logic settings class, it is processed after the LV*n* settings, as shown in *Table F.4*. With these example settings, the SEL-351 will trip just as fast for a 67G1T assertion as if 67G1T * LT1 appeared directly in the TR equation.
- When the SEL-351 is powered up, Relay Word bits LV11 and LV12 are both at logical 0.
- LV11 is processed before LV12.
- LT1 is being used as a ground trip enable. If latch LT1 is deasserted, LV11 cannot assert, and neither can LV12.

Timeline Description for *Figure F.4*

Day 1: The first part of the LV12 equation (LV11 * !TRIP) works like a fast rising edge detector, evaluating to logical 1 only when LV11 asserts to trip the relay. This works because the TRIP Relay Word bit is still at logical 0 when LV11 first asserts and LV12 is evaluated. In effect, LV12 is processed between LV11 and the TR equation. As shown in *Figure F.4*, the expression LV11 * !TRIP is only logical 1 for one processing interval.

Night 1: Once asserted, LV12 remains asserted until TRGTR asserts to break the seal-in condition created by LV12 * !TRGTR. One way to assert TRGTR is to press the **TARGET RESET** pushbutton.

Day 2: The relay trips for 67P1T asserting, and then 67G1T asserts. Because TRIP is already asserted when LV11 asserts, the LV11 * !TRIP term in the LV12 equation does not evaluate to logical 1, and LV12 does not newly assert.

SELOGIC Control Equation Limitations

Maximum Number of Relay Word Bits Allowed in a SELOGIC Control Equation

Any single SELOGIC control equation setting is *limited to 30 Relay Word bits* that can be combined together with the SELOGIC control equation operators listed in *Table F.3*. If this limit must be exceeded, use a logic variable (SELOGIC control equation settings LV1–LV32) as an intermediate setting step.

For example, assume that the trip equation (SELOGIC control equation trip setting TR) needs more than 30 Relay Word bits in its equation setting. Instead of placing all Relay Word bits into TR, program some of them into the SELOGIC control equation setting LV1. Next use the resultant SELOGIC control equation variable output (Relay Word bit LV1) in the SELOGIC control equation trip setting TR.

Processing Order Considerations

Note in *Table F.4* that the SELOGIC control equation variables (SELOGIC control equation settings SV1–SV16) are processed after the trip equation (SELOGIC control equation trip setting TR). Thus, any tripping via Relay Word bits SV1–SV16 can be delayed as much as 1/4 cycle. For most applications, this is probably of no consequence.

However, if a Relay Word bit listed later in *Table F.4* is used in a SELOGIC control equation that is listed earlier in *Table F.4* (e.g., in Group 3, TR = SV7 + …), and multiple setting groups are being considered, the Relay Word bit could remain asserted through a group change operation and evaluate to logical 1 for the first run through the SELOGIC control equation processing order in the new setting group.

In this example, if the SV7 Relay Word bit is asserted just before changing to setting Group 3, the SV7 Relay Word bit remains asserted and the TR equation evaluates to logical 1 for one processing interval, causing a relay trip. See *SELOGIC Variable and Timer Behavior After Power Loss, Settings Change, or Group Change* on page 7.28.

NOTE: If multiple setting groups are planned for the relay settings scheme, inspect or test any mission-critical SELOGIC settings for desired behavior after a group change.

A safe method of planning multigroup relay settings is to use variables for the same purpose in each settings group and where critical functions are involved (such as breaker open and close operations).

Note in *Table F.4* that the Logic Variables (SELOGIC control equation settings LV1–LV32) are processed prior to the trip equation. When power is lost to the relay, Logic Variables are reset to logical 0 (See *Logic Variable Behavior After Power Loss, Settings Change, or Group Change* on page 7.32). When power is applied to the relay, the Logic Variables will be processed in order from LV1 to LV32. For example, if a Logic Variable is used in a mission critical SELOGIC control equation (TR = LV6 + ...) which is dependent on a previously processed Logic Variable (LV6 = !LV4), then the trip equation will evaluate to logical one. A safe method of using Logic Variables in applications like this is to inspect or test any mission-critical SELOGIC settings for desired behavior on power up of the relay.

Maximum Total Number of Elements, Rising-Edge, and Falling-Edge Operators

The SELOGIC control equation settings as a whole in a particular setting group have the following limitations:

- Total number of elements ≤ 851
- Total number of rising-edge or falling-edge operators ≤ 60

SELOGIC control equation settings that are set directly to 1 (logical 1) or 0 (logical 0) also have to be included in these limitations—each such setting is counted as one element. Optional MIRRORED BITS communications and extra I/O board SELOGIC settings are also counted as elements, even if not ordered.

After SELOGIC control equation settings changes have been made and the settings are saved, the SEL-351 responds with the following message:

xxx Elements and yy Edges remain available

indicating that “xxx” Relay Word bits can still be used and “yy” rising- or falling-edge operators can still be applied in the SELOGIC control equations for the particular settings group.

Processing Order and Processing Interval

The relay elements and logic (and corresponding SELOGIC control equation settings and resultant Relay Word bits) are processed in the order shown in *Table F.4* (top to bottom). They are processed every quarter-cycle (1/4-cycle), and the Relay Word bit states (logical 1 or logical 0) are updated with each quarter-cycle pass. Thus, the relay processing interval is 1/4 cycle. Once a Relay Word bit is asserted, it retains the state (logical 1 or logical 0) until it is updated again in the next processing interval.

Table F.4 Processing Order of Relay Elements and Logic (Top to Bottom) (Sheet 1 of 3)

Relay Elements and Logic (Related SELOGIC Control Equations Listed in Parentheses)	Order of Processing of the SELOGIC Control Equations (Listed in Parentheses) and Relay Word Bits	Reference Instruction Manual Section
Analog and digital data acquisition	DCLO, DCHI, IN101–IN106, IN201–IN216 (extra I/O board), IAMET, IBMET, ICMET, INMET, V0GAIN	*Section 7*, *Section 8*, *Section 9*
Polarizing Voltage	VPOLV	*Section 4*
Received MIRRORED BITS elements	ROKA, LBOKA, RMB8A–RMB1A, ROKB, LBOKB, RMB8B–RMB1B	*Appendix H*
Virtual bits from received GOOSE	VB001–VB128	*Appendix P*
Power Elements	PWRA1, PWRA2, PWRA3, PWRA4, PWRB1, PWRB2, PWRB3, PWRB4, PWRC1, PWRC2, PWRC3, PWRC4, 3PWR1, 3PWR2, 3PWR3, 3PWR4	*Section 3*
Miscellaneous Instantaneous Overcurrent Elements	50A1–50A4, 50B1–50B4, 50C1–50C4, 50A, 50B, 50C, 50AB1–50AB4, 50BC1–50BC4, 50CA1–50CA4, 50L, 50P5, 50P6, 50QF, 50QR, 50Q5, 50Q6, 50GF, 50GR, 50G5, 50G6, 50N5, 50N6	*Section 3*
Open Breaker Logic (52A)	(52A), 52A, 3PO	*Section 5*
Loss-of-Potential	LOP, V1GOOD	*Section 4*
Fault Identification Logic	FSA, FSB, FSC	*Section 5*

Table F.4 Processing Order of Relay Elements and Logic (Top to Bottom) (Sheet 2 of 3)

Relay Elements and Logic (Related SELogic Control Equations Listed in Parentheses)	Order of Processing of the SELogic Control Equations (Listed in Parentheses) and Relay Word Bits	Reference Instruction Manual Section
Load Encroachment	ZLOAD, ZLOUT, ZLIN	*Section 4*
Latch Control Switches (SET*n*, RST*n*, where *n* = 1 to 16)	(SET1–SET16, RST1–RST16), LT1–LT16	*Section 7*
Voltage Sag/Swell/Interruption Elements	SAGA, SAGB, SAGC, SAGAB, SAGBC, SAGCA, SAG3P, SWA, SWB, SWC, SWAB, SWBC, SWCA, SW3P, INTA, INTB, INTC, INTAB, INTBC, INTCA, INT3P	*Section 3*
Frequency Elements	27B81, FREQOK, 27B81A, FRQ81OK, FRQ81FZ, (81TC), 81D1, 81D1T, 81D2, 81D2T, 81D3, 81D3T, 81D4, 81D4T, 81D5, 81D5T, 81D6, 81D6T, (81RTC), 81R1T, 81R2T, 81R3T, 81R4T, 81RT	*Section 3*
Voltage Elements	59A1, 27A1, 59A2, 27A2, 59B1, 27B1, 59B2, 27B2, 59C1, 27C1, 59C2, 27C2, 59AB, 27AB, 59AB2, 27AB2, 59BC, 27BC, 59BC2, 27BC2, 59CA, 27CA, 59CA2, 27CA2, 3P27, 3P59, 59S1, 27S, 59S2, 59V1, 59Q, 59Q2, 59N1, 59N2	*Section 3*
Synchronism-Check Elements and Vs (BSYNCH)	(BSYNCH), 59VS, 59VP, 59VA, SSLOW, SFAST, SF, 25A1, 25A2	*Section 3*
Second Harmonic Blocking (HBL2TC)	(HBL2TC), HBL2AT, HBL2BT, HBL2CT, HBL2T	*Section 3*
Directional Elements (E32IV)	(E32IV), 32VE, 32IE, 32QE, 32QGE, GNDSW, 50NF, 50NR, 32NE, F32N, R32N, 50P32, F32P, R32P, F32I, R32I, F32V, R32V, F32QG, R32QG, F32Q, R32Q, 32PF, 32QR, 32QF, 32PR, 32GR, 32GF, 32NF, 32NR, NSA, NSB, NSC, F32C, R32C, F32W, R32W	*Section 4*
Torque Control for Instantaneous/ Definite-Time Overcurrent Elements (67P1TC–67P4TC, 67N1TC–67N4TC, 67G1TC–67G4TC, 67Q1TC–67Q4TC)	(67P1TC–67P4TC, 67N1TC–67N4TC, 67G1TC–67G4TC, 67Q1TC–67Q4TC)	*Section 3*
Switch-onto-Fault Logic (CLMON)	(CLMON)	*Section 5*
Instantaneous/Definite-Time Overcurrent Elements (67P1TC–67P4TC, 67N1TC–67N4TC, 67G1TC–67G4TC, 67Q1TC–67Q4TC)	50P1, 67P1, 67P1T, 50P2, 67P2, 67P2S, 67P2T, 50P3, 67P3, 67P3T, 50P4, 67P4, 67P4T, 50N1, 67N1, 67N1T, 50N2, 67N2, 67N2S, 67N2T, 50N3, 67N3, 67N3T, 50N4, 67N4, 67N4T, 50G1, 67G1, 67G1T, 50G2, 67G2, 67G2S, 67G2T, 50G3, 67G3, 67G3T, 50G4, 67G4, 67G4T, 50Q1, 67Q1, 67Q1T, 50Q2, 67Q2, 67Q2S, 67Q2T, 50Q3, 67Q3, 67Q3T, 50Q4, 67Q4, 67Q4T	*Section 3*
Time-Overcurrent Elements (51ATC, 51BTC, 51CTC, 51PTC, 51NTC, 51GTC, 51G2TC, 51QTC)	(51ATC, 51BTC, 51CTC, 51PTC, 51NTC, 51GTC, 51G2TC, 51QTC), 51A, 51AT, 51AR, 51B, 51BT, 51BR, 51C, 51CT, 51CR, 51P, 51PT, 51PR, 51N, 51NT, 51NR, 51G, 51GT, 51GR, 51G2, 51G2T, 51G2R, 51Q, 51QT, 51QR	*Section 3*
Switch-onto-Fault Logic (CLMON)	SOTFE	*Section 5*
Logic Variables (LV1–LV32)	(LV1–LV32) LV1–LV32	*Section 7*
Trip Logic (TR, TRQUAL, TRSOTF, TRCOMM, DTT, ULTR) and Communications-Assisted Trip (PT1, LOG1, PT2, LOG2, BT) Schemes	(TR, TRQUAL, TRCOMM, TRSOTF, DTT, ULTR, PT1, LOG1, PT2, LOG2, BT, RSTTRGT), PT, Z3RB, EKEY, KEY, WFC, ECTT, UBB2, PTRX2, UBB1, PTRX1, UBB, DSTRT, Z3XT, NSTRT, STOP, BTX, PTRX, TRIP	*Section 5*
Breaker Failure	(BFI), 50BFA, 50BFB, 50BFC, 50BFT, RT, BFT	*Section 5*
Close Logic (CL, ULCL) Reclosing Relay (79RI, 79RIS, 79DTL, 79DLS, 79SKP, 79STL, 79BRS, 79SEQ, 79CLS)	(CL, ULCL, 79RI, 79RIS, 79DTL, 79DLS, 79SKP, 79STL, 79BRS, 79SEQ, 79CLS), 79LO, 79CY, 79RS, RCSF, RSTMN, OPTMN, CLOSE, CF, SH0, SH1, SH2, SH3, SH4	*Section 6*
Breaker Monitor (BKMON, BKCLS)	(BKMON, BKCLS), BCWA, BCWB, BCWC, BCW, ESTRA, ESTRB, ESTRC, ESCLA, ESCLB, ESCLC, ESOAL, MSTR, MSCL, MSOAL	*Section 8*

Table F.4 Processing Order of Relay Elements and Logic (Top to Bottom) (Sheet 3 of 3)

Relay Elements and Logic (Related SELOGIC Control Equations Listed in Parentheses)	Order of Processing of the SELOGIC Control Equations (Listed in Parentheses) and Relay Word Bits	Reference Instruction Manual Section
SELOGIC Control Equation Variables/Timers (SV1–SV16)	(SV1–SV16), SV1–SV16, SV1T–SV16T	*Section 7*
Breaker Failure Trip	(BFTR, BFULTR), BFTRIP	*Section 5*
Software Alarm Equation	(SALARM) SALARM	*Section 7*
OUT101–OUT107 OUT201–OUT212 (extra I/O board)	(OUT101–OUT107, ALRMOUT) OUT101–OUT107, ALRMOUT (OUT201–OUT212) OUT201–OUT212 (extra I/O board)	*Section 7*
Display Points (DP1–DP16)	(DP1–DP16)	*Section 7*
Setting Group control (SS1–SS6)	(SS1–SS6)	*Section 7*
Event Report Trigger (ER)	(ER)	*Section 12*
Fault detector for Target Logic and Metering (FAULT)	(FAULT)	*Section 5* and *Section 8*
PMU Trigger Equations (TREA1–4, PMTRIG)	PMTRIG, TREA1–4	*Appendix N*
Transmit MIRRORED BITS (TMB1A–TMB8A, TMB1B–TMB8B)	(TMB1A–TMB8A, TMB1B–TMB8B),TMB1A–TMB8A, TMB1B–TMB8B	*Appendix H*
Setting Group indication	SG1–SG6	*Section 7*
Reset Equations (RST_DEM, RST_PDM, RST_BK, RST_HIS, RST_ENE, RST_MML, RST_HAL, RSTDNPE)	(RST_DEM, RST_PDM, RST_BK, RST_HIS, RST_ENE, RST_MML, RST_HAL, RSTDNPE) RST_DEM, RST_PDM, RST_BK, RST_HIS, RST_ENE, RST_MML, RST_HAL, RSTDNPE	*Section 8*
Target LEDs	TRGTR, RSTTRGT	*Section 5* and *Section 11*
Transmit GOOSE	Processed according to CID file	*Appendix P*
Ethernet Link status	LINK5, LINK5A, LINK5B, LNKFAIL, P5ASEL, P5BSEL	*Appendix F*

The Relay Word bits in the following table are processed separately from the above list. They can be thought of as being processed just before (or just after) *Table F.4*.

Table F.5 Asynchronous Processing Order of Relay Elements (Sheet 1 of 2)

Relay Elements and Logic (related SELOGIC Control Equations listed in parentheses)	Order of processing of the SELOGIC Control Equations (listed in parentheses) and Relay Word Bits	Reference Instruction Manual Section
Voltage input configuration	WYE, SINGLE, DELTA, 3V0	*Section 9*
IRIG-B and Synchrophasor status	PMDOK, TIRIG, TSOK	*Appendix N*
Simple Network Time Protocol status	TSNTPP, TSNTPB	*Section 10*
Ethernet Link status	LINK5, LINK5A, LINK5B, LNKFAIL, P5ASEL, P5BSEL	*Section 10*
Test Database command	TESTDB	*Section 10*
Target Reset	TRGTR	*Section 5*
Setting Group indication (SS1–SS6)	SG6–SG1	*Section 7*
Breaker remote control bits	CC, OC	*Section 10*
Demand Ammeters	QDEM, GDEM, NDEM, PDEM	*Section 8*
MIRRORED BITS element status	RBADA, CBADA, RBADB, CBADB	*Appendix H*
Alarm processing	ALARM, HALARM, HALARML, HALARMP, HALARMA, BADPASS, CHGPASS, GRPSW, SETCHG, ACCESS, ACCESSP, PASNVAL	*Section 7* and *Section 13*

Table F.5 Asynchronous Processing Order of Relay Elements (Sheet 2 of 2)

Relay Elements and Logic (related SELogic Control Equations listed in parentheses)	Order of processing of the SELogic Control Equations (listed in parentheses) and Relay Word Bits	Reference Instruction Manual Section
Local Control Switch	LB1–LB16	*Section 7*
Remote Control Switch	RB1–RB32	*Section 7*

APPENDIX G

Setting Negative-Sequence Overcurrent Elements

Setting Negative-Sequence Definite-Time Overcurrent Elements

Negative-sequence instantaneous overcurrent elements 50Q1–50Q6 and 67Q1–67Q4 should not be set to trip directly. This is because negative-sequence current can transiently appear when a circuit breaker is closed and balanced load current suddenly appears.

To avoid tripping for this transient condition, use negative-sequence definite-time overcurrent elements 67Q1T–67Q4T with at least 1.5 cycles of time delay (transient condition lasts less than 1.5 cycles). For example, make time delay setting:

67Q1D = **1.50**

for negative-sequence definite-time overcurrent element 67Q1T. Refer to *Figure 3.12* and *Figure 3.13* for more information on negative-sequence instantaneous and definite-time overcurrent elements.

Negative-sequence instantaneous overcurrent elements 50Q5 and 50Q6 do not have associated timers (compare *Figure 3.13* to *Figure 3.12*). If 50Q5 or 50Q6 need to be used for tripping, run them though SELOGIC control equation variable timers (see *Figure 7.24* and *Figure 7.25*) and use the outputs of the timers for tripping.

Continue reading in *Coordinating Negative-Sequence Overcurrent Elements* on page G.2 for guidelines on coordinating negative-sequence definite-time overcurrent elements and a following coordination example. The coordination example uses time-overcurrent elements, but the same principles can be applied to definite-time overcurrent elements.

Setting Negative-Sequence Time-Overcurrent Elements

Negative-sequence time-overcurrent element 51QT should not be set to trip directly when it is set with a low time-dial setting 51QTD, that results in curve times below 3 cycles (see curves in *Figure 9.1–Figure 9.10*). This is because negative-sequence current can transiently appear when a circuit breaker is closed and balanced load current suddenly appears. Refer to *Figure 3.21* for more information on negative-sequence time-overcurrent element 51QT.

To avoid having negative-sequence time-overcurrent element 51QT with such low time-dial settings trip for this transient negative-sequence current condition, make settings similar to the following:

SV6PU = **1.50 cycles** (minimum response time; transient condition lasts less than 1.5 cycles)

SV6 = **51Q** (run pickup of negative-sequence time-overcurrent element 51QT through SELOGIC control equation variable timer SV6)

TR = **.. +51QT * SV6T + ..** (trip conditions; SV6T is the output of the SELOGIC control equation variable timer SV6)

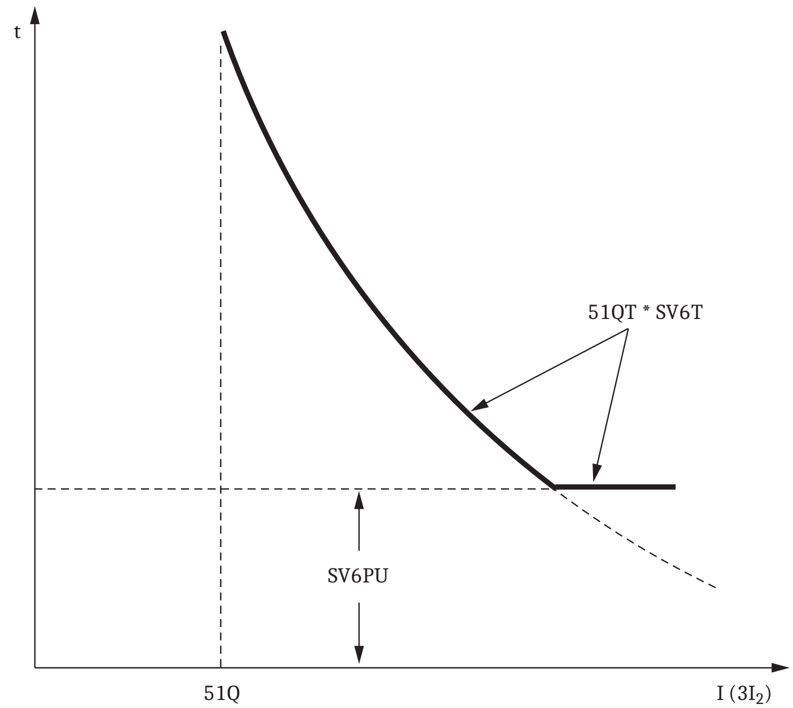


Figure G.1 Minimum Response Time Added to a Negative-Sequence Time-Overcurrent Element 51QT

Continue reading in *Coordinating Negative-Sequence Overcurrent Elements* on page G.2 for guidelines on coordinating negative-sequence time-overcurrent elements and a following coordination example.

Coordinating Negative-Sequence Overcurrent Elements

The following coordination guidelines and example assume that the negative-sequence overcurrent elements operate on $3I_2$ magnitude negative-sequence current and that the power system is radial. The negative-sequence overcurrent elements in the SEL-351 Relay operate on $3I_2$ magnitude negative-sequence current.

The coordination example is a generic example that can be used with any relay containing negative-sequence overcurrent elements that operate on $3I_2$ magnitude negative-sequence current. The SEL-351 can be inserted as the feeder relay in this example. Note that the overcurrent element labels in the example are not the same as the labels of the corresponding SEL-351 overcurrent elements.

Coordination Guidelines

Step 1. Start with the furthest downstream negative-sequence overcurrent element (e.g., distribution feeder relay in a substation).

Step 2. Identify the phase overcurrent device (e.g., line recloser, fuse) downstream from the negative-sequence overcurrent element that is of greatest concern for coordination. This is usually the phase overcurrent device with the longest clearing time.

Step 3. Consider the negative-sequence overcurrent element as an "equivalent" phase overcurrent element. Derive pickup, time dial (lever), curve type, or time-delay settings for this "equivalent" element to coordinate with the downstream phase overcurrent device, as any phase coordination would be performed. Load considerations can be disregarded when deriving the "equivalent" phase overcurrent element settings.

Step 4. Multiply the "equivalent" phase overcurrent element pickup setting by $\sqrt{3}$ to convert it to the negative-sequence overcurrent element pickup setting in terms of $3I_2$ current.

$$\left.\begin{array}{c}\text{Negative-}\\\text{sequence}\\\text{overcurrent}\\\text{element}\\\text{pickup}\end{array}\right\} = \sqrt{3} \cdot (\text{"equivalent" phase overcurrent element pickup})$$

Any time dial (lever), curve type, or time delay calculated for the "equivalent" phase overcurrent element is also used for the negative-sequence overcurrent element with no conversion factor applied.

Step 5. Set the next upstream negative-sequence overcurrent element to coordinate with the first downstream negative-sequence overcurrent element and so on. Again, coordination is not influenced by load considerations.

Coordination Example

In *Figure G.2*, the phase and negative-sequence overcurrent elements of the feeder relay (51F and 51QF, respectively) must coordinate with the phase overcurrent element of the line recloser (51R).

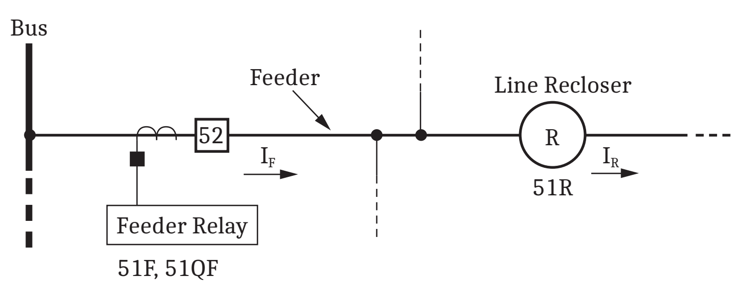


Figure G.2 Distribution Feeder Protective Devices

where:

I_F = Maximum load current through feeder relay = 450 A

I_R = Maximum load current through line recloser = 150 A

51F = Feeder relay phase time-overcurrent element

51QF = Feeder relay negative-sequence time-overcurrent element

51R = Line recloser phase time-overcurrent element (phase "slow curve")

Traditional Phase Coordination

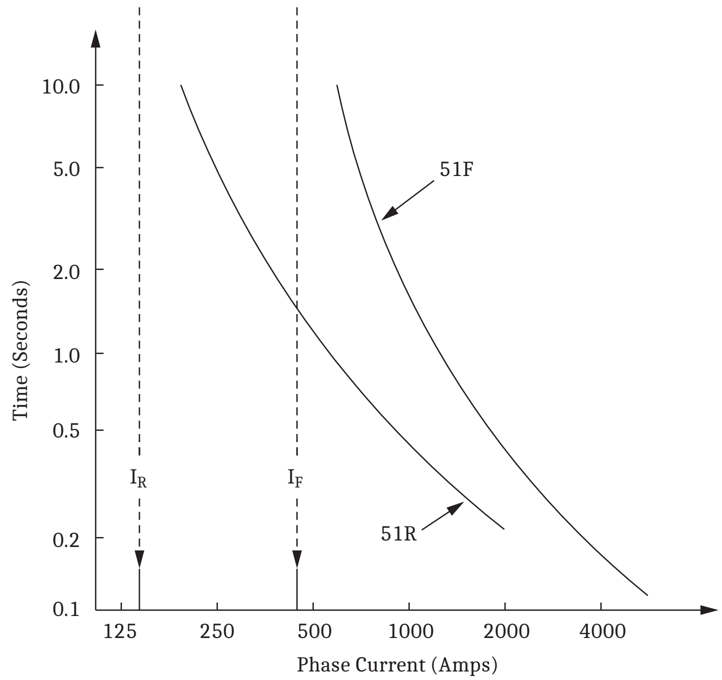


Figure G.3 Traditional Phase Coordination

where:

51F: pickup = 600 A (above max. feeder load, I_F)

51R: pickup = 200 A (above max. line recloser load, I_R)

Figure G.3 shows traditional phase overcurrent element coordination between the feeder relay and line recloser phase overcurrent elements. Phase overcurrent elements must accommodate load and cold load pickup current. The 450 A maximum feeder load current limits the sensitivity of the feeder phase overcurrent element, 51F, to a pickup of 600 A. The feeder relay cannot back up the line recloser for phase faults below 600 A.

Apply the Feeder Relay Negative-Sequence Overcurrent Element (Guidelines 1 to 3)

Applying negative-sequence overcurrent element coordination Guidelines 1 to 3 results in the feeder relay "equivalent" phase overcurrent element (51EP) in *Figure G.4*. Curve for 51F is shown for comparison only.

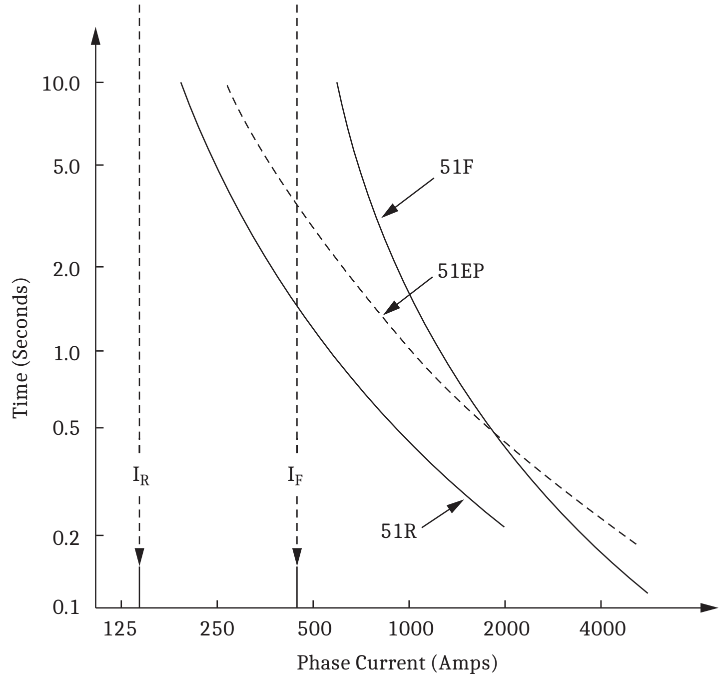


Figure G.4 Phase-to-Phase Fault Coordination

where:

51EP: pickup = 300 A (below max. feeder load, I_F)

Considerable improvement in sensitivity and speed of operation for phase-to-phase faults is achieved with the 51EP element. The 51EP element pickup of 300 A has twice the sensitivity of the 51F element pickup of 600 A. The 51EP element speed of operation for phase-to-phase faults below about 2000 A is faster than that for the 51F element.

Convert "Equivalent" Phase Overcurrent Element Settings to Negative-Sequence Overcurrent Element Settings (Guideline 4)

The "equivalent" phase overcurrent element (51EP element in *Figure G.4*) converts to true negative-sequence overcurrent element settings (51QF in *Figure G.5*) by applying the equation given in Guideline 4. The time dial (lever) and curve type of the element remain the same (if the element is a definite-time element, the time delay remains the same).

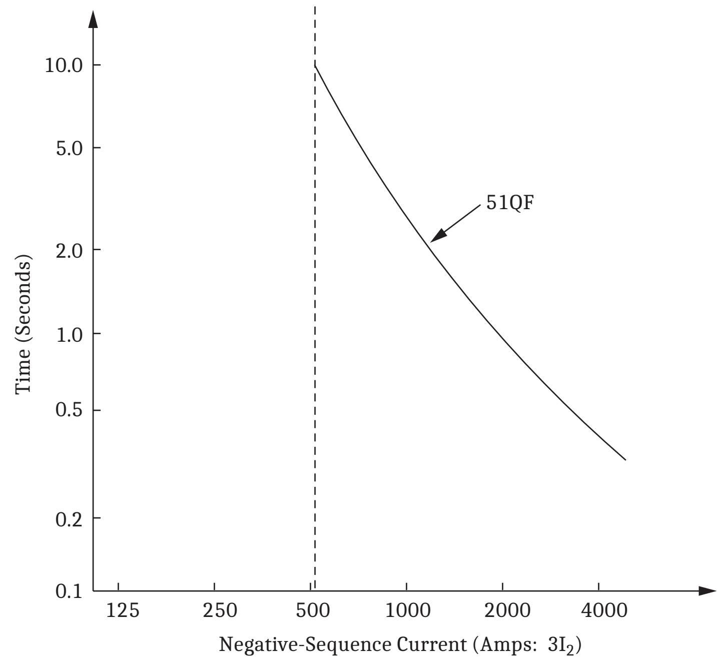


Figure G.5 Negative-Sequence Overcurrent Element Derived From "Equivalent" Phase Overcurrent Element, 51EP

where:

51QF: pickup = $\sqrt{3}$ • (300 A) = 520 A

Having achieved coordination between the feeder relay negative-sequence overcurrent element (51QF) and the downstream line recloser phase overcurrent element (51R) for phase-to-phase faults, coordination between the two devices for other fault types is also achieved.

Negative-Sequence Overcurrent Element Applied at a Distribution Bus (Guideline 5)

The preceding example was for a distribution feeder. A negative-sequence overcurrent element protecting a distribution bus provides an even more dramatic improvement in phase-to-phase fault sensitivity.

The distribution bus phase overcurrent element pickup must be set above the combined load of all the feeders on the bus, plus any emergency load conditions. The bus phase overcurrent element pickup is often set at least four times greater than the pickup of the feeder phase overcurrent element it backs up. Thus, sensitivity to both bus and feeder phase faults is greatly reduced. Feeder relay backup by the bus relay is limited.

Negative-sequence overcurrent elements at the distribution bus can be set significantly below distribution bus load levels and provide dramatically increased sensitivity to phase-to-phase faults. It is coordinated with the distribution feeder phase or negative-sequence overcurrent elements and provides more-sensitive and faster phase-to-phase fault backup.

Ground Coordination Concerns

If the downstream protective device includes ground overcurrent elements, in addition to phase overcurrent elements, there should be no need to check the coordination between the ground overcurrent elements and the upstream negative-sequence overcurrent elements. The downstream phase overcurrent element, whether it operates faster or slower than its complementary ground overcurrent element, will operate faster than the upstream negative-sequence overcurrent element for all faults, including those that involve ground.

Other Negative-Sequence Overcurrent Element References

A. F. Elneweihi, E. O. Schweitzer, M. W. Feltis, "Negative-Sequence Overcurrent Element Application and Coordination in Distribution Protection," IEEE Transactions on Power Delivery, Volume 8, Number 3, July 1993, pp. 915–924.

This IEEE paper is the source of the coordination guidelines and example given in this appendix. The paper also contains analyses of system unbalances and faults and the negative-sequence current generated by such conditions.

A. F. Elneweihi, "Useful Applications for Negative-Sequence Overcurrent Relaying," 22nd Annual Western Protective Relay Conference, Spokane, Washington, October 24–26, 1995.

This conference paper gives many good application examples for negative-sequence overcurrent elements. The focus is on the transmission system, where negative-sequence overcurrent elements provide better sensitivity than zero-sequence overcurrent elements in detecting some single-line-to-ground faults.

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APPENDIX H

MIRRORED BITS Communications (in Firmware Versions 6 and 7)

Overview

MIRRORED BITS communications is a direct relay-to-relay communications protocol, which allows protective relays to exchange information quickly and securely, and with minimal expense. Use MIRRORED BITS communications for remote control and remote sensing or communications-assisted protection schemes.

The MIRRORED BITS protocol is available on serial ports 1, 2, 3, or F of SEL-351-6, and SEL-351-7 relays.

SEL products support several variations of MIRRORED BITS communications protocols. Through port settings, you can set the SEL-351 for compatible operation with SEL-300 series relays, SEL-400 series relays, SEL-600 series relays, SEL-700 series relays, the SEL-2505 Remote I/O Modules, and the SEL-2100 Logic Processors. These devices use MIRRORED BITS communications to exchange the states of eight logic bits.

The PROTO = MB*c* option (*c* = A or B) is provided for compatibility with older SEL products that only support this version of MIRRORED BITS communications. Use PROTO = MB8*c* if each relay supports this MIRRORED BITS version. Use the RTSCTS = MBT selection if your application includes Pulsar MBT9600 modems.

SEL Application Guide AG 2002-23, *Applying Two SEL-351S Relays to Provide Automatic Source Transfer for Critical Loads* provides an example of how to use MIRRORED BITS communications in the SEL-351 Relay.

SEL Application Guide *AG2001-12, Implementing MIRRORED BITS Technology Over Various Communications Media*, provides an overview of the different types of communications channels that might be used for MIRRORED BITS communications.

Communications Channels and Logical Data Channels

The SEL-351 supports two MIRRORED BITS communications channels, designated A and B. Use the port setting PROTO to assign one of the MIRRORED BITS communications channels to a serial port; PROTO = MB8A (or MBA) for MIRRORED BITS communications Channel A or PROTO = MB8B (or MBB) for MIRRORED BITS communications Channel B. See *Settings for MIRRORED BITS* on page H.5.

Transmitted bits include TMB1A–TMB8A and TMB1B–TMB8B. The last letter (A or B) designates the channel with which the bits are associated. These bits are controlled by SELOGIC control equations. Received bits include RMB1A–RMB8A and RMB1B–RMB8B. You can use received bits as operands in SELOGIC control equations. The channel status bits are ROKA, RBADA, CBADA, LBOKA, ROKB, RBADB, CBADB, and LBOKB. You can also use these bits as operands in SELOGIC control equations. Use the **COM** command for additional channel status information.

Within each MIRRORED BITS communications message for a given channel (A or B), there are eight logical data channels (1–8). Each channel can be used to communicate with either channel A or channel B on another relay, or as TMB1 through TMB8 if connected to a relay with a single MIRRORED BITS communications channel, as shown in *Figure H.1*.

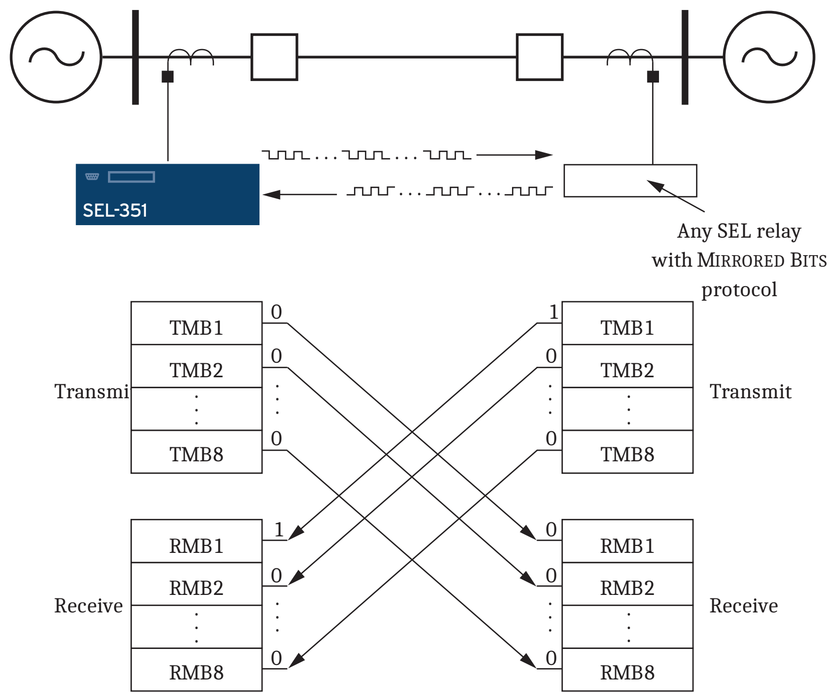

Figure H.1 Relay-to-Relay Logic Communication

Operation

Message Transmission

Depending on the settings, the SEL-351 transmits a MIRRORED BITS communications message every 1/4 to 1/2 of an electrical cycle (see *Table H.2*). Each message contains the most recent values of the transmit bits. All messages are transmitted without idle bits between characters. Idle bits are allowed between messages.

Message Reception

When the devices are synchronized and the MIRRORED BITS communications channel is in a normal state, the relay decodes and checks each received message. If the message is valid, the relay sends each received logic bit (RMB*nc*, where *n* = 1–8, *c* = A or B) to the corresponding pickup and dropout security counters, that in turn set or clear the RMB*nc* relay element bits.

Message Decoding and Integrity Checks

The relay provides indication of the status of each MIRRORED BITS communications channel, with element bits ROKA and ROKB. During normal operation, the relay sets the ROK*c* bit. The relay clears the bit upon detecting any of the following conditions:

- Parity, framing, or overrun errors.
- Receive data redundancy error.
- Receive message identification error.
- No message received in the time three messages have been sent.

The relay will assert ROK*c* only after successful synchronization as described below and two consecutive messages pass all of the data checks described above. After ROK*c* is reasserted, received data may be delayed while passing through the security counters described below.

While ROK*c* is not set, the relay does not transfer new RMB data to the pickup-dropout security counters described below. Instead, the relay sends one of the user-definable default values to the security counter inputs. For each bit RMB1*c*–RMB8*c*, specify the default value with setting RXDFLT, as follows:

- 1
- 0
- X (to use the last valid value)

Pickup/dropout security counters supervise the transfer of received data to RMB1*c*–RMB8*c*. Set these counters between 1 (allow every occurrence to pass) and 8 (require eight consecutive occurrences to pass). The pickup and dropout security count settings are separate. MIRRORED BITS communications security meets IEC 60834-1 recommendations for direct tripping when the security counter (debounce) is set to 2, and can be further improved by increasing the security counter.

A pickup/dropout security counter operates identically to a pickup/dropout timer, except that the counter uses units of “counted received messages,” instead of time. An SEL-351 communicating with another SEL-351 sends and receives MIRRORED BITS messages four times per power system cycle. Therefore, a security counter set to two counts will delay a bit by about 1/2 power system cycle. You must consider the impact of the security counter settings in the receiving device to determine the channel timing performance.

Things become slightly more complicated when two relays of different processing rates are connected via MIRRORED BITS communications (for instance, an SEL-321 talking to an SEL-351). The SEL-321 processes power system information each 1/8 power system cycle but processes the pickup/dropout security counters as messages are received. Because the SEL-321 is receiving messages from the SEL-351, it will receive a message each 1/4 cycle processing interval. So, a counter set to two will again delay a bit by about 1/2 cycle. However, in that same example, a security counter set to two on the SEL-351 will delay a bit by 1/4 cycle, because the SEL-351 is receiving new MIRRORED BITS messages each 1/8 cycle from the SEL-321.

Channel Synchronization

When an SEL-351 detects a communications error, it deasserts ROK*c*. If a node detects two consecutive communications errors, it transmits an attention message, which includes its TXID setting.

When a node receives an attention message, it checks to see if its TXID is included.

If its own TXID is included and at least one other TXID is included, the node transmits data.

If its own TXID is not included, the node deasserts ROK*c*, includes its TXID in the attention message, and transmits the new attention message.

If its own TXID is the only TXID included, the relay assumes the message is corrupted unless the loopback mode has been enabled. If loopback is not enabled, the node deasserts ROK*c* and transmits the attention message with its TXID included. If loopback is enabled, the relay transmits data.

In summary, when a node detects two consecutive errors, it transmits attention until it receives an attention with its own TXID included. If three or four relays are connected in a ring topology, then the attention message will go all the way around the loop, and eventually will be received by the originating node. It will then be killed and data transmission will resume. This method of synchronization allows the relays to determine reliably which byte is the first byte of the message. It also forces mis-synchronized UARTs to become re-synchronized. On the down side, this method takes down the entire loop for a receive error at any node in the loop. This decreases availability. It also makes one-way communications impossible.

Loopback Testing

Use the **LOO** (loopback) command to enable loopback testing. While in loopback mode, ROK*c* is deasserted, and LBOK*c* asserts and deasserts based on the received data checks. See ***LOO** (Loop Back—Available in Firmware Versions 6 and 7)* on page 10.54 for full details on the **LOO** command.

Channel Monitoring

Based on the results of data checks described above, the relay will collect information regarding the 255 most recent communications errors. Each record contains at least the following fields:

- Dropout Time/Date
- Pickup Time/Date
- Time elapsed during dropout
- Reason for dropout (see *Message Decoding and Integrity Checks* on page H.3)

Use the **COM** command to generate a long or summary report of the communications errors.

There is a single record for each outage, but an outage can evolve. For example, the initial cause could be a data disagreement, but framing errors can extend the outage. If the channel is presently down, the **COM** record will only show the initial cause, but the **COM** summary will display the present cause of failure.

When the duration of an outage on Channel A or B exceeds a user-definable threshold, the relay will assert a user-accessible flag, RBAD*c*.

When channel unavailability exceeds a user-settable threshold, the relay will assert a user accessible flag, hereafter called CBAD*c*.

See ***COM*** *(Communication Data—Available in Firmware Versions 6 and 7)* on page 10.41 for full details on the **COM** command, including sample reports.

MIRRORED BITS Protocol for the Pulsar 9600 Baud Modem

Setting RTSCTS = MBT indicates that a Pulsar MBT modem is connected. When the user selects MBT, the baud rate setting must be set to 9600 baud.

NOTE: The MBT mode will not work with PROTO=MB8A or MB8B.

The MIRRORED BITS protocol compatible with the Pulsar MBT-9600 modem is identical to the standard MIRRORED BITS protocol with the following exceptions:

- The relay injects a delay (idle time) between messages.
- The length of the delay is one relay processing interval.
- The relay resets RTS (to a negative voltage at the EIA-232 connector).
- The relay resets RTS (to a negative voltage at the EIA-232 connector).

  The relay sets RTS (to a positive voltage at the EIA-232 connector) for MIRRORED BITS communications that use the R6 or original R version of MIRRORED BITS communications.
- The relay monitors the CTS signal on the EIA-232 connector, which the modem will deassert if the channel has too many errors.

Settings for MIRRORED BITS

The SEL-351 port settings associated with MIRRORED BITS communications are shown in *Table H.1*.

For convenience, MIRRORED BITS settings are included in the settings sheets. See *Port n Settings (for Serial Ports 1, 2, 3 and F) (Serial Port SET P n Command and Front Panel)* on page SET.34.

Table H.1 MIRRORED BITS (Sheet 1 of 2)

Name	Description	Range	Default
PROTO	Protocol	SEL, LMD, DNP, MOD, MBA, MBB, MB8A, MB8B, PMU	SEL[a]
SPEED	Baud Rate	300, 1200, 2400, 4800, 9600, 19200, 38400, 57600	9600 (see *Table H.2*)
RTSCTS	Enable Hardware Handshaking	Y, N, MBT	N
TXID	MIRRORED BITS Transmit Identifier	1–4	2

Table H.1 MIRRORED BITS (Sheet 2 of 2)

Name	Description	Range	Default
RXID	MIRRORED BITS Receive Identifier	1–4	1
RBADPU	MIRRORED BITS RX Bad Pickup Time	1–10000 s	60
CBADPU	PPM MIRRORED BITS Channel Bad Pickup[b]	1–10000	1000
RXDFLT	MIRRORED BITS Receive Default State	8 character string of 1s, 0s, or *X*s	XXXXXXXX
RMB1PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB1DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB2PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB2DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB3PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB3DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB4PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB4DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB5PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB5DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB6PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB6DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB7PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB7DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1
RMB8PU	MIRRORED BITS RMB_ Pickup Debounce Msgs	1–8	1
RMB8DO	MIRRORED BITS RMB_ Dropout Debounce Msgs	1–8	1

[a] Set PROTO = MBA, MBB, MB8A, or MB8B to access the remaining settings.
[b] PPM = Parts per million.

Set PROTO = MBA or MB8A to enable the MIRRORED BITS protocol channel A on this port. Set PROTO = MBB or MB8B to enable the MIRRORED BITS protocol channel B on this port. PROTO can be set to MBA or MB8A on only one port at a time. Similarly, PROTO can be set to MBB or MB8B on only one port at a time.

The MIRRORED BITS protocols MBA and MBB use a 7-data bit format for data encoding. These selections are provided for compatibility with existing equipment.

The MB8 protocols MB8A and MB8B use an 8-data bit format, which allows MIRRORED BITS communications to operate on communication channels requiring an 8-data bit format. These selections are compatible with more equipment types and are recommended for new installations.

As a function of the settings for SPEED, the message transmission periods are shown in *Table H.2*.

Table H.2 Message Transmission Periods (Sheet 1 of 2)

SPEED	SEL-351
57600	1 message per 1/4 cycle
38400	1 message per 1/4 cycle
19200	1 message per 1/4 cycle

Table H.2 Message Transmission Periods (Sheet 2 of 2)

SPEED	SEL-351
9600	1 message per 1/4 cycle
4800	1 message per 1/2 cycle

Use the RTSCTS = MBT option if you are using a Pulsar MBT 9600 baud modem. When RTSCTS = MBT, SPEED must be set to 9600.

Set the RXID of the local relay to match the TXID of the remote relay. For example, for a two-terminal application, where Relay X transmits to Relay Y and Relay Y transmits to Relay X:

	TXID	RXID
Relay X	1	2
Relay Y	2	1

See SEL Application Guide *AG96-17, Three-Terminal Line Protection Using SEL-321-1 Relays With MIRRORED BITS Communications* for details on three-terminal applications.

Use the RBADPU setting to determine how long a channel error must last before the relay element RBADA is asserted. RBADA is deasserted when the channel error is corrected. RBADPU is accurate to ±1 second.

Use the CBADPU setting to determine the ratio of channel down time to the total channel time before the relay element CBAD*c* is asserted. The times used in the calculation are those that are available in the **COM** records. See the ***COM*** *(Communication Data—Available in Firmware Versions 6 and 7)* on page 10.41 for a description of the **COM** records.

Use the RXDFLT setting to determine the default state the MIRRORED BITS communications should use in place of received data if an error condition is detected. The setting is a mask of 1s, 0s and/or *X*s, for RMB1*c*–RMB8*c*, where *X* represents the most recently received valid value. The order of the MIRRORED BITS communications in the RXDFLT mask setting is 87654321.

Supervise the transfer of received data (or default data) to RMB1*c*–RMB8*c* with the MIRRORED BITS pickup and dropout security counters. Set the pickup and dropout counters individually for each bit.

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APPENDIX I

SEL Distributed Port Switch Protocol

Overview

SEL Distributed Port Switch Protocol (LMD) permits multiple SEL relays to share a common communications channel. It is appropriate for low-cost, low-speed port switching applications where updating a real-time database is not a requirement.

LMD is often used with EIA-485 serial communications. In the SEL-351 the PROTO = LMD setting choice is allowed on any serial port, even on relays without the optional EIA-485 port.

Settings

Use the front-panel SET pushbutton or the serial port **SET P** command to activate the LMD protocol. Change the port PROTO setting from the default SEL to LMD to reveal the following settings:

Settings	Description
PREFIX:	One character to precede the address. This should be a character that does not occur in the course of other communications with the relay. Valid choices are one of the following: "@", "#", "$", "%", "&". The default is "@."
ADDR:	Two-character ASCII address. The range is "01" to "99." The default is "01."
SETTLE:	Time in seconds that transmission is delayed after the request to send (RTS line) asserts. This delay accommodates transmitters with a slow rise time.

Operation

NOTE: You can use the front-panel SET pushbutton to change the port settings to return to SEL protocol.

1. The relay ignores all input from this port until it detects the prefix character and the two-byte address.
2. Upon receipt of the prefix and address, the relay enables echo and message transmission.
3. Wait until you receive a prompt before entering commands to avoid losing echoed characters while the external transmitter is warming up.
4. Until the relay connection terminates, you can use the standard commands that are available when PROTO is set to SEL.

5. The **QUIT** command terminates the connection. If no data are sent to the relay before the port time-out period, it automatically terminates the connection.
6. Enter the sequence **<Ctrl+X> QUIT <CR>** before entering the prefix character if all relays in the multidrop network do not have the same prefix setting.

APPENDIX J

Configuration, Fast Meter, and Fast Operate Commands

Overview

SEL relays have two separate data streams that share the same serial port. Data communications with the relay consist of ASCII character commands and reports that are intelligible using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information and then allow the ASCII data stream to continue.

This mechanism allows a single communications channel to be used for ASCII communications (e.g., transmission of a long event report) interleaved with short bursts of binary data to support fast acquisition of metering data. The device connected to the other end of the link requires software that uses the separate data streams to exploit this feature. The binary commands and ASCII commands can also be accessed by a device that does not interleave the data streams.

SEL Application Guide *AG95-10, Configuration and Fast Meter Messages*, is a comprehensive description of the SEL binary messages. Below is a description of the messages provided in the SEL-351.

Message Lists

Binary Message List

Table J.1 Binary Message List (Sheet 1 of 2)

Request to Relay (hex)	Response From Relay
A5C0	Relay Definition Block
A5C1	Fast Meter Configuration Block
A5D1	Fast Meter Data Block
A5C2	Demand Fast Meter Configuration Block
A5D2	Demand Fast Meter Data Message
A5C3	Peak Demand Fast Meter Configuration Block
A5D3	Peak Demand Fast Meter Data Message
A5B9	Fast Meter Status Acknowledge
A5CE	Fast Operate Configuration Block
A5E0	Fast Operate Remote Bit Control
A5E3	Fast Operate Breaker Control

Table J.1 Binary Message List (Sheet 2 of 2)

Request to Relay (hex)	Response From Relay
A5CD	Fast Reset Configuration Block
A5ED	Fast Reset Control

ASCII Configuration Message List

Table J.2 ASCII Configuration Message List

Request to Relay (ASCII)	Response From Relay
ID	ASCII Firmware ID String and Terminal ID Setting (TID)
DNA	ASCII Names of Relay Word bits
BNA	ASCII Names of bits in the A5D1 Status Byte
SNS	ASCII Names of bits in the SER trigger settings

Message Definitions

A5C0 Relay Definition Block

In response to the A5C0 request, the relay sends the following block.

Table J.3 A5C0 Relay Definition Block (Sheet 1 of 2)

Data	Description
A5C0	Command
2A	Message length
07	Support seven protocols: SEL, MIRRORED BITS, DNP, LMD, Modbus, IEEE C37.118, and IEC 61850.
03	Support Fast Meter, fast demand, and fast peak
01	Status flag for Settings change
A5C1	Fast Meter configuration
A5D1	Fast Meter message
A5C2	Fast demand configuration
A5D2	Fast demand message
A5C3	Fast peak configuration
A5D3	Fast peak message
0001	Settings change bit
A5C100000000	Reconfigure Fast Meter on settings change
0300	SEL protocol with Fast Operate and Fast Message (unsolicited SER messaging)
0101	LMD protocol with Fast Operate
0002	Modbus
0005	DNP3
0006	MIRRORED BITS protocol

Table J.3 A5C0 Relay Definition Block (Sheet 2 of 2)

Data	Description
0007	IEEE C37.118 Synchrophasors
0008	IEC 61850
00	Reserved
xx	1-byte checksum of all preceding bytes

A5C1 Fast Meter Configuration Block

In response to the A5C1 request, the relay sends the following block.

NOTE: Analog channel names are transmitted by the relay as part of the A5C1 message. To support legacy applications, some Fast Meter analog channel names differ from the analog labels used for DNP and Modbus protocols documented in *Appendix E: Analog Quantities*, *Appendix J: Configuration, Fast Meter, and Fast Operate Commands*, and *Appendix O: Modbus RTU and TCP Communications*. The analog channel names shown in brackets [] in *Table J.4* are those contained in the Fast Meter message. The analog labels from *Appendix E: Analog Quantities* are shown in parentheses.

NOTE: See *Appendix E: Analog Quantities* for definitions of analog channel names.

Table J.4 A5C1 Fast Meter Configuration Block (Sheet 1 of 2)

Data	Description
A5C1	Fast Meter command
84	Length
01	One status flag byte
00	Scale factors in Fast Meter message
00	No scale factors
0A	# of analog input channels
02	# of samples per channel
67	# of digital banks
01	One calculation block
0004	Analog channel offset
0054	Time stamp offset
005C	Digital offset
494100000000	Analog channel name [IA] (IA)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
494200000000	Analog channel name [IB] (IB)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
494300000000	Analog channel name [IC] (IC)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
494E00000000	Analog channel name [IN] (IN)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
564100000000[a]	Analog channel name [VA] (VA)
564142000000[b]	Analog channel name [VAB] (VAB)
01	Analog channel type

Table J.4 A5C1 Fast Meter Configuration Block (Sheet 2 of 2)

Data	Description
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
564200000000[a]	Analog channel name [VB] (VB)
564243000000[b]	Analog channel name [VBC] (VBC)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
564300000000[a]	Analog channel name [VC] (VC)
564341000000[b]	Analog channel name [VCA] (VCA)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
565300000000	Analog channel name [VS] (VS)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
465245510000	Analog channel name [FREQ] (FREQ)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
564241540000	Analog channel name [VBAT] (VDC)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
00	Line Configuration (00-ABC PTCONN = WYE or SINGLE, 01-ACB PTCONN = WYE or SINGLE, 02-ABC PTCONN = DELTA, 03-ACB PTCONN = DELTA)
00	Power Calculations (00 for PTCONN = WYE or SINGLE, 01 for PTCONN = DELTA)
FFFF	No Deskew angle
FFFF	No Rs compensation (–1)
FFFF	No Xs compensation (–1)
00	IA channel index
01	IB channel index
02	IC channel index
04	VA channel index (VAB for PTCONN = DELTA)
05	VB channel index (VBC for PTCONN = DELTA)
06	VC channel index (VCA for PTCONN = DELTA)
00	Reserved
xx	1-byte checksum of all preceding bytes

[a] Included in message when Global setting PTCONN = WYE or SINGLE.
[b] Included in message when Global setting PTCONN = DELTA.

A5D1 Fast Meter Data Block

In response to the A5D1 request, the relay sends the following block.

Table J.5 A5D1 Fast Meter Data Block

Data	Description
A5D1	Command
C6	Length
1 byte	1 Status Byte
80 bytes	X and Y components of: IA, IB, IC, IN, VA/VAB, VB/VBC, VC/VCA, VS, FREQ and VDC in 4-byte IEEE FPS
8 bytes	Time stamp
103 bytes	Two target LED rows and 101 digital banks: TAR0–TAR102
2 bytes	Reserved
xx	1-byte checksum of all preceding bytes

A5C2/A5C3 Demand/Peak Demand Fast Meter Configuration Messages

In response to the A5C2 or A5C3 request, the relay sends the following block.

NOTE: Analog channel names are transmitted by the relay as part of the A5C2 and A5C3 messages. To support legacy applications, some Fast Meter analog channel names differ from the analog labels used for DNP and Modbus protocols documented in *Appendix E: Analog Quantities*, *Appendix J: Configuration, Fast Meter, and Fast Operate Commands*, and *Appendix O: Modbus RTU and TCP Communications*. The analog channel names shown in brackets [] in *Table J.6* are those contained in the Fast Meter message. The analog labels from *Appendix E: Analog Quantities* are shown in parentheses.

Table J.6 A5C2/A5C3 Demand/Peak Demand Fast Meter Configuration Messages (Sheet 1 of 3)

Data	Description
A5C2 or A5C3	Command; Demand (A5C2) or Peak Demand (A5C3)
EE	Length
01	# of status flag bytes
00	Scale factors in meter message
00	# of scale factors
16	# of analog input channels
01	# of samples per channel
00	# of digital banks
00	# of calculation blocks
0004	Analog channel offset
00B4	Time stamp offset
FFFF	Digital offset
494100000000	Analog channel name [IA] (IADEM or IAPK)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
494200000000	Analog channel name [IB] (IBDEM or IBPK)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
494300000000	Analog channel name [IC] (ICDEM or ICPK)
02	Analog channel type

Table J.6 A5C2/A5C3 Demand/Peak Demand Fast Meter Configuration Messages (Sheet 2 of 3)

Data	Description
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
494E00000000	Analog channel name [IN] (INDEM or INPK)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
494700000000	Analog channel name [IG] (IGDEM or IGPK)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
334932000000	Analog channel name [3I2] (3I2DEM or 3I2PK)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
50412B000000	Analog channel name [PA+] (MWADO or MWAPO)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
50422B000000	Analog channel name [PB+] (MWBDO or MWBPO)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
50432B000000	Analog channel name [PC+] (MWCDO or MWCPO)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
50332B000000	Analog channel name [P3+] (MW3DO or MW3PO)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51412B000000	Analog channel name [QA+] (MVRADO or MVRAPO)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51422B000000	Analog channel name [QB+] (MVRBDO or MVRBPO)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51432B000000	Analog channel name [QC+] (MVRCDO or MVRCPO)
02	Analog channel type

Table J.6 A5C2/A5C3 Demand/Peak Demand Fast Meter Configuration Messages (Sheet 3 of 3)

Data	Description
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51332B000000	Analog channel name [Q3+] (MVR3DO or MVR3PO)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
50412D000000	Analog channel name [PA–] (MWADI or MWAPI)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
50422D000000	Analog channel name [PB–] (MWBDI or MWBPI)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
50432D000000	Analog channel name [PC–] (MWCDI or MWCPI)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
50332D000000	Analog channel name [P3–] (MW3DI or MW3PI)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51412D000000	Analog channel name [QA–] (MVRADI or MVRAPI)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51422D000000	Analog channel name [QB–] (MVRBDI or MVRBPI)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51432D000000	Analog channel name [QC–] (MVRCDI or MVRCPI)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51332D000000	Analog channel name [Q3–] (MVR3DI or MVR3PI)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
00	Reserved
xx	1-byte checksum of preceding bytes

A5D2/A5D3 Demand/Peak Demand Fast Meter Message

In response to the A5D2 or A5D3 request, the relay sends the following block.

Table J.7 A5D2/A5D3 Demand/Peak Demand Fast Meter Message

Data	Description
A5D2 or A5D3	Command
BE	Length
1 byte	1 Status Byte
176 bytes	IADEM/IAPK, IBDEM/IBPK, ICDEM/ICPK, INDEM/INPK, IGDEM/IGPK, 3I2DEM/3I2PK, MWADI/MWAPI, MWBDI/MWBPI, MWCDI/MWCPI, MW3DI/MW3PI, MVRADI/MVRAPI, MVRBDI/MVRBPI, MVRCDI/MVRCPI, MVR3DI/MVR3PI, MWADO/MWAPO, MWBDO/MWBPO, MWCDO/MWCPO, MW3DO/MW3PO, MVRADO/MVRAPO, MVRBDO/MVRBPO, MVRCDO/MVRCPO, MVR3DO/MVR3PO in 8-byte IEEE FPS
8 bytes	Time stamp
1 byte	Reserved
xx	1-byte checksum of all preceding bytes

NOTE: When Global setting PTCONN = DELTA, the single-phase power values [MWA__, MWB__, MWC__, MVARA__, MVARB__, MVARC__] are set to zero.

NOTE: When Global setting PTCONN = SINGLE, symmetrical component values are set to zero.

NOTE: When Global settings PTCONN = SINGLE and PHANTV = OFF, all power quantities are set to zero.

A5B9 Fast Meter Status Acknowledge Message

In response to the A5B9 request, the relay clears the Fast Meter (message A5D1) Status Byte. The SEL-351 Status Byte contains two active bits: STSET (bit 1) and PWRUP (bit 2); both bits are set on power up. The STSET bit is also set on settings changes. If the STSET bit is set, the external device should request the A5C1, A5C2, and A5C3 messages. The external device can then determine if the scale factors or line configuration parameters have been modified.

A5CE Fast Operate Configuration Block

In response to the A5CE request, the relay sends the following block.

Table J.8 A5CE Fast Operate Configuration Block (Sheet 1 of 4)

Data	Description
A5CE	Command
6C	Length
01	Support 1 circuit breaker
0020	Support 32 remote bit set/clear commands
0100	Allow remote bit pulse commands
31	Operate code, open breaker 1
11	Operate code, close breaker 1
00	Operate code, clear remote bit RB1
20	Operate code, set remote bit RB1
40	Operate code, pulse remote bit RB1
01	Operate code, clear remote bit RB2
21	Operate code, set remote bit RB2
41	Operate code, pulse remote bit RB2

Table J.8 A5CE Fast Operate Configuration Block (Sheet 2 of 4)

Data	Description
02	Operate code, clear remote bit RB3
22	Operate code, set remote bit RB3
42	Operate code, pulse remote bit RB3
03	Operate code, clear remote bit RB4
23	Operate code, set remote bit RB4
43	Operate code, pulse remote bit RB4
04	Operate code, clear remote bit RB5
24	Operate code, set remote bit RB5
44	Operate code, pulse remote bit RB5
05	Operate code, clear remote bit RB6
25	Operate code, set remote bit RB6
45	Operate code, pulse remote bit RB6
06	Operate code, clear remote bit RB7
26	Operate code, set remote bit RB7
46	Operate code, pulse remote bit RB7
07	Operate code, clear remote bit RB8
27	Operate code, set remote bit RB8
47	Operate code, pulse remote bit RB8
08	Operate code, clear remote bit RB9
28	Operate code, set remote bit RB9
48	Operate code, pulse remote bit RB9
09	Operate code, clear remote bit RB10
29	Operate code, set remote bit RB10
49	Operate code, pulse remote bit RB10
0A	Operate code, clear remote bit RB11
2A	Operate code, set remote bit RB11
4A	Operate code, pulse remote bit RB11
0B	Operate code, clear remote bit RB12
2B	Operate code, set remote bit RB12
4B	Operate code, pulse remote bit RB12
0C	Operate code, clear remote bit RB13
2C	Operate code, set remote bit RB13
4C	Operate code, pulse remote bit RB13
0D	Operate code, clear remote bit RB14
2D	Operate code, set remote bit RB14
4D	Operate code, pulse remote bit RB14
0E	Operate code, clear remote bit RB15
2E	Operate code, set remote bit RB15
4E	Operate code, pulse remote bit RB15
0F	Operate code, clear remote bit RB16
2F	Operate code, set remote bit RB16

Table J.8 A5CE Fast Operate Configuration Block (Sheet 3 of 4)

Data	Description
4F	Operate code, pulse remote bit RB16
10	Operate code, clear remote bit RB17
30	Operate code, set remote bit RB17
50	Operate code, pulse remote bit RB17
11	Operate code, clear remote bit RB18
31	Operate code, set remote bit RB18
51	Operate code, pulse remote bit RB18
12	Operate code, clear remote bit RB19
32	Operate code, set remote bit RB19
52	Operate code, pulse remote bit RB19
13	Operate code, clear remote bit RB20
33	Operate code, set remote bit RB20
53	Operate code, pulse remote bit RB20
14	Operate code, clear remote bit RB21
34	Operate code, set remote bit RB21
54	Operate code, pulse remote bit RB21
15	Operate code, clear remote bit RB22
35	Operate code, set remote bit RB22
55	Operate code, pulse remote bit RB22
16	Operate code, clear remote bit RB23
36	Operate code, set remote bit RB23
56	Operate code, pulse remote bit RB23
17	Operate code, clear remote bit RB24
37	Operate code, set remote bit RB24
57	Operate code, pulse remote bit RB24
18	Operate code, clear remote bit RB25
38	Operate code, set remote bit RB25
58	Operate code, pulse remote bit RB25
19	Operate code, clear remote bit RB26
39	Operate code, set remote bit RB26
59	Operate code, pulse remote bit RB26
1A	Operate code, clear remote bit RB27
3A	Operate code, set remote bit RB27
5A	Operate code, pulse remote bit RB27
1B	Operate code, clear remote bit RB28
3B	Operate code, set remote bit RB28
5B	Operate code, pulse remote bit RB28
1C	Operate code, clear remote bit RB29
3C	Operate code, set remote bit RB29
5C	Operate code, pulse remote bit RB29
1D	Operate code, clear remote bit RB30

Table J.8 A5CE Fast Operate Configuration Block (Sheet 4 of 4)

Data	Description
3D	Operate code, set remote bit RB30
5D	Operate code, pulse remote bit RB30
1E	Operate code, clear remote bit RB31
3E	Operate code, set remote bit RB31
5E	Operate code, pulse remote bit RB31
1F	Operate code, clear remote bit RB32
3F	Operate code, set remote bit RB32
5F	Operate code, pulse remote bit RB32
00	Reserved
xx	1-byte checksum of all preceding bytes

A5E0 Fast Operate Remote Bit Control

The external device sends the following message to perform a remote bit operation.

Table J.9 A5E0 Fast Operate Remote Bit Control

Data	Description
A5E0	Command
06	Length
1 byte	Operate code: 00–1F clear remote bit RB1–RB32 20–3F set remote bit RB1–RB32 40–5F pulse remote bit for RB1–RB32 for one processing interval
1 byte	Operate validation: 4 • Operate code + 1
xx	1-byte checksum of preceding bytes

The relay performs the specified remote bit operation if the following conditions are true:

- ➤ The Operate code is valid.
- ➤ The Operate validation = 4 • Operate code + 1.
- ➤ The message checksum is valid.
- ➤ The FASTOP port setting is set to Y.
- ➤ The relay is enabled.

Remote bit set and clear operations are latched by the relay. Remote bit pulse operations assert the remote bit for one processing interval (1/4 cycle).

It is common practice to route remote bits to output contacts to provide remote control of the relay outputs. If you want to pulse an output contact closed for a specific duration, SEL recommends using the remote bit pulse command and SELOGIC control equations to provide secure and accurate contact control. The remote device sends the remote bit pulse command; the relay controls the timing of the output contact assertion. You can use any remote bit (RB1–RB32), and any SELOGIC control equation timer (SV1–SV16) to control any of the output contacts. For example, to pulse output contact OUT104 for 30 cycles with Remote Bit RB4 and SELOGIC control equation timer SV4, issue the following relay settings:

Via the **SET** command:

ESV = **4** enable 4 SELOGIC control equations

SV4PU = **0** SV4 pickup time = 0

SV4DO = **30** SV4 dropout time is 30 cycles

Via the **SET L** command:

SV4 = **RB4** SV4 input is RB4

OUT104 = **SV4T** route SV4 timer output to **OUT104**

To pulse the contact, send the **A5E006430DDB** command to the relay.

A5E3 Fast Operate Breaker Control

The external device sends the following message to perform a fast breaker open/close.

Table J.10 A5E3 Fast Operate Breaker Control

Data	Description
A5E3	Command
06	Length
l byte	Operate code: 31—OPEN breaker 11—CLOSE breaker
1 byte	Operate Validation: 4 • Operate code + 1
xx	1-byte checksum of preceding bytes

The relay performs the specified breaker operation if the following conditions are true:

- ➤ Conditions 1–5 defined in the A5E0 message are true.
- ➤ The breaker jumper (JMP1B) is in place on the SEL-351 main board.

A5CD Fast Operate Reset Definition Block

In response to an A5CD request, the relay sends the configuration block for the Fast Operate Reset message.

Table J.11 A5CD Fast Operate Reset Definition Block

Data	Description
A5CD	Command
0E	Message length
01	The number of Fast Operate reset codes supported
00	Reserved for future use
00	Fast Operate reset code (“00” for target reset)
54415220520D00	Fast Operate reset description string (“TAR R”)
xx	1-byte checksum of preceding bytes

A5ED Fast Operate Reset Command

The Fast Operate Reset commands take the following form.

Table J.12 A5ED Fast Operate Reset Command

Data	Description
A5ED	Command
06	Message Length—always 6
00	Operate Code (“00” for target reset, “TAR R”)
01	Operate Validation—(4 • Operate Code) + 1
xx	1-byte checksum of preceding bytes

ID Message

In response to the **ID** command, the relay sends the firmware ID (FID), boot firmware ID (BFID), firmware checksum (CID), relay TID setting (DEVID), Modbus device code (DEVCODE)—for use by an SEL Communications Processor, relay part number (PARTNO), relay serial number (SERIALNO), and configuration string (CONFIG)—for use by other IEDs or software.

A sample response is shown below; responses will differ depending on relay model, settings, and firmware.

```
<STX>
"FID=SEL-351-5-R5xx-V0-Zxxxxxx-D2009xxxx","yyyy"<CR><LF>
"BFID=SLBT-3CF1-Rxxx-V0-Zxxxxxx-D2009xxxx","yyyy"<CR><LF>
"CID=xxxx","yyyy"<CR><LF>
"DEVID=STATION A","yyyy"<CR><LF>
"DEVCODE=51","yyyy"<CR><LF>
"PARTNO=035173C3E14XX2","yyyy"<CR><LF>
"SERIALNO=11001001","yyyy"<CR><LF>
"CONFIG=11222201","yyyy"<CR><LF>
"SPECIAL=11000","yyyy"<CR><LF>
"iedName=","yyyy"<CR><LF>
"type=","yyyy"<CR><LF>
"configVersion=","yyyy"<CR><LF>
<ETX>
```

where:

<STX> is the STX character (02)

<ETX> is the ETX character (03)

xxxx is the 4-byte ASCII hex representation of the checksum of the relay firmware

yyyy is the 4-byte ASCII hex representation of the checksum for each line

The ID message is available from Access Level 0 and higher.

DNA Message

In response to the **DNA T** or **DNA X** command, the relay sends names of the Relay Word bits transmitted in the A5D1 message. The first name is associated with the MSB, the last name with the LSB. These names are listed in the Relay Word Bits table for the appropriate model in *Appendix D: Relay Word Bits* of this manual. The **DNA** command is available from Access Level 0 and higher.

In response to the **DNA** command (without T or X modifier), the relay sends the **DNA X** command with all Relay Word bit names replaced with *. This is necessary for compatibility with older communications processors.

The DNA X message for an SEL-351 with a 5 A nominal neutral channel (**IN**) and IEC 61850 is shown below.

```
<STX>
"EN","TRIP","INST","COMM","SOTF","50","51","81","yyyy"<CR><LF>
"A","B","C","G","N","RS","CY","LO","yyyy"<CR><LF>
"50A1","50B1","50C1","50A2","50B2","50C2","50A3","50B3","yyyy"<CF><LF>
"50C3","50A4","50B4","50C4","50AB1","50BC1","50CA1","50AB2","yyyy"<CF><LF>
"50BC2","50CA2","50AB3","50BC3","50CA3","50AB4","50BC4","50CA4","yyyy"<CF><LF>
"50A","50B","50C","51A","51AT","51AR","51B","51BT","yyyy"<CF><LF>
"51BR","51C","51CT","51CR","51P","51PT","51PR","51N","yyyy"<CF><LF>
"51NT","51NR","51G","51GT","51GR","51Q","51QT","51QR","yyyy"<CF><LF>
"50P1","50P2","50P3","50P4","50N1","50N2","50N3","50N4","yyyy"<CF><LF>
"67P1","67P2","67P3","67P4","67N1","67N2","67N3","67N4","yyyy"<CF><LF>
"67P1T","67P2T","67P3T","67P4T","67N1T","67N2T","67N3T","67N4T","yyyy"<CF><LF>
"50G1","50G2","50G3","50G4","50Q1","50Q2","50Q3","50Q4","yyyy"<CF><LF>
"67G1","67G2","67G3","67G4","67Q1","67Q2","67Q3","67Q4","yyyy"<CF><LF>
"67G1T","67G2T","67G3T","67G4T","67Q1T","67Q2T","67Q3T","67Q4T","yyyy"<CF><LF>
"50P5","50P6","50N5","50N6","50G5","50G6","50Q5","50Q6","yyyy"<CF><LF>
"50QF","50QR","50GF","50GR","32VE","32QGE","32IE","32QE","yyyy"<CF><LF>
"F32P","R32P","F32Q","R32Q","F32QG","R32QG","F32V","R32V","yyyy"<CF><LF>
"F32I","R32I","32PF","32PR","32QF","32QR","32GF","32GR","yyyy"<CF><LF>
"27A1","27B1","27C1","27A2","27B2","27C2","59A1","59B1","yyyy"<CF><LF>
"59C1","59A2","59B2","59C2","27AB","27BC","27CA","59AB","yyyy"<CF><LF>
"59BC","59CA","59N1","59N2","59Q","59V1","27S","59S1","yyyy"<CF><LF>
"59S2","59VP","59VS","SF","25A1","25A2","3P27","3P59","yyyy"<CF><LF>
"81D1","81D2","81D3","81D4","81D5","81D6","27B81","50L","yyyy"<CF><LF>

"81D1T","81D2T","81D3T","81D4T","81D5T","81D6T","VPOLV","LOP","yyyy"<CF><LF>
"SFAST","SSLOW","IN106","IN105","IN104","IN103","IN102","IN101","yyyy"<CF><LF>
"LB1","LB2","LB3","LB4","LB5","LB6","LB7","LB8","yyyy"<CF><LF>
"LB9","LB10","LB11","LB12","LB13","LB14","LB15","LB16","yyyy"<CF><LF>
"RB1","RB2","RB3","RB4","RB5","RB6","RB7","RB8","yyyy"<CF><LF>
"RB9","RB10","RB11","RB12","RB13","RB14","RB15","RB16","yyyy"<CF><LF>
"LT1","LT2","LT3","LT4","LT5","LT6","LT7","LT8","yyyy"<CF><LF>
"LT9","LT10","LT11","LT12","LT13","LT14","LT15","LT16","yyyy"<CF><LF>
"SV1","SV2","SV3","SV4","SV1T","SV2T","SV3T","SV4T","yyyy"<CF><LF>
"SV5","SV6","SV7","SV8","SV5T","SV6T","SV7T","SV8T","yyyy"<CF><LF>
"SV9","SV10","SV11","SV12","SV9T","SV10T","SV11T","SV12T","yyyy"<CF><LF>
"SV13","SV14","SV15","SV16","SV13T","SV14T","SV15T","SV16T","yyyy"<CF><LF>
"79RS","79CY","79LO","SH0","SH1","SH2","SH3","SH4","yyyy"<CF><LF>
"CLOSE","CF","RCSF","OPTMN","RSTMN","FSA","FSB","FSC","yyyy"<CF><LF>
"BCW","50P32","*","59VA","TRGTR","52A","*","*","yyyy"<CF><LF>
"SG1","SG2","SG3","SG4","SG5","SG6","ZLOUT","ZLIN","yyyy"<CF><LF>
"ZLOAD","BCWA","BCWB","BCWC","*","51G2","51G2T","51G2R","yyyy"<CF><LF>
"ALARM","OUT107","OUT106","OUT105","OUT104","OUT103","OUT102","OUT101","yyyy"<CF>
    <LF>

"3PO","SOTFE","Z3RB","KEY","EKEY","ECTT","WFC","PT","yyyy"<CF><LF>
"PTRX2","PTRX","PTRX1","UBB1","UBB2","UBB","Z3XT","DSTRT","yyyy"<CF><LF>
"NSTRT","STOP","BTX","TRIP","OC","CC","DCHI","DCLO","yyyy"<CF><LF>
"67P2S","67N2S","67G2S","67Q2S","PDEM","NDEM","GDEM","QDEM","yyyy"<CF><LF>
"OUT201","OUT202","OUT203","OUT204","OUT205","OUT206","OUT207","OUT208","yyyy"<CF>
    <LF>
"OUT209","OUT210","OUT211","OUT212","*","*","*","*","yyyy"<CF><LF>
"IN208","IN207","IN206","IN205","IN204","IN203","IN202","IN201","yyyy"<CF><LF>
"*","*","*","*","*","*","*","*","yyyy"<CF><LF>
"RMB8A","RMB7A","RMB6A","RMB5A","RMB4A","RMB3A","RMB2A","RMB1A","yyyy"<CF><LF>
"TMB8A","TMB7A","TMB6A","TMB5A","TMB4A","TMB3A","TMB2A","TMB1A","yyyy"<CF><LF>
"RMB8B","RMB7B","RMB6B","RMB5B","RMB4B","RMB3B","RMB2B","RMB1B","yyyy"<CF><LF>
"TMB8B","TMB7B","TMB6B","TMB5B","TMB4B","TMB3B","TMB2B","TMB1B","yyyy"<CF><LF>
"LBOKB","CBADB","RBADB","ROKB","LBOKA","CBADA","RBADA","ROKA","yyyy"<CF><LF>
"PWRA1","PWRB1","PWRC1","PWRA2","PWRB2","PWRC2","INTC","INT3P","yyyy"<CF><LF>
"PWRA3","PWRB3","PWRC3","PWRA4","PWRB4","PWRC4","INTA","INTB","yyyy"<CF><LF>
"SAGA","SAGB","SAGC","SAG3P","SWA","SWB","SWC","SW3P","yyyy"<CF><LF>
"SAGAB","SAGBC","SAGCA","SWAB","SWBC","SWCA","TSOK","TIRIG","yyyy"<CF><LF>
"3PWR1","3PWR2","3PWR3","3PWR4","INTAB","INTBC","INTCA","*","yyyy"<CF><LF>
"27AB2","27BC2","27CA2","59AB2","59BC2","59CA2","59Q2","3V0","yyyy"<CF><LF>
"V1GOOD","*","*","VOGAIN","INMET","ICMET","IBMET","IAMET","yyyy"<CF><LF>
"*","*","*","*","*","*","32NF","32NR","yyyy"<CF><LF>
"PMDOK","*","*","*","*","*","*","*","yyyy"<CF><LF>
```

```
"DELTA","WYE","SINGLE","TESTDB","*","*","*","FREQOK","yyyy"<CF><LF>
"DST","DSTP","LPSEC","LPSECP","TQUAL4","TQUAL3","TQUAL2","TQUAL1","yyyy"<CF><LF>
"RSTTRGT","RST_MML","RST_ENE","RST_HIS","RST_BK","RST_PDM","RST_DEM","RST_HAL",
    "yyyy"<CF><LF>
"*","*","*","PMTRIG","TREA4","TREA3","TREA2","TREA1","yyyy"<CF><LF>
"*","LINK5A","LINK5B","LNKFAIL","P5ASEL","P5BSEL","TSNTPP","TSNTPB","yyyy"<CF><LF>
"RB17","RB18","RB19","RB20","RB21","RB22","RB23","RB24","yyyy"<CF><LF>
"RB25","RB26","RB27","RB28","RB29","RB30","RB31","RB32","yyyy"<CF><LF>
"LV1","LV2","LV3","LV4","LV5","LV6","LV7","LV8","yyyy"<CF><LF>
"LV9","LV10","LV11","LV12","LV13","LV14","LV15","LV16","yyyy"<CF><LF>
"LV17","LV18","LV19","LV20","LV21","LV22","LV23","LV24","yyyy"<CF><LF>
"LV25","LV26","LV27","LV28","LV29","LV30","LV31","LV32","yyyy"<CF><LF>
"*","*","*","*","*","*","*","*","yyyy"<CF><LF>
"*","*","*","*","*","*","*","*","yyyy"<CF><LF>
"*","*","*","*","*","*","*","*","yyyy"<CF><LF>
"*","*","*","*","*","*","*","*","yyyy"<CF><LF>

"VB001","VB002","VB003","VB004","VB005","VB006","VB007","VB008","yyyy"<CF><LF>
"VB009","VB010","VB011","VB012","VB013","VB014","VB015","VB016","yyyy"<CF><LF>
"VB017","VB018","VB019","VB020","VB021","VB022","VB023","VB024","yyyy"<CF><LF>
"VB025","VB026","VB027","VB028","VB029","VB030","VB031","VB032","yyyy"<CF><LF>
"VB033","VB034","VB035","VB036","VB037","VB038","VB039","VB040","yyyy"<CF><LF>
"VB041","VB042","VB043","VB044","VB045","VB046","VB047","VB048","yyyy"<CF><LF>
"VB049","VB050","VB051","VB052","VB053","VB054","VB055","VB056","yyyy"<CF><LF>
"VB057","VB058","VB059","VB060","VB061","VB062","VB063","VB064","yyyy"<CF><LF>
"VB065","VB066","VB067","VB068","VB069","VB070","VB071","VB072","yyyy"<CF><LF>
"VB073","VB074","VB075","VB076","VB077","VB078","VB079","VB080","yyyy"<CF><LF>
"VB081","VB082","VB083","VB084","VB085","VB086","VB087","VB088","yyyy"<CF><LF>
"VB089","VB090","VB091","VB092","VB093","VB094","VB095","VB096","yyyy"<CF><LF>
"VB097","VB098","VB099","VB100","VB101","VB102","VB103","VB104","yyyy"<CF><LF>
"VB105","VB106","VB107","VB108","VB109","VB110","VB111","VB112","yyyy"<CF><LF>
"VB113","VB114","VB115","VB116","VB117","VB118","VB119","VB120","yyyy"<CF><LF>
"VB121","VB122","VB123","VB124","VB125","VB126","VB127","VB128","yyyy"<CF><LF>
"SALARM","ACCESS","ALRMOUT","*","HALARMA","HALARMP","HALARML","HALARM","yyyy"<CF>
    <LF>

"*","*","PASNVAL","ACCESSP","GRPSW","SETCHG","CHGPASS","BADPASS","yyyy"<CF><LF>
"DD","LOPRST","LOPBLK","LOP2","LOP3","*","*","*","yyyy"<CF><LF>
"ESTRA","ESTRB","ESTRC","ESCLA","ESCLB","ESCLC","ESOAL","MSOAL","yyyy"<CF><LF>
"*","*","HBL2T","HBL2AT","HBL2BT","HBL2CT","MSTR","MSCL","yyyy"<CF><LF>
"*","*","*","81R4T","81R3T","81R2T","81R1T","81RT","yyyy"<CF><LF>
"*","50BFA","50BFB","50BFC","50BFT","RT","BFT","BFTRIP","yyyy"<CF><LF>
"*","*","*","*","*","*","*","RSTDNPE","yyyy"<CF><LF>
"*","*","*","*","*","*","*","*","yyyy"<CF><LF>
<ETX>
```

where:

<STX>	is the STX character (02)
<ETX>	is the ETX character (03)
the last field in each line (yyyy)	is the 4-byte ASCII hex representation of the checksum for the line
“*”	indicates an unused bit location

Messages for other relay models may be derived from the appropriate tables in *Appendix D: Relay Word Bits* of this manual, using the above format.

BNA Message

In response to the **BNA** command, the relay sends names of the bits transmitted in the Status Byte in the A5D1 message. The first name is the MSB, the last name is the LSB. The BNA message is:

```
"*","*","*","*","*","PWRUP","STSET","*","07AD"
```

where:

“*” indicates an unused bit location

The **BNA** command is available from Access Level 0 and higher.

SNS Message

In response to the **SNS** command, the relay sends the name string of the SER (SER1 SER2 SER3) settings. The **SNS** command is available at Access Level 0 and higher.

The relay responds to the **SNS** command with the name string in the SER settings. The name string starts with SER1, followed by SER2 and SER3.

For example, if

SER1 = 50A1 OUT101

SER2 = 67P1T 81D1T

SER3 = OUT102 52A

The name string will be

"50A1","OUT101","67P1T","81D1T","OUT102","52A".

If there are more than eight settings in SER, the SNS message will have several rows. Each row will have eight strings, followed by the checksum and carriage return. The last row may have less than eight strings.

The SNS message for the SEL-351 is shown below:

```
<STX>"xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","yyyy"<CR><LF>
     "xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","yyyy"<CR><LF>
     "xxxx","xxxx","yyyy",<CR><LF><ETX>
```

where:

xxxx is a string from the settings in SER (SER1, SER2 and SER3)

yyyy is the 4-byte ASCII representation of the checksum

APPENDIX K

Compressed ASCII Commands

Overview

The SEL-351 Relay provides Compressed ASCII versions of some of the relay ASCII commands. The Compressed ASCII commands allow an external device to obtain data from the relay, in a format which directly imports into spreadsheet or database programs, and which can be validated with a checksum.

The SEL-351 provides the following Compressed ASCII commands:

Command	Description
CASCII	Configuration message
CSTATUS	Status message
CHISTORY	History message
CEVENT	Event message
CSUMMARY	Event summary message

CASCII Command—General Format

The Compressed ASCII configuration message provides data for an external computer to extract data from other Compressed ASCII commands. To obtain the configuration message for the Compressed ASCII commands available in an SEL relay, type:

CAS <CR>

The relay sends:

```
<STX>"CAS",n,"yyyy"<CR><LF>
"COMMAND 1",ll,"yyyy"<CR><LF>
"#H","xxxxx","xxxxx",......,"xxxxx","yyyy"<CR><LF>
"#D","ddd","ddd","ddd","ddd",......,"ddd","yyyy"<CR><LF>
"COMMAND 2",ll,"yyyy"<CR><LF>
"#h","ddd","ddd",......,"ddd","yyyy"<CR><LF>
"#D","ddd","ddd","ddd","ddd",......,"ddd","yyyy"<CR><LF>
    .
    .
    .
"COMMAND n",ll,"yyyy"<CR><LF>
"#H","xxxxx","xxxxx",......,"xxxxx","yyyy"<CR><LF>
"#D","ddd","ddd","ddd","ddd",......,"ddd","yyyy"<CR><LF><ETX>
```

where:

`n` is the number of Compressed ASCII command descriptions to follow

`COMMAND` is the ASCII name for the Compressed ASCII command as sent by the requesting device. The naming convention for the Compressed ASCII commands is a C preceding the typical command. For example, `CSTATUS` (abbreviated to `CST`) is the compressed **STATUS** command

`ll` is the minimum access level at which the command is available

`#H` identifies a header line to precede one or more data lines; # is the number of subsequent ASCII names. For example, `21H` identifies a header line with 21 ASCII labels.

`#h` identifies a header line to precede one or more data lines; # is the number of subsequent format fields. For example, `8h` identifies a header line with 8 format fields.

`xxxxx` is an ASCII name for corresponding data on following data lines. Maximum ASCII name width is 10 characters.

`#D` identifies a data format line; # is the maximum number of subsequent data lines

`ddd` identifies a format field containing one of the following type designators:

I Integer data
F Floating-point data
mS String of maximum m characters (e.g., 10S for a 10-character string)

`yyyy` is the 4-byte hex ASCII representation of the checksum

A Compressed ASCII command may require multiple header and data configuration lines.

If a Compressed ASCII request is made for data that are not available, (e.g. the history buffer is empty or invalid event request), the relay responds with the following message:

```
<STX>"No Data Available","yyyy"<CR><LF><ETX>
```

CASCII Command—SEL-351

Display the SEL-351 Compressed ASCII configuration message by sending:

CAS <CR>

Sample SEL-351 response:

```
<STX>
"CAS",6,"yyyy"<CR><LF>
"CST",1,"yyyy"<CR><LF>
"1H","FID","yyyy"<CR><LF>
"1D","45S","yyyy"<CR><LF>
"7H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy"<CR><LF>
"1D","I","I","I","I","I","I","I","yyyy"<CR><LF>
"28H","IA_OS","IB_OS","IC_OS","IN_OS","VA_OS","VB_OS","VC_OS","VS_OS","MOF_OS",
   "IA_OSH",
"IB_OSH","IC_OSH","IN_OSH","15V_PS","5V_REG","3.3V_REG","RAM","ROM","FPGA",
   "EEPROM","FLASH","A/D","USB_BRD","COM_BRD","IO_BRD","TEMP","RTC","HMI",
   "yyyy"<CR><LF>
"1D","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S",
   "9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","yyyy"<CR><LF>
"CHI",1,"yyyy"<CR><LF>

"1H","FID","yyyy"<CR><LF>
"1D","45S","yyyy"<CR><LF>
"16H","REC_NUM","REF_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","EVENT",
   "LOCATION","CURR","FREQ","GROUP","SHOT","TARGETS","yyyy"<CR><LF>
"44D","I","I","I","I","I","I","I","I","6S","F","I","F","I","I","22S","yyyy"<CR><LF>
"CEV",1,"yyyy"<CR><LF>
"1H","FID","yyyy"<CR><LF>
"1D","45S","yyyy"<CR><LF>
"7H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy"<CR><LF>
"1D","I","I","I","I","I","I","I","yyyy"<CR><LF>
"15H","REF_NUM","FREQ","SAM/CYC_A","SAM/CYC_D","NUM_OF_CYC","EVENT","LOCATION",
   "SHOT","TARGETS","IA","IB","IC","IN","IG","3I2","yyyy"<CR><LF>
"1D","F","I","I","I","6S","F","I","22S","I","I","I","I","I","I","yyyy"<CR><LF>
"13H","IA","IB","IC","IN","IG","VA(kV)","VB(kV)","VC(kV)","VS(kV)","VDC","FREQ",
   "TRIG","Names of elements in relay word, separated by spaces","yyyy"<CR><LF>
"60D","F","F","F","F","F","F","F","F","F","I","F","2S","184S","yyyy"<CR><LF>

"CEV C",1,"yyyy"<CR><LF>
"1H","FID","yyyy"<CR><LF>
"1D","45S","yyyy"<CR><LF>
"7H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy"<CR><LF>
"1D","I","I","I","I","I","I","I","yyyy"<CR><LF>
"15H","REF_NUM","FREQ","SAM/CYC_A","SAM/CYC_D","NUM_OF_CYC","EVENT","LOCATION",
   "SHOT","TARGETS","IA","IB","IC","IN","IG","3I2","yyyy"<CR><LF>
"1D","F","I","I","I","6S","F","I","22S","I","I","I","I","I","I"," yyyy "<CR><LF>
"13H","IA","IB","IC","IN","IG","VA(kV)","VB(kV)","VC(kV)","VS(kV)","VDC","FREQ",
   "TRIG","Names of elements in relay word, separated by spaces","yyyy"<CR><LF>
"240D","F","F","F","F","F","F","F","F","F","I","F","2S","184S","yyyy"<CR><LF>
"CEV R",1,"yyyy"<CR><LF>
"1H","FID","yyyy"<CR><LF>
"1D","45S","yyyy"<CR><LF>

"7H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy"<CR><LF>
"1D","I","I","I","I","I","I","I","yyyy"<CR><LF>
"15H","REF_NUM","FREQ","SAM/CYC_A","SAM/CYC_D","NUM_OF_CYC","EVENT","LOCATION",
   "SHOT","TARGETS","IA","IB","IC","IN","IG","3I2","yyyy"<CR><LF>
"1D","F","I","I","I","6S","F","I","22S","I","I","I","I","I","I","yyyy"<CR><LF>
"13H","IA","IB","IC","IN","IG","VA(kV)","VB(kV)","VC(kV)","VS(kV)","VDC","FREQ",
   "TRIG",
"Names of elements in relay word, separated by spaces", "yyyy"<CR><LF>
"1952","F","F","F","F","F","F","F","F","F","I","F","2S","184S","yyyy"<CR><LF>
"CSU",1,"yyyy"<CR><LF>
"1H", "FID","yyyy"<CR><LF>
"1D","45S", "yyyy"<CR><LF>
"7H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy"<CR><LF>
"1D","I","I","I","I","I","I","I","yyyy"<CR><LF>
"16H","REF_NUM","EVENT","LOCATION","HOUR_T","MIN_T","SEC_T","MSEC_T","SHOT","FREQ",
   "GROUP","HOUR_C","MIN_C","SEC_C","MSEC_C","TARGETS","BREAKER","yyyy"<CR><LF>

"1D","I","6S","F","I","I","I","I","I","F","I","I","I","I","I","143S","6S","yyyy"
   <CR><LF>
“18H”,”IA_PF”,”IA_DEG_PF”,”IB_PF”,”IB_DEG_PF”,”IC_PF”,”IC_DEG_PF”,“IN_PF”,
   ”IN_DEG_PF”,”IG_PF”,”IG_DEG_PF”,”3I2_PF”,”3I2_DEG_PF","VA_PF”,”VA_DEG_PF”,
   ”VB_PF”,”VB_DEG_PF”,”VC_PF”,”VC_DEG_PF”,"yyyy"<CR><LF>
“1D”,”I”,”F”,”I”,”F”,”I”,”F”,”I”,”F”,”I”,”F”,”I”,”F”,”F”,”F”,”F”,”F”,”F”,”F”,”yyyy”
   <CR><LF>
“18H”,”IA”,”IA_DEG”,”IB”,”IB_DEG”,”IC”,”IC_DEG","IN","IN_DEG","IG","IG_DEG","3I2",
   "3I2_DEG",“VA”,”VA_DEG”,”VB”,”VB_DEG”,”VC”,”VC_DEG","yyyy"<CR><LF>
   “1D”,”I”,”F”,”I”,”F”,”I”,”F”,”I”,”F”,”I”,”F”,”I”,”F”,”F”,”F”,”F”,”F”,”F”,”F”,
   ”yyyy”<CR><LF>
“2H”,”TRIG”,"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 LBOKB CBADB RBADB ROKB LBOKA
   CBADA RBADA ROKA",”yyyy”<CR><LF>
“2D”,”1S”,”10S”,”yyyy”<CR><LF>
<ETX>
```

`yyyy` is the 4-byte hex ASCII representation of the checksum. See *CEVENT Command—SEL-351* on page K.5 for definition of the *"Names of elements in the relay word, separated by spaces"* field.

CSTATUS Command—SEL-351

Display status data in Compressed ASCII format by sending:

CST <CR>

Sample SEL-351 response:

```
<STX>"FID","yyyy"<CR><LF>
"Relay FID string","yyyy"<CR><LF>
"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy"<CR><LF>
xxxx, xxxx, xxxx, xxxx, xxxx, xxxx, xxxx,"yyyy"<CR><LF>
"IA_OS","IB_OS","IC_OS","IN_OS","VA_OS","VB_OS","VC_OS","VS_OS","MOF_OS","IA_OSH",
"IB_OSH","IC_OSH","IN_OSH","15V_PS","5V_REG","3.3V_REG","RAM","ROM","FPGA",
   "EEPROM","FLASH","A/D","USB_BRD","COM_BRD","IO_BRD","TEMP","RTC","HMI",
   "yyyy"<CR><LF>
"xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx",
   "xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx",
   "xxxx ","xxxx","xxxx",
"xxxx","xxxx","xxxx","xxxx","yyyy"<CR><LF><ETX>
```

where:

`xxxx` are the data values corresponding to the first line labels

`yyyy` is the 4-byte hex ASCII representation of the checksum

CHISTORY Command—SEL-351

Display history data in Compressed ASCII format by sending:

CHI <CR>

The relay sends:

```
<STX>"FID","yyyy"<CR><LF>
"Relay FID string","yyyy"<CR><LF>
"REC_NUM","REF_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","EVENT",
   "LOCATION",
"CURR","FREQ","GROUP","SHOT","TARGETS","yyyy"<CR><LF>
xxxx, xxxx, xxxx, xxxx, xxxx, xxxx, xxxx, xxxx, xxxx, xxxx,"xxxx", xxxx, xxxx,
   xxxx, xxxx, xxxx,"xxxx","xxxx","yyyy"<CR><LF><ETX>
```

(the last line is then repeated for each record)

where:

`xxxx` are the data values corresponding to the first line labels

`yyyy` is the 4-byte hex ASCII representation of the checksum

If the history buffer is empty, the relay responds:

```
<STX>"No Data Available","yyyy"<CR><LF><ETX>
```

CEVENT Command—SEL-351

Display event report in Compressed ASCII format by sending:

CEV [*n* S*x* L*y* L R C P] (parameters in [ ] are optional)

where:

n event number, defaults to 1

S*x* *x* samples per cycle (4, 16, 32, or 128); defaults to 4
If S*x* parameter is present, it overrides the L parameter. S128 must be accompanied by R parameter (**CEV S128 R**)

L*y* *y* cycles event report length (1 – LER) for filtered event reports, (1 – LER + 1) for raw event reports, defaults to LER if not specified. Raw reports always contain one extra cycle of data, except for raw reports with S128 parameter, which contain two extra cycles of data.

L 32 samples per cycle; overridden by the S*x* parameter, if present

R specifies raw (unfiltered) data; defaults to 32 samples per cycle unless overridden by the S*x* parameter. Defaults to LER + 1 cycles in length unless overridden with the L*y* parameter.

C specifies 16 samples per cycle analog data, 4 samples per cycle digital data, LER-cycle length, unless overridden by the S*x*, L*y*, L, or R parameters

P precise to synchrophasor-level accuracy for signal content at nominal frequency. This option is available when TSOK = logical 1 when the event report was triggered.

The relay responds to the **CEV** command with the *n*th event report as shown in the sample below.

```
<STX>"FID","yyyy"<CR><LF>
"Relay FID string","yyyy"<CR><LF>
"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","USEC","yyyy"<CR><LF>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"yyyy"<CR><LF>
"REF_NUM","FREQ","SAM/CYC_A","SAM/CYC_D","NUM_OF_CYC","EVENT",
"LOCATION","SHOT","TARGETS","IA","IB","IC","IN","IG","3I2","yyyy"<CR><LF>
xxxx,xxxx,xxxx,xxxx,xxxx,"xxxx",xxxx,xxxx,"xxxx",xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,
"yyyy"<CR><LF>
"IA","IB","IC","IN","IG","VA(kV)"/"VAB(kV)","VB(kV)"/"VBC(kV)","VC(kV)"/"VCA(kV)",
"VS(kV)","VDC","FREQ","DT","TRIG",
"Names of elements in the relay word separated by spaces ","yyyy"<CR><LF>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,z,"HEX-ASCII Relay
   Word","yyyy"<CR><LF>
"SETTINGS","yyyy"<CR><LF>
"Relay group, global, and logic settings as displayed with the showset command
   (surrounded by quotes)","yyyy"<CR><LF><ETX>
```

where:

`xxxx` are the data values corresponding to the line labels

`yyyy` is the 4-byte hex ASCII representation of the checksum

`REF_NUM` is the unique identification number

`FREQ` is the power system frequency at the first visible row of the event

`SAM/CYC_A` is the number of analog data samples per cycle

`SAM/CYC_D` is the number of digital data samples per cycle

`NUM_OF_CYC` is the number of cycles of data in the event report

`EVENT` is the event type

`LOCATION` is the fault location

`SHOT`	is the recloser shot counter
`TARGETS`	are the front-panel tripping targets
`IA, IB, IC, IN, IG, 3I2`	is the fault current
`DT`	is the difference time referenced to previous row (μs)
`TRIG`	refers to the trigger record
z	`>` for the trigger row, `*` for the fault current row and empty for all others. If the trigger row and fault current row are the same, both characters are included (e.g., `>*`)
`HEX-ASCII Relay Word`	is the hex ASCII format of the Relay Word. The first element in the Relay Word is the most significant bit in the first character.

For filtered events, if samples per cycle are specified as 16, the analog data are displayed at 1/16-cycle intervals and digital data are displayed at 1/4-cycle intervals. If samples per cycle are specified as 32, the analog data are displayed at 1/32-cycle intervals and digital data are displayed at 1/4-cycle intervals.

For raw events, both analog and digital data are displayed at the interval specified by the Sx parameter. Digital data are updated every 1/4 cycle. Optoisolated inputs IN101–IN106 are updated every 1/16 cycle.

The digital data are displayed as a series of hex ASCII characters. The relay displays digital data only when they are available. When no data are available, the relay sends only the comma delimiter in the digital data field.

If the specified event does not exist, the relay responds:

```
<STX>"No Data Available","yyyy"<CR><LF><ETX>
```

The “*Names of elements in the Relay Word separated by spaces*” field is shown below for an SEL-351-5 with the nominal neutral channel (**IN**) = 5 A.

```
“50A1 50B1 50C1 50A2 50B2 50C2 50A3 50B3 50C3 50A4 50B4 50C4 50AB1 50BC1 50CA1 50AB2
50BC2 50CA2 50AB3 50BC3 50CA3 50AB4 50BC4 50CA4 50A 50B 50C 51A 51AT 51AR 51B 51BT
51BR 51C 51CT 51CR 51P 51PT 51PR 51N 51NT 51NR 51G 51GT 51GR 51Q 51QT 51QR 50P1 50P2
50P3 50P4 50N1 50N2 50N3 50N4 67P1 67P2 67P3 67P4 67N1 67N2 67N3 67N4 67P1T 67P2T
67P3T 67P4T 67N1T 67N2T 67N3T 67N4T 50G1 50G2 50G3 50G4 50Q1 50Q2 50Q3 50Q4 67G1 67G2
67G3 67G4 67Q1 67Q2 67Q3 67Q4 67G1T 67G2T 67G3T 67G4T 67Q1T 67Q2T 67Q3T 67Q4T 50P5
50P6 50N5 50N6 50G5 50G6 50Q5 50Q6 50QF 50QR 50GF 50GR 32VE 32QGE 32IE 32QE F32P R32P
F32Q R32Q F32QG R32QG F32V R32V F32I R32I 32PF 32PR 32QF 32QR 32GF 32GR 27A1 27B1
27C1 27A2 27B2 27C2 59A1 59B1 59C1 59A2 59B2 59C2 27AB 27BC 27CA 59AB 59BC 59CA 59N1
59N2 59Q 59V1 27S 59S1 59S2 59VP 59VS SF 25A1 25A2 3P27 3P59 81D1 81D2 81D3 81D4 81D5
81D6 27B81 50L 81D1T 81D2T 81D3T 81D4T 81D5T 81D6T VPOLV LOP SFAST SSLOW IN106 IN105

IN104 IN103 IN102 IN101 LB1 LB2 LB3 LB4 LB5 LB6 LB7 LB8 LB9 LB10 LB11 LB12 LB13 LB14
LB15 LB16 RB1 RB2 RB3 RB4 RB5 RB6 RB7 RB8 RB9 RB10 RB11 RB12 RB13 RB14 RB15 RB16 LT1
LT2 LT3 LT4 LT5 LT6 LT7 LT8 LT9 LT10 LT11 LT12 LT13 LT14 LT15 LT16 SV1 SV2 SV3 SV4
SV1T SV2T SV3T SV4T SV5 SV6 SV7 SV8 SV5T SV6T SV7T SV8T SV9 SV10 SV11 SV12 SV9T SV10T
SV11T SV12T SV13 SV14 SV15 SV16 SV13T SV14T SV15T SV16T 79RS 79CY 79LO SH0 SH1 SH2
SH3 SH4 CLOSE CF RCSF OPTMN RSTMN FSA FSB FSC BCW 50P32 * 59VA TRGTR 52A * * SG1 SG2
SG3 SG4 SG5 SG6 ZLOUT ZLIN ZLOAD BCWA BCWB BCWC * 51G2 51G2T 51G2R ALARM OUT107
OUT106 OUT105 OUT104 OUT103 OUT102 OUT101 3PO SOTFE Z3RB KEY EKEY ECTT WFC PT PTRX2
PTRX PTRX1 UBB1 UBB2 UBB Z3XT DSTRT NSTRT STOP BTX TRIP OC CC DCHI DCLO 67P2S 67N2S
67G2S 67Q2S PDEM NDEM GDEM QDEM OUT201 OUT202 OUT203 OUT204 OUT205 OUT206 OUT207
OUT208 OUT209 OUT210 OUT211 OUT212 * * * * IN208 IN207 IN206 IN205 IN204 IN203 IN202

IN201 * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * TSOK
TIRIG * * * * * * * * 27AB2 27BC2 27CA2 59AB2 59BC2 59CA2 59Q2 3V0 V1GOOD * * V0GAIN
INMET ICMET IBMET IAMET * * * * * * 32NF 32NR PMDOK * * * * * * * DELTA WYE SINGLE
TESTDB * * * FREQOK DST DSTP LPSEC LPSECP TQUAL4 TQUAL3 TQUAL2 TQUAL1 RSTTRGT RST_MML
RST_ENE RST_HIS RST_BK RST_PDM RST_DEM RST_HAL * * * PMTRIG TREA4 TREA3 TREA2 TREA1
* LINK5A LINK5B LNKFAIL P5ASEL P5BSEL TSNTPP TSNTPB RB17 RB18 RB19 RB20 RB21 RB22
RB23 RB24 RB25 RB26 RB27 RB28 RB29 RB30 RB31 RB32 LV1 LV2 LV3 LV4 LV5 LV6 LV7 LV8 LV9
LV10 LV11 LV12 LV13 LV14 LV15 LV16 LV17 LV18 LV19 LV20 LV21 LV22 LV23 LV24 LV25 LV26
LV27 LV28 LV29 LV30 LV31 LV32 * * * * * * * * * * * * * * * * * * * * * * * * * * *
* * * * * VB001 VB002 VB003 VB004 VB005 VB006 VB007 VB008 VB009 VB010 VB011 VB012
```

```
VB013 VB014 VB015 VB016 VB017 VB018 VB019 VB020 VB021 VB022 VB023 VB024 VB025 VB026
VB027 VB028 VB029 VB030 VB031 VB032 VB033 VB034 VB035 VB036 VB037 VB038 VB039 VB040
VB041 VB042 VB043 VB044 VB045 VB046 VB047 VB048 VB049 VB050 VB051 VB052 VB053 VB054
VB055 VB056 VB057 VB058 VB059 VB060 VB061 VB062 VB063 VB064 VB065 VB066 VB067 VB068
VB069 VB070 VB071 VB072 VB073 VB074 VB075 VB076 VB077 VB078 VB079 VB080 VB081 VB082
VB083 VB084 VB085 VB086 VB087 VB088 VB089 VB090 VB091 VB092 VB093 VB094 VB095 VB096
VB097 VB098 VB099 VB100 VB101 VB102 VB103 VB104 VB105 VB106 VB107 VB108 VB109 VB110
VB111 VB112 VB113 VB114 VB115 VB116 VB117 VB118 VB119 VB120 VB121 VB122 VB123 VB124
VB125 VB126 VB127 VB128 SALARM ACCESS ALRMOUT * HALARMA HALARMP HALARML HALARM * *
PASNVAL ACCESSP GRPSW SETCHG CHGPASS BADPASS DD LOPRST LOPBLK LOP2 LOP3 * * * ESTRA
ESTRB ESTRC ESCLA ESCLB ESCLC ESOAL MSOAL * * HBL2T HBL2AT HBL2BT HBL2CT MSTR MSCL *
* * 81R4T 81R3T 81R2T 81R1T 81RT * 50BFA 50BFB 50BFC  50BFT RT BFT BFTRIP * * * * *
* * RSTDNPE * * * * * * * *",“yyyy”
```

These names are listed in the Relay Word Bits table for the appropriate model of relay in *Table D.1*. Lists for other relay models may have different Relay Word bits than shown in this sample.

A typical *HEX-ASCII Relay Word* is shown below:

> 00000004100000000000000000000000000000002000000000000000000
> 0000028000080000080000000000000000000C20000000000000000000000
> 01F0000400F0000180000000000000000000000000000000000000000000
> 00000000

Each bit in the *HEX-ASCII Relay Word* reflects the status of a Relay Word bit. The order of the labels in the "*Names of elements in the relay word separated by spaces*" field matches the order of the *HEX-ASCII Relay Word*. In the example above, the fourth byte in the *HEX-ASCII Relay Word* is "04." In binary, this evaluates to 00000100. Mapping the labels to the bits yields:

Table K.1 Mapping Labels to Bits

Labels	50A	50B	50C	51A	51AT	51AR	51B	51BT
Bits	0	0	0	0	0	1	0	0

In this example, the 51AR element is asserted (logical 1); all others are deasserted (logical 0).

CSU Command

Display long summary event report in Compressed ASCII format by sending:

CSU [N[EXT]] [TERSE]

CSU [[ACK] | [TERSE]] [*n*]

where:

No parameters	outputs the newest chronological event summary
ACK	acknowledges the oldest unacknowledged event report summary available on this port, or if a number is supplied, acknowledges the specified summary. Reports acknowledged within a Telnet session are acknowledged for all Telnet sessions on the Ethernet port.
N[EXT]	views oldest unacknowledged event report
n	displays (or acknowledge if ACK present) event summary with this corresponding number in the **HIS E** command.
TERSE	does not display label headers

The relay responds to the **CSU** command with the *n*th long summary event report as shown in the example below:

```
<STX>"FID","yyyy"<CR>
"Relay FID string","yyyy"<CR>
"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy"<CR><LF>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"yyyy"<CR>
"REF_NUM","EVENT","LOCATION","HOUR_T","MIN_T","SEC_T","MSEC_T","SHOT","FREQ",
"GROUP","HOUR_C","MIN_C","SEC_C","MSEC_C","TARGETS","BREAKER","yyyy"<CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,
   "yyyy"<CR><LF>
"IA_PF","IA_DEG_PF","IB_PF","IB_DEG_PF","IC_PF","IC_DEG_PF","IN_PF","IN_DEG_PF",
"IG_PF","IG_DEG_PF","3I2_PF","3I2_DEG_PF","VA_PF","VA_DEG_PF","VB_PF","VB_DEG_PF",
"VC_PF","VC_DEG_PF","yyyy"<CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,
   xxxx,xxxx,"yyyy"<CR><LF>
"IA","IA_DEG","IB","IB_DEG","IC","IC_DEG","IN","IN_DEG","IG","IG_DEG","3I2",
"3I2_DEG","VA","VA_DEG","VB","VB_DEG","VC","VC_DEG","yyyy"<CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,
   xxxx,xxxx,"yyyy"<CR><LF>
"TRIG","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 LBOKB CBADB RBADB ROKB LBOKA CBADA RBADA
ROKA","yyyy"<CR><LF>
">","mmmmmmmmmm","yyyy"<CR><LF>
"*","mmmmmmmmmm","yyyy"<CR><LF><ETX>
```

where:

xxxx	are the data values corresponding to the line labels
yyyy	is the 4-byte hex ASCII representation of the checksum
REF_NUM	is the unique identification number
EVENT	is the event type
LOCATION	is the fault location
HOUR_T, MIN_T, SEC_T, and MSEC_T	are the breaker trip time
SHOT	is the recloser shot counter
FREQ	is the power system frequency at the first visible row of the event
GROUP	is the Active Settings Group
HOUR_C, MIN_C, SEC_C, and MSEC_C	are the breaker close time
TARGETS	are the front-panel tripping targets
BREAKER	is the breaker position at the end of the event
IA_PF	is the phase A current prefault magnitude, IA_DEG_PF is the phase A current angle. IB, IC, IG, 3I2, VA, VB, and VC are similar
IA	is the phase A current fault magnitude, IA_DEG is the phase A current angle. IB, IC, IG, 3I2, VA, VB, and VC are similar
">"	indicates MIRRORED BITS status at the trigger row
"*"	indicates MIRRORED BITS status at the time of trip
mmmmmmmmmm	is the hexidecimal representation of the five MIRRORED BITS status bytes

If the specified event does not exist, the relay responds:

```
<STX>"No Data Available","yyyy"<CR><LF>
<ETX>
```

APPENDIX L

DNP3 Communications

Overview

The SEL-351 Relay provides a Distributed Network Protocol Version 3.0 (DNP3) Level 2 Outstation interface for direct serial and LAN/WAN network connections to the relay.

This section covers the following topics:

Introduction to DNP3

A Supervisory Control and Data Acquisition (SCADA) manufacturer developed the first versions of DNP from the lower layers of IEC 60870-5. Originally designed for use in telecontrol applications, Version 3.0 of the protocol has also become popular for local substation data collection. DNP3 is one of the protocols included in the IEEE 1379-7000, Recommended Practice for Data Communication between Remote Terminal Units (RTUs) and Intelligent Electronic Devices (IEDs) in a Substation.

The DNP Users Group maintains and publishes DNP3 standards. See the DNP Users Group website, www.dnp.org, for more information on standards, implementers, and tools for working with DNP3.

DNP3 Specifications

DNP3 is a feature-rich protocol with many ways to accomplish tasks, defined in an eight-volume series of specifications. Volume 8 of the specification, called the Interoperability Specification, simplifies DNP3 implementation by providing four standard interoperable implementation levels. The levels are listed in *Table L.1*.

Table L.1 DNP3 Implementation Levels (Sheet 1 of 2)

Level	Description	Equipment Types
1	Simple: limited communication requirements	Meters, simple IEDs
2	Moderately complex: monitoring and metering devices and multifunction devices that contain more data	Protective relays, RTUs

Table L.1 DNP3 Implementation Levels (Sheet 2 of 2)

Level	Description	Equipment Types
3	Sophisticated: devices with great amounts of data or complex communication requirements	Large RTUs, SCADA masters
4	Enhanced: additional data types and functionality for more complex requirements	Large RTUs, SCADA masters

Each level is a proper superset of the previous lower-numbered level. A higher-level device can act as a master to a lower-level device, but can only use the data types and functions implemented in the lower level device. For example, a typical SCADA master is a Level 3 device and can use Level 2 (or lower) functions to poll a Level 2 (or lower) device for Level 2 (or lower) data. Similarly, a lower-level device can poll a higher-level device, but the lower level device can only access the features and data available to its level.

In addition to the eight-volume DNP3 specification, the protocol is further refined by conformance requirements, optional features, and a series of technical bulletins. The technical bulletins supplement the specifications with discussion and examples of specific features of DNP3.

Data Handling Objects

DNP3 uses a system of data references called objects, defined by Volume 6 of the DNP3 specification. Each subset level specification requires a minimum implementation of object types and recommends several optional object types. DNP3 object types, commonly referred to as objects, are specifications for the type of data the object carries. An object can include a single value or more complex data. Some objects serve as shorthand references for special operations, including collections of data, time synchronization, or even all data within the DNP3 device.

Each instance of the object includes an index that makes it unique. For example, each binary status point (Object 1) has an index. If there are 16 binary status points, these points are Object 1, Index 0 through Object 1, Index 15.

Each object also includes multiple versions called variations. For example, Object 1 (binary inputs) has three variations: 0, 1, and 2. You can use variation 0 to request the default variation, variation 1 to specify binary input values only, and variation 2 to specify binary input values with status information.

Each DNP3 device has both a list of objects and a map of object indices. The list of objects defines the available objects, variations, and qualifier codes. The map defines the indices for objects that have multiple instances and defines what data or control points correspond with each index.

A master initiates all DNP3 message exchanges except unsolicited data. DNP3 terminology describes all points from the perspective of the master. Binary points for control that move from the master to the outstation are called Binary Outputs, while binary status points within the outstation are called Binary Inputs.

Function Codes

Each DNP3 message includes a function code. Each object has a limited set of function codes that a master may use to manipulate the object. The object listing for the device shows the permitted function codes for each type of object. The most common DNP3 function codes are listed in *Table L.2*.

Table L.2 Selected DNP3 Function Codes

Function Code	Function	Description
1	Read	Request data from the outstation
2	Write	Send data to the outstation
3	Select	First part of a select-before-operate operation
4	Operate	Second part of a select-before-operate operation
5	Direct operate	One-step operation with reply
6	Direct operate, no reply	One-step operation with no reply

Qualifier Codes and Ranges

DNP3 masters use qualifier codes and ranges to make requests for specific objects by index. Qualifier codes specify the style of range, and the range specifies the indices of the objects of interest. DNP3 masters use qualifier codes to compose the shortest, most concise message possible when requesting points from a DNP3 outstation.

For example, the qualifier code 01 specifies that the request for points will include a start address and a stop address. Each of these two addresses uses two bytes. An example request using qualifier code 01 might have the four hexadecimal byte range field, 00h 04h 00h 10h, which specifies points in the range 4 to 16.

Access Methods

DNP3 has many features that help obtain maximum possible message efficiency. DNP3 masters send requests with the least number of bytes using special objects, variations, and qualifiers that reduce the message size. Other features eliminate the continual exchange of static (unchanging) data values. These features optimize use of bandwidth and maximize performance over a connection of any speed.

DNP3 event data collection eliminates the need to use bandwidth to transmit values that have not changed. Event data are time-stamped records that show when observed measurements changed. For binary points, the remote device (DNP3 outstation) logs changes from logical 1 to logical 0 and from logical 0 to logical 1. For analog points, the outstation device logs changes that exceed a deadband. DNP3 outstation devices collect event data in a buffer that either the master can request or the device can send to the master without a request message. Data sent from the outstation to the master without a polling request are called unsolicited data.

DNP3 data fit into one of four event classes: 0, 1, 2, or 3. Class 0 is reserved for reading the present value (static) data. Classes 1, 2, and 3 are event data classes. The meaning of Classes 1 to 3 is arbitrary and defined by the application at hand. With outstations that contain great amounts of data or in large systems, the three event classes provide a framework for prioritizing different types of data. For example, you can poll once a minute for Class 1 data, once an hour for Class 2 data, and once a day for Class 3 data.

DNP3 also supports static polling: simple polling of the present value of data points within the outstation. By combining event data, unsolicited polling, and static polling, you can operate your system in one of the four access methods shown in *Table L.3*.

The access methods listed in *Table L.3* are listed in order of increasing communication efficiency. With various trade offs, each method is less demanding of communication bandwidth than the previous one. For example, unsolicited report-by-exception consumes less communication bandwidth than polled report-by-exception because that method does not require polling messages from the master. In order to properly evaluate which access method provides optimum performance for your application, you should also consider overall system size and the volume of data communication expected.

Table L.3 DNP3 Access Methods

Access Method	Description
Polled static	Master polls for present value (Class 0) data only
Polled report-by-exception	Master polls frequently for event data and occasionally for Class 0 data
Unsolicited report-by-exception	Outstation devices send unsolicited event data to the master, and the master occasionally polls for Class 0 data
Quiescent	Master never polls and relies on unsolicited reports only

Binary Control Operations

DNP3 masters use Object 12, control device output block, to perform DNP3 binary control operations. The control device output block has both a trip/close selection and a code selection. The trip/close selection allows a single DNP3 index to operate two related control points such as trip and close or raise and lower. Trip/close pair operation is not recommended for new DNP3 devices, but is often included for interoperability with older DNP3 master implementations.

The control device output block code selection specifies either a latch or pulse operation on the point. In many cases, DNP3 outstations have only a limited subset of the possible combinations of the code field. Sometimes, DNP3 outstations assign special operation characteristics to the latch and pulse selections.

Conformance Testing

In addition to the protocol specifications, the DNP Users Group has approved conformance-testing requirements for Level 1 and Level 2 devices. Some implementers perform their own conformance specification testing, while some contract with independent companies to perform conformance testing.

Conformance testing does not always guarantee that a master and outstation will be fully interoperable (that is, work together properly for all implemented features). Conformance testing does help to standardize the testing procedure and move the DNP3 implementers toward a higher level of interoperability.

DNP3 Serial Network Issues

Data Link Layer Operation

DNP3 employs a three-layer version of the seven-layer OSI (Open Systems Interconnect) model called the enhanced performance architecture. The layer definition helps to categorize functions and duties of various software components that make up the protocol. The middle layer, the Data Link Layer, includes several functions for error checking and media access control.

A feature called data link confirmation is a mechanism that provides positive confirmation of message receipt by the receiving DNP3 device. While this feature helps you recognize a failed device or failed communications link quickly, it also adds significant overhead to the DNP3 conversation. You should consider whether you require this link integrity function in your application at the expense of overall system speed and performance.

The DNP3 technical bulletin (*DNP Confirmation and Retry Guidelines 9804-002*) on confirmation processes recommends against using data link confirmations because these processes can add to traffic in situations where communications are marginal. The increased traffic will reduce connection throughput further, possibly preventing the system from operating properly.

Network Medium Contention

When more than one device requires access to a single (serial) network medium, you should provide a mechanism to resolve the resulting network medium contention. For example, unsolicited reporting results in network medium contention if you do not design your serial network as a star topology of point-to-point connections or use carrier detection on a multidrop network.

To avoid collisions among devices trying to send messages, DNP3 includes a collision avoidance feature. Before sending a message, a DNP3 device listens for a carrier signal to verify that no other node is transmitting data. The device transmits if there is no carrier or waits for a random time before transmitting. However, if two nodes both detect a lack of carrier at the same instant, these two nodes could begin simultaneous transmission of data and cause a data collision. If your serial network allows for spontaneous data transmission including unsolicited event data transmissions, you also should use application confirmation to provide a retry mechanism for messages lost because of data collisions.

DNP3 LAN/WAN Overview

The main process for carrying DNP3 over an Ethernet Network (LAN/WAN) involves encapsulating the DNP3 data link layer data frames within the transport layer frames of the Internet Protocol (IP) suite. This allows the IP stack to deliver the DNP3 data link layer frames to the destination in place of the original DNP3 physical layer.

The DNP User Group Technical Committee has recommended the following guidelines for carrying DNP3 over a network:

NOTE: Link layer confirmations are explicitly disabled for DNP3 LAN/WAN. The IP suite already provides a reliable delivery mechanism, which is backed up at the application layer by confirmations when required.

- DNP3 uses the IP suite to transport messages over a LAN/WAN
- Ethernet is the recommended physical link, though others may be used
- TCP must be used for WANs
- TCP is strongly recommended for LANs
- User Datagram Protocol (UDP) may be used for highly reliable single segment LANs
- UDP is necessary if broadcast messages are required
- The DNP3 protocol stack is retained in full
- Link layer confirmations is disabled

The Technical Committee has registered a standard port number, 20000, for DNP3 with the Internet Assigned Numbers Authority (IANA). This port is used for either TCP or UDP.

TCP/UDP Selection

The Committee recommends the selection of TCP or UDP protocol as per the guidelines in *Table L.4*.

Table L.4 TCP/UDP Selection Guidelines

Use in the case of...	TCP	UDP
Most situations	X	
Non-broadcast or multicast	X	
Mesh Topology WAN	X	
Broadcast		X
Multicast		X
High-reliability single-segment LAN		X
Pay-per-byte, non-mesh WAN, for example, Cellular Digital Packet Data (CDPD)		X
Low priority data, for example, data monitor or configuration information		X

DNP3 in the SEL-351

The SEL-351 is a DNP3 Level 2 remote (outstation) device.

Data Access

Table L.5 lists DNP3 data access methods along with corresponding SEL-351 settings. You must select a data access method and configure each DNP3 master for polling as specified.

NOTE: Because unsolicited messaging is problematic in most circumstances, SEL recommends using the polled report-by-exception access method to maximize performance and minimize risk of configuration problems.

NOTE: In the settings below, the suffix n represents the DNP3 LAN/WAN session number from 1 to 6. This suffix is not present in Serial Port DNP3 settings. All settings with the same numerical suffix comprise the complete DNP3 session configuration.

Table L.5 DNP3 Access Methods

Access Method	Master Polling	SEL-351 Settings
Polled static	Class 0	Set ECLASSB*n*, ECLASSC*n*, ECLASSA*n* to 0; UNSOL*n* to N.
Polled report-by-exception	Class 0 occasionally, Class 1, 2, 3 frequently	Set ECLASSB*n*, ECLASSC*n*, ECLASSA*n* to the desired event class; UNSOL*n* to N.
Unsolicited report-by-exception	Class 0 occasionally, optional Class 1, 2, 3 less frequently; mainly relies on unsolicited messages	Set ECLASSB*n*, ECLASSC*n*, ECLASSA*n* to the desired event class; set UNSOL*n* to Y and PUNSOL*n* to Y or N.
Quiescent	Class 0, 1, 2, 3 never; relies completely on unsolicited messages	Set ECLASSB*n*, ECLASSC*n*, ECLASSA*n* to the desired event class; set UNSOL*n* and PUNSOL*n* to Y.

In both the unsolicited report-by-exception and quiescent polling methods shown in *Table L.5*, you must make a selection for the PUNSOL*n* setting. This setting enables or disables unsolicited data reporting at power up. If your DNP3 master can send a message to enable unsolicited reporting on the SEL-351, you should set PUNSOL*n* to No.

While automatic unsolicited data transmission on power up is convenient, this can cause problems if your DNP3 master is not prepared to start receiving data immediately on power up. If the master does not acknowledge the unsolicited data with an Application Confirm, the device will resend the data until it is acknowledged. On a large system, or in systems where the processing power of the master is limited, you may have problems when several devices simultaneously begin sending data and waiting for acknowledgment messages.

If the SEL-351 does not receive an Application Confirm in response to unsolicited data, it will wait for ETIMEO*n* seconds and then repeat the unsolicited message. In order to prevent clogging of the network with unsolicited data retries, the SEL-351 uses the URETRY*n* and UTIMEO*n* settings to increase retry time when the number of retries set in URETRY*n* is exceeded. After URETRY*n* has been exceeded, the SEL-351 pauses UTIMEO*n* seconds and then transmits the unsolicited data again. *Figure L.1* provides an example with URETRY*n* = 2.

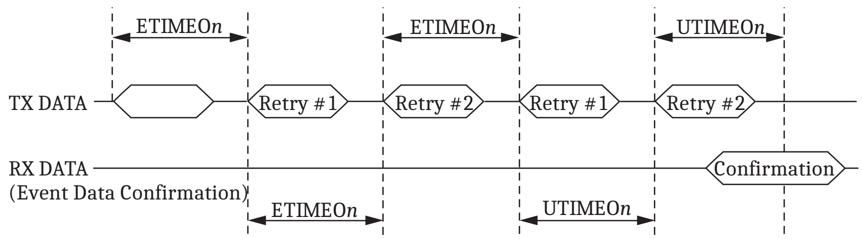

Figure L.1 Application Confirmation Timing With URETRYn = 2

Collision Avoidance

If your application uses unsolicited reporting on a serial network, you must select a half-duplex medium or a medium that includes carrier detection to avoid data collisions. EIA-485 two-wire networks are half-duplex. EIA-485 four-wire networks do not provide carrier detection, while EIA-232 systems can support carrier detection. DNP3 LAN/WAN uses features of the IP suite for collision avoidance, so does not require these settings.

NOTE: MINDLY and MAXDLY settings are only available for EIA-232 and EIA-485 serial port sessions.

The SEL-351 uses Application Confirmation messages to guarantee delivery of unsolicited event data before erasing the local event data buffer. Data collisions are typically resolved when messages are repeated until confirmed.

The SEL-351 pauses for a random delay between the settings MAXDLY and MINDLY when it detects a carrier through data on the receive line or the CTS pin. For example, if you use the settings of 0.10 seconds for MAXDLY and 0.05 seconds for MINDLY, the SEL-351 will insert a random delay of 50 to 100 ms (milliseconds) between the end of carrier detection and the start of data transmission (see *Figure L.2*).

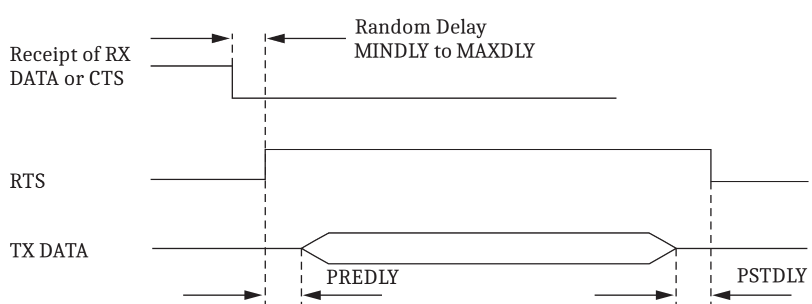

Figure L.2 Message Transmission Timing

Transmission Control

NOTE: PREDLY and POSTDLY settings are only available for EIA-232 and EIA-485 serial port sessions.

If you use a media transceiver (for example, EIA-232 to EIA-485) or a radio system for your DNP3 network, you may need to adjust data transmission properties. Use the PREDLY and POSTDLY settings to provide a delay between RTS signal control and data transmission (see *Figure L.2*). For example, an EIA-485 transceiver typically requires 10 to 20 ms to change from receive to transmit. If you set the predelay to 30 ms, you will avoid data loss resulting from data transmission beginning at the same time as RTS signal assertion.

Event Data

NOTE: Time stamps reported in the SER are truncated to the nearest millisecond while time stamps reported through DNP are rounded to the nearest millisecond. As a result, the time stamps reported in each interface may occasionally be different by 1 ms.

DNP3 event data objects contain change-of-state and time-stamp information that the SEL-351 collects and stores in a buffer. Points assigned in the Binary Input Map that are also assigned in the Sequential Events Recorder (SER) settings carry the time stamp of actual occurrence. Binary input points not assigned in the SER settings will carry a time stamp based on the DNP map scan time. This may be significantly delayed from when the original source changed and should not be used for sequence-of-events determination. The DNP map is scanned approximately once per second to generate events. You can configure the SEL-351 to either report the data without a polling request from the master (unsolicited data) or hold the data until the master requests it with an event poll message.

With the event class settings ECLASSB*n*, ECLASSC*n*, and ECLASSA*n*, you can set the event class for binary, counter, and analog inputs for Ethernet port session *n* (the suffix *n* is not present for serial port event class settings). You can use the classes as a simple priority system for collecting event data. The SEL-351 does not treat data of different classes differently with respect to message scanning, but it does allow the master to perform independent class polls.

NOTE: Most RTUs that act as substation DNP3 masters perform an event poll that collects event data of all classes simultaneously. You must confirm that the polling configuration of your master allows independent polling for each class before implementing separate classes in the SEL-351.

For event data collection you must also consider and enter appropriate settings for deadband and scaling operation on analog points shown in *Table L.10*. You can either:

- set and use default deadband and scaling according to data type, or
- use a custom data map to select deadbands on a point-by-point basis.

Deadbands for analog inputs can be modified at run-time by writing to object 34. Deadband changes via Object 34 are stored in volatile memory. Make sure to reissue the Object 34 deadband changes you want to retain after a change to DNP port settings, after issuing a **STA C** command, or after a relay power-cycle.

The settings ANADBA*n*, ANADBV*n*, and ANADBM*n* control default deadband operation for each type of analog data. Because DNP3 Objects 30 and 32 use integer data by default, you may have to use scaling to send digits after the decimal point and avoid rounding to a simple integer value.

You can set the default analog value class level scaling with the DECPLA*n*, DECPLV*n*, and DECPLM*n* settings. Application of event reporting deadbands occurs after scaling. For example, if you set DECPLA*n* to 2 and ANADBA*n* to 10, a measured current of 10.14 A would be scaled to the value 1014 and would have to increase to more than 1024 or decrease to less than 1004 (a change in magnitude of ± 0.1 A) for the device to report a new event value.

With no scaling and transmitting with the default variation, the value of 12.632 would be truncated and sent as 13. With a class level scaling setting of 1, the value transmitted is 126. With a class level scaling setting of 3, the value transmitted is 12632. You must make certain that the maximum value does not exceed

32767 if you are polling the default 16-bit variations for Objects 30 and 32, but you can send some decimal values using this technique. You must also configure the master to perform the appropriate division on the incoming value to display it properly.

The SEL-351 uses the NUM1EVE*n* and AGE1EVE*n* settings to decide when to send unsolicited data to the master. The device sends an unsolicited report when the total number of events accumulated in the event buffer for master *n* reaches NUM1EVE*n*. The device also sends an unsolicited report if the age of the oldest event in the master n buffer exceeds AGE1EVE*n*. The SEL-351 has the per-session buffer capacities listed in *Table L.6*.

Table L.6 SEL-351 Event Buffer Capacity

Type	Maximum Number of Events
Binary	1024
Analog	200
Counters	8

Binary Controls

The SEL-351 provides more than one way to control individual points. The SEL-351 maps incoming control points either to remote bits or to internal command bits that cause circuit breaker operations.

A DNP3 technical bulletin (*Control Relay Output Block Minimum Implementation 9701-002*) recommends that you use one point per Object 12, control block output device. You can use this method to perform Pulse On, Pulse Off, Latch On, and Latch Off operations on selected remote bits.

If your master does not support the single-point-per-index messages or single operation database points, you can use the trip/close operation or use the code field in the DNP3 message to specify operation of the points.

Time Synchronization

The accuracy of DNP3 time synchronization is insufficient for most protection and oscillography needs. DNP3 time synchronization provides backup time synchronization in the event the device loses primary synchronization through the IRIG-B input or the Simple Network Time protocol (SNTP). You can enable time synchronization with the TIMERQ*n* setting and then use Object 50, Variation 1, and Object 52, Variation 2, to set the time via the Session *n* DNP3 master (Object 50, variation 3 for DNP3 LAN/WAN).

By default, the SEL-351 accepts but does not act on time set requests (TIMERQ*n* = I for “ignore”). This mode allows the SEL-351 to use a high accuracy, IRIG time source, but still interoperate with DNP3 masters that send time synchronization messages. It can be set to request time synchronization periodically by setting the TIMERQ*n* setting to the desired period. It can also be set to not request, but accept and act on time synchronization requests from the master (TIMERQ*n* = M for “master”).

If the relay time is only synchronized over DNP, the relay time is considered synchronized for a period based on the TIMERQ Port setting. When the TIMERQ setting is less than 30 minutes, the relay time is considered synchronized for two times the TIMERQ setting. When the TIMERQ setting is greater than 30 minutes, the relay time is considered synchronized for 30 minutes plus the TIMERQ setting. When TIMERQ is not set to a time (TIMERQ = M) for any port, the time is considered synchronized for 60 minutes. When the device time is considered synchronized, an Object 2, Variation 3 (Binary Input Event with Relative Time) request will result in an Object 51, Variation 1 (Time and Date Common Time-of-Occurrence - synchronized) response. When the device time is no longer considered synchronized, an Object 2, Variation 3 (Binary Input Event with Relative Time) request will result in an Object 51, Variation 2 (Time and Date Common Time-of-Occurrence—unsynchronized) response.

Global setting DNPSRC controls the time base for DNP time. If the master sends time in UTC, set DNPSRC to UTC. If the master sends local time, set DNPSRC to local.

DNP3 Settings

The DNP3 port configuration settings available on the SEL-351 are shown in *Table L.7*. You can enable DNP3 on any of the serial Ports 1, 2, 3, or F or on Ethernet Port 5, to a maximum of six concurrent DNP3 sessions. All DNP sessions can be on the Ethernet port, or on four separate serial ports, or a combination of the two. See *Table 10.8* for DNP protocol session limitations.

Each session defines the characteristics of the connected DNP3 Master, to which you assign one of the three available custom maps. Some settings only apply to DNP3 LAN/WAN, and are visible only when configuring the Ethernet port. For example, you only have the ability to define multiple sessions (as many as six) on Port 5, the Ethernet port. For this reason, DNP settings for Ethernet sessions have a suffix *n* that indicates the session number from one to six, for example, DNPIP1, ETIMEO2, and AGE1EVE3. Serial DNP3 ports do not support multiple sessions, so they do not have the suffix *n*.

Table L.7 Port DNP3 Protocol Settings (Sheet 1 of 4)

Name	Description	Range	Default
Serial Port 1–4 Settings			
DNPADR	Device DNP3 address	0–65519	0
REPADR	DNP3 address of the Master to send messages to	0–65519	0
DNPMAP	DNP3 Session Custom Map	1–3	1
DVARAI	Analog Input Default Variation	1–6	4
ECLASSB	Class for binary event data, 0 disables	0–3	1
ECLASSC	Class for counter event data, 0 disables	0–3	0
ECLASSA	Class for analog event data, 0 disables	0–3	2
DECPLA	Decimal places scaling for Current data	0–3	1
DECPLV	Decimal places scaling for Voltage data	0–3	1
DECPLM	Decimal places scaling for Miscellaneous data	0–3	1
ANADBA	Analog reporting deadband for current; hidden if ECLASSA set to 0	0–32767	100
ANADBV	Analog reporting deadband for voltages; hidden if ECLASSA set to 0	0–32767	100
ANADBM	Analog reporting deadband for miscellaneous analogs; hidden if ECLASSA and ECLASSC set to 0	0–32767	100
TIMERQ	Time-set request interval, minutes (M = Disables time sync requests, but still accepts and applies time syncs from Master; I = Ignores (does not apply) time syncs from Master)	I, M, 1–32767	I
STIMEO	Select/operate time-out, seconds	0.0–30.0	1.0
DRETRY	Data link retries	0–15	0

Table L.7 Port DNP3 Protocol Settings (Sheet 2 of 4)

Name	Description	Range	Default
DTIMEO	Data link time-out, seconds; hidden if DRETRY set to 0	0.0–5.0	1
ETIMEO	Event message confirm time-out, seconds	1–50	5
UNSOL	Enable unsolicited reporting; hidden and set to N if ECLASSB, ECLASSC, and ECLASSA set to 0	Y, N	N
PUNSOL[a]	Enable unsolicited reporting at power up; hidden and set to N if UNSOL set to N	Y, N	N
NUM1EVE[a]	Number of events to transmit on	1–200	10
AGE1EVE[a]	Oldest event to transmit on, seconds	0.0–99999.0	2.0
URETRY[a]	Unsolicited messages maximum retry attempts	2–10	3
UTIMEO[a]	Unsolicited messages offline timeout, seconds	1–5000	60
MINDLY	Minimum delay from DCD to TX, seconds	0.00–1.00	0.05
MAXDLY	Maximum delay from DCD to TX, seconds	0.00–1.00	0.10
PREDLY	Settle time from RTS on to TX, seconds; Off disables PSTDLY	OFF, 0.00–30.00	0.00
PSTDLY	Settle time from TX to RTS off, seconds; hidden if PREDLY set to Off	0.00–30.00	0.00
MINDIST	Event minimum fault location	OFF, –10000.0 to 10000.0	OFF
MAXDIST	Event maximum fault location	OFF, –10000.0 to 10000.0	OFF
EVEMODE	Event mode for startup	SINGLE, MULTI	SINGLE
RPEVTYP	Event type to report	TRIP, ALL	ALL
Ethernet DNP Settings			
EDNP	Enable DNP3 Sessions	0–6	0
DNPNUM	DNP3 TCP and UDP Port	1–65534	20000
DNPADR	Device DNP3 address	0–65519	0
Session 1 Settings			
DNPIP1[b]	IP address (*zzz.yyy.xxx.www*)	15 characters	“”
DNPTR1	Transport protocol	UDP, TCP	TCP
DNPUDP1	UDP response port; hidden if DNPTR1 set to TCP	REQ, 1–65534	20000
REPADR1	DNP3 address of the Master to send messages to	0–65519	0
DNPMAP1	DNP3 Session Custom Map	1–3	1
DVARAI1	Analog Input Default Variation	1–6	4
ECLASSB1	Class for binary event data, 0 disables	0–3	1
ECLASSC1	Class for counter event data, 0 disables	0–3	0
ECLASSA1	Class for analog event data, 0 disables	0–3	2
DECPLA1	Decimal places scaling for Current data	0–3	1
DECPLV1	Decimal places scaling for Voltage data	0–3	1
DECPLM1	Decimal places scaling for Miscellaneous data	0–3	1
ANADBA1	Analog reporting deadband for current; hidden if ECLASSA1 set to 0	0–32767	100
ANADBV1	Analog reporting deadband for voltages; hidden if ECLASSA1 set to 0	0–32767	100
ANADBM1	Analog reporting deadband for miscellaneous analogs; hidden if ECLASSA1 and ECLASSC1 set to 0	0–32767	100

Table L.7 Port DNP3 Protocol Settings (Sheet 3 of 4)

Name	Description	Range	Default
TIMERQ1	Time-set request interval, minutes (M = Disables time sync requests, but still accepts and applies time syncs from Master; I = Ignores (does not apply) time syncs from Master)	I, M, 1–32767	I
STIMEO1	Select/operate time-out, seconds	0.0–30.0	1.0
DNPINA1	Send Data Link Heartbeat, seconds; hidden if DNPTR1 set to UDP	0.0–7200	120
ETIMEO1	Event message confirm time-out, seconds	1–50	5
UNSOL1	Enable unsolicited reporting; hidden and set to N if ECLASSB1, ECLASSC1, and ECLASSA1 set to 0	Y, N	N
PUNSOL1[a]	Enable unsolicited reporting at power up; hidden and set to N if UNSOL1 set to N	Y, N	N
NUM1EVE1[a]	Number of events to transmit on	1–200	10
AGE1EVE1[a]	Oldest event to transmit on, seconds	0.0–99999.0	2.0
URETRY1[a]	Unsolicited messages maximum retry attempts	2–10	3
UTIMEO1[a]	Unsolicited messages offline timeout, seconds	1–5000	60
MINDIST1	Event minimum fault location	OFF, –10000.0 to 10000.0	OFF
MAXDIST1	Event maximum fault location	OFF, –10000.0 to 10000.0	OFF
EVEMODE1	Event mode for startup	SINGLE, MULTI	SINGLE
RPEVTYP1	Event type to report	TRIP, ALL	ALL
Session 2 Settings			
DNPIP2[b]	IP address (*zzz.yyy.xxx.www*)	15 characters	“”
DNPTR2	Transport protocol	UDP, TCP	TCP
• • •			
EVEMODE2	Event mode for startup	SINGLE, MULTI	SINGLE
RPEVTYP2	Event type to report	TRIP, ALL	ALL
Session 3 Settings			
DNPIP3[b]	IP address (*zzz.yyy.xxx.www*)	15 characters	“”
DNPTR3	Transport protocol	UDP, TCP	TCP
• • •			
EVEMODE3	Event mode for startup	SINGLE, MULTI	SINGLE
RPEVTYP3	Event type to report	TRIP, ALL	ALL
Session 4 Settings			
DNPIP4[b]	IP address (*zzz.yyy.xxx.www*)	15 characters	“”
DNPTR4	Transport protocol	UDP, TCP	TCP
• • •			

Table L.7 Port DNP3 Protocol Settings (Sheet 4 of 4)

Name	Description	Range	Default
EVEMODE4	Event mode for startup	SINGLE, MULTI	SINGLE
RPEVTYP4	Event type to report	TRIP, ALL	ALL
Session 5 Settings			
DNPIP5[b]	IP address (*zzz.yyy.xxx.www*)	15 characters	“”
DNPTR5	Transport protocol	UDP, TCP	TCP
• • •			
EVEMODE5	Event mode for startup	SINGLE, MULTI	SINGLE
RPEVTYP5	Event type to report	TRIP, ALL	ALL
Session 6 Settings			
DNPIP6[b]	IP address (*zzz.yyy.xxx.www*)	15 characters	“”
DNPTR6	Transport protocol	UDP, TCP	TCP
• • •			
EVEMODE6	Event mode for startup	SINGLE, MULTI	SINGLE
RPEVTYP6	Event type to report	TRIP, ALL	ALL

[a] Hidden if UNSOLn set to N.
[b] DNP IP address of each session (DNPIP1, DNPIP2, etc.) must be unique.

DNP3 Documentation

Device Profile

The DNP3 Device Profile XML document, available as a download from the SEL website, contains the standard device profile information for the SEL-351. Please refer to this document for complete information on the DNP3 Protocol support in the SEL-351.

Table L.8 contains the standard DNP3 device profile information. Rather than check boxes in the example Device Profile in the DNP3 Subset Definitions, only the relevant selections are shown.

Table L.8 SEL-351 DNP3 Device Profile (Sheet 1 of 2)

Parameter	Value
Vendor name	Schweitzer Engineering Laboratories
Device name	SEL-351-5, -6, -7, SEL-351A, SEL-351A-1
Highest DNP request level	Level 2
Highest DNP response level	Level 2
Device function	Outstation
Notable objects, functions, and/or qualifiers supported	Analog Deadband Objects (object 34)
Maximum data link frame size transmitted/received (octets)	292

Table L.8 SEL-351 DNP3 Device Profile (Sheet 2 of 2)

Parameter	Value
Maximum data link retries	Configurable, range 0–15
Requires data link layer confirmation	Configurable by setting
Maximum application fragment size transmitted/received (octets)	2048
Maximum application layer retries	None
Requires application layer confirmation	When reporting Event Data
Data link confirm time-out	Configurable
Complete application fragment time-out	None
Application confirm time-out	Configurable
Complete Application response time-out	None
Executes control WRITE binary outputs	Always
Executes control SELECT/OPERATE	Always
Executes control DIRECT OPERATE	Always
Executes control DIRECT OPERATE-NO ACK	Always
Executes control count greater than 1	Never
Executes control Pulse On	Always
Executes control Pulse Off	Always
Executes control Latch Off	Always
Executes control Latch On	Always
Executes control Queue	Never
Executes control Clear Queue	Never
Reports binary input change events when no specific variation requested	Only time-tagged
Reports time-tagged binary input change events when no specific variation requested	Binary Input change with time
Sends unsolicited responses	Configurable with unsolicited message enable settings. Increases retry time (configurable) when a maximum retry setting is exceeded.
Sends static data in unsolicited responses	Never
Default counter object/variation	Object 20, Variation 6
Counter roll-over	16 bits
Sends multifragment responses	Yes

In response to the delay measurement function code, the SEL-351 will return a time delay accurate to within 50 milliseconds.

Object List

Table L.9 lists the objects and variations with supported function codes and qualifier codes available in the SEL-351. The list of objects conforms to the format laid out in the DNP specifications and includes supported objects for DNP3 implementation Level 2 and above and non-supported objects for DNP3 implementation Level 2 only. DNP3 implementation Level 2 functionality that is not supported is noted.

Table L.9 SEL-351 DNP Object List (Sheet 1 of 5)

Obj.	Var.	Description	Request[a]		Response[b]	
			Func. Codes[c]	Qual. Codes[d]	Func. Codes[c]	Qual. Codes[d]
0	211	Device Attributes—User-specific sets of attributes	1	0, 6	129	0, 17
0	212	Device Attributes—Master data set prototypes	1	0, 6	129	0, 17
0	213	Device Attributes—Outstation data set prototypes	1	0, 6	129	0, 17
0	214	Device Attributes—Master data sets	1	0, 6	129	0, 17
0	215	Device Attributes—Outstation data sets	1	0, 6	129	0, 17
0	216	Device Attributes—Max binary outputs per request	1	0, 6	129	0, 17
0	219	Device Attributes—Support for analog output events	1	0, 6	129	0, 17
0	220	Device Attributes—Max analog output index	1	0, 6	129	0, 17
0	221	Device Attributes—Number of analog outputs	1	0, 6	129	0, 17
0	222	Device Attributes—Support for binary output events	1	0, 6	129	0, 17
0	223	Device Attributes—Max binary output index	1	0, 6	129	0, 17
0	224	Device Attributes—Number of binary outputs	1	0, 6	129	0, 17
0	225	Device Attributes—Support for frozen counter events	1	0, 6	129	0, 17
0	226	Device Attributes—Support for frozen counters	1	0, 6	129	0, 17
0	227	Device Attributes—Support for counter events	1	0, 6	129	0, 17
0	228	Device Attributes—Max counter index	1	0, 6	129	0, 17
0	229	Device Attributes—Number of counters	1	0, 6	129	0, 17
0	230	Device Attributes—Support for frozen analog inputs	1	0, 6	129	0, 17
0	231	Device Attributes—Support for analog input events	1	0, 6	129	0, 17
0	232	Device Attributes—Max analog input index	1	0, 6	129	0, 17
0	233	Device Attributes—Number of analog inputs	1	0, 6	129	0, 17
0	234	Device Attributes—Support for double-bit events	1	0, 6	129	0, 17
0	235	Device Attributes—Max double-bit binary index	1	0, 6	129	0, 17
0	236	Device Attributes—Number of double-bit binaries	1	0, 6	129	0, 17

Table L.9 SEL-351 DNP Object List (Sheet 2 of 5)

Obj.	Var.	Description	Request[a]		Response[b]	
			Func. Codes[c]	Qual. Codes[d]	Func. Codes[c]	Qual. Codes[d]
0	237	Device Attributes—Support for binary input events	1	0, 6	129	0, 17
0	238	Device Attributes—Max binary input index	1	0, 6	129	0, 17
0	239	Device Attributes—Number of binary inputs	1	0, 6	129	0, 17
0	240	Device Attributes—Max transmit fragment size	1	0, 6	129	0, 17
0	241	Device Attributes—Max receive fragment size	1	0, 6	129	0, 17
0	242	Device Attributes—Device manufacturer's software version (FID string)	1	0, 6	129	0, 17
0	243	Device Attributes—Device manufacturer's hardware version (Part number)	1	0, 6	129	0, 17
0	245	Device Attributes—User-assigned location name (TID setting)	1	0, 6	129	0, 17
0	246	Device Attributes—User assigned ID code/number (RID setting)	1	0, 6	129	0, 17
0	247	Device Attributes—User-assigned device name (RID setting)	1	0, 6	129	0, 17
0	248	Device Attributes—Device serial number	1	0, 6	129	0, 17
0	249	Device Attributes—DNP subset and conformance (e.g., "2:2009")	1	0, 6	129	0, 17
0	250	Device Attributes—Device manufacturer's product name and model (e.g., "SEL-351 Relay")	1	0, 6	129	0, 17
0	252	Device Attributes—Device manufacturer's name ("SEL")	1	0, 6	129	0, 17
0	254	Device Attributes—Nonspecific all attributes request	1	0, 6	129	0, 17
0	255	Device Attributes—List of attribute variations	1	0, 6	129	0, 17
1	0	Binary Input—Any Variation	1, 22	0, 1, 6, 7, 8, 17, 28		
1	1	Binary Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
1	2[e]	Binary Input With Status	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
2	0	Binary Input Change—Any Variation	1	6, 7, 8		
2	1	Binary Input Change Without Time	1	6, 7, 8	129	17, 28
2	2[e]	Binary Input Change With Time	1	6, 7, 8	129, 130	17, 28
2	3	Binary Input Change With Relative Time	1	6, 7, 8	129	17, 28
10	0	Binary Output—Any Variation	1	0, 1, 6, 7, 8, 17, 28		
10	2[e]	Binary Output Status	1	0, 1, 6, 7, 8	129	0, 1
12	1	Control Relay Output Block	3, 4, 5, 6	17, 28	129	echo of request
12	2	Pattern Control Block	3, 4, 5, 6	7	129	echo of request

Table L.9 SEL-351 DNP Object List (Sheet 3 of 5)

Obj.	Var.	Description	Request[a]		Response[b]	
			Func. Codes[c]	Qual. Codes[d]	Func. Codes[c]	Qual. Codes[d]
12	3	Pattern Mask	3, 4, 5, 6	0, 1	129	echo of request
20	0	Binary Counter—Any Variation	1, 22	0, 1, 6, 7, 8, 17, 28		
20	0	Binary Counter—Any Variation	7, 8, 9, 10[f]	0, 1, 6, 7, 8		
20	1	32-Bit Binary Counter	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	2	16-Bit Binary Counter	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	5	32-Bit Binary Counter Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	6[e]	16-Bit Binary Counter Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
21[g]	0	Frozen Counter—Any Variation	1, 22	6, 7, 8		
21[g]	1	32-Bit Frozen Counter	1	6, 7, 8	129	0, 1, 17, 28
21[g]	2	16-Bit Frozen Counter	1	6, 7, 8	129	0, 1, 17, 28
21[g]	5	32-Bit Frozen Counter With Time of Freeze	1	6, 7, 8	129	0, 1, 17, 28
21[g]	6	16-Bit Frozen Counter With Time of Freeze	1	6, 7, 8	129	0, 1, 17, 28
21[g]	9	32-Bit Frozen Counter Without Flag	1	6, 7, 8	129	0, 1, 17, 28
21[g]	10	16-Bit Frozen Counter Without Flag	1	6, 7, 8	129	0, 1, 17, 28
22	0	Counter Change Event—Any Variation	1	6, 7, 8		
22	1	32-Bit Counter Change Event Without Time	1	6, 7, 8	129	17, 28
22	2[e]	16-Bit Counter Change Event Without Time	1	6, 7, 8	129, 130	17, 28
22	5	32-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
22	6	16-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
30[h]	0	Analog Input—Any Variation	1, 22	0, 1, 6, 7, 8, 17, 28		
30[h]	1	32-Bit Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30[h]	2	16-Bit Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30[h]	3	32-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30[h]	4	16-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30[h]	5	Short Floating-Point Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30[h]	6	Long Floating-Point Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
32[h]	0	Analog Change Event—Any Variation	1	6, 7, 8		
32[h]	1	32-Bit Analog Change Event Without Time	1	6, 7, 8	129, 130[g]	17, 28
32[h]	2	16-Bit Analog Change Event Without Time	1	6, 7, 8	129, 130	17, 28
32[h]	3	32-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
32[h]	4	16-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28

Table L.9 SEL-351 DNP Object List (Sheet 4 of 5)

Obj.	Var.	Description	Request[a]		Response[b]	
			Func. Codes[c]	Qual. Codes[d]	Func. Codes[c]	Qual. Codes[d]
32[h]	5	Short Floating-Point Analog Change Event	1	6, 7, 8	129	17, 28
32[h]	6	Long Floating-Point Analog Change Event	1	6, 7, 8	129	17, 28
32[h]	7	Short Floating-Point Analog Change Event With Time	1	6, 7, 8	129	17, 28
32[h]	8	Long Floating-Point Analog Change Event With Time	1	6, 7, 8	129	17, 28
34	0	Analog Deadband—Any Variation	1, 2	0, 1, 6, 7, 8, 17, 28		
34	1[e]	16-Bit Analog Input Reporting Dead-band Object	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	2	32-Bit Analog Input Reporting Dead-band Object	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	3	Short Floating-Point Analog Input Reporting Deadband Object	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
40	0	Analog Output Status—Any Variation	1	0, 1, 6, 7, 8		
40	1	32-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	2[e]	16-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	3	Short Floating-Point Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	4	Long Floating-Point Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
41	0	Analog Output Block—Any Variation	3, 4, 5, 6	17, 28		
41	1	32-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
41	2[e]	16-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
41	3	Short Floating-Point Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
41	4	Long Floating-Point Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
50	0	Time and Date—Any Variation	1, 2	7, 8		
50	1	Time and Date	1, 2	7, 8 index = 0	129	07, quantity = 1
50	3	Time and Date Last Recorded	2	7 quantity = 1	129	
51	1	Time and Date CTO			129, 130[g]	07, quantity = 1
51	2	Unsynchronized Time and Date CTO			129, 130[g]	07, quantity = 1
52	1	Time Delay, Coarse			129[g]	07, quantity = 1
52	2	Time Delay, Fine			129	07, quantity = 1
60	0	All Classes of Data	1, 20, 21, 22	6, 7, 8		
60	1	Class 0 Data	1, 22	6, 7, 8		
60	2	Class 1 Data	1, 20, 21, 22	6, 7, 8		
60	3	Class 2 Data	1, 20, 21, 22	6, 7, 8		
60	4	Class 3 Data	1, 20, 21, 22	6, 7, 8		

Table L.9 SEL-351 DNP Object List (Sheet 5 of 5)

Obj.	Var.	Description	Request[a]		Response[b]	
			Func. Codes[c]	Qual. Codes[d]	Func. Codes[c]	Qual. Codes[d]
80	1	Internal Indications	2	0, 1 index = 7		
N/A		No object required for the following function codes: 13 cold start, 14 warm start, 23 delay measurement	13, 14, 23			

[a] Supported in requests from master.
[b] May generate in response to master.
[c] Decimal.
[d] Hexadecimal.
[e] Default variation.
[f] The relay accepts function codes 7, 8, 9, and 10 and responds without an error, but takes no action, because the frozen counters are not supported.
[g] DNP3 implementation Level 2 functionality which is not supported by the relay.
[h] Default variation specified by serial port setting DVARAI (or DVARAIn for Ethernet session n [n = 1–6]).

Reference Data Map

Table L.10 shows the SEL-351 reference data map. The reference map shows the data available to a DNP3 master. You can use the default map or the custom DNP3 mapping functions of the SEL-351 to retrieve only the points required by your application.

NOTE: Deadband changes via Object 34 are stored in volatile memory. Make sure to reissue any Object 34 deadband changes you want to retain after a change to DNP port settings, after issuing a **STA C** command, or after the relay restarts.

NOTE: In *Table L.10*, index numbers are provided as a reference to aid in the conversion of settings from relays with firmware prior to R500.

In order to retrieve SER-quality binary inputs, SEL-351 models prior to firmware R500 required mapping points within the range of indexes (500–999) dedicated to SER inputs. This is not necessary for the SEL-351 Relays with firmware R500 or higher. If a point is registered in the SER, it will automatically have an SER time stamp when included in the default or custom data map.

When PTCONN = DELTA, the per-phase power values, power factors, and 3V0 are set to 0, but three-phase values are defined and valid. Also, VA, VB, and VC are replaced with values of VAB, VBC, and VCA respectively, so these points do not need to be remapped if you change the PTCONN setting.

The SEL-351 scales analog values by the indicated settings or fixed scaling indicated in the description. Analog deadbands for event reporting use the indicated settings, or ANADBM if you have not specified a setting.

Table L.10 DNP3 Reference Data Map (Sheet 1 of 6)

Obj. Type	Label	Description	Index (for firmware prior to R500)
Binary Inputs			
01, 02	Relay Word	Relay Word Bit label, (rows 2–62), where index 0 is 50B3 and 487 is PMDOK. See *Appendix D: Relay Word Bits*.	000–499 (500–999 from SER)
01, 02	Relay Word	Relay Word bits rows 63–102. See *Appendix D: Relay Word Bits*.	–
01, 02	81	Relay Front-panel target/status LED	1000
01, 02	51	Relay Front-panel target/status LED	1001
01, 02	50	Relay Front-panel target/status LED	1002
01, 02	SOTF	Relay Front-panel target/status LED	1003
01, 02	COMM	Relay Front-panel target/status LED	1004
01, 02	INST	Relay Front-panel target/status LED	1005
01, 02	TRIP_LED	Relay Front-panel target/status LED	1006

Table L.10 DNP3 Reference Data Map (Sheet 2 of 6)

Obj. Type	Label	Description	Index (for firmware prior to R500)
01, 02	EN	Relay Front-panel target/status LED	1007
01, 02	LO	Relay Front-panel target/status LED	1008
01, 02	CY	Relay Front-panel target/status LED	1009
01, 02	RS	Relay Front-panel target/status LED	1010
01, 02	N	Relay Front-panel target/status LED	1011
01, 02	G	Relay Front-panel target/status LED	1012
01, 02	C	Relay Front-panel target/status LED	1013
01, 02	B	Relay Front-panel target/status LED	1014
01, 02	A	Relay Front-panel target/status LED	1015
01, 02	LDPFA[a], LDPFB[a], LDP-FC[a], LDPF3[a]	Power factor leading for A, B, C and 3 phase	1016–1019
01, 02	RLYDIS	Relay disabled	1020
01, 02	STFAIL	Relay diagnostic failure	1021
01, 02	STWARN	Relay diagnostic warning	1022
01, 02	UNRDEV	An unread relay event is available	1023
01, 02	STSET	Settings change or relay restart	1024
01, 02	NUNREV	A more recent unread relay event is available	1025
Binary Outputs			
10, 12	RB1–RB16	Remote bits	00–15
10, 12	RB17–RB32	Remote bits	–
10, 12	OC	Breaker Pulse Open command OC	16
10, 12	CC	Breaker Pulse Close command CC	17
10, 12	DRST_DEM	Reset demands	18
10, 12	DRST_PDM	Reset peak demands	19
10, 12	DRST_ENE	Reset energies	20
10, 12	DRST_BK	Reset breaker monitor	21
10, 12	DRST_TAR	Reset front panel targets	22
10, 12	NXTEVE	Read next relay event	23
10, 12	RB1:RB2, RB3:RB4, RB5:RB6, RB7:RB8, RB9:RB10, RB11:RB12, RB13:RB14, RB15:RB16	Remote bit pairs	24–31
10, 12	RB17:RB18, RB19:RB20, RB21:RB22, RB23:RB24, RB25:RB26, RB27:RB28, RB29:RB30, RB31:RB32	Remote bit pairs	–
10, 12	OC:CC	Breaker Open/Close pair OC & CC	32
10, 12	RBx:RBy	Remote bit pairs, non-sequential (Open bit listed first, followed by Close bit)	–
10, 12	DRST_MML	Reset Max Min	–
10, 12	DRST_HIS	Reset event history	–
10, 12	DRST_HAL	Reset HALARMA	–

Table L.10 DNP3 Reference Data Map (Sheet 3 of 6)

Obj. Type	Label	Description	Index (for firmware prior to R500)
10, 12	DRSTDNPE	Reset DNP Event Registers	–
10, 12	SINGEVE	Switch to Single-Event Mode	–
Counter Inputs			
20, 22	ACTGRP	Active settings group	0
20, 22	INTTR	Internal breaker trips	1
20, 22	EXTTR	External breaker trips	2
20, 22	ESOALCNT	Electrical operation time alarm counter	–
20, 22	MSOALCNT	Mechanical operation time alarm counter	–
Analog Inputs			
30, 32, 34	IA[b], IAFA[c]	IA magnitude and angle	00, 01
30, 32, 34	IB[b], IBFA[c]	IB magnitude and angle	02, 03
30, 32, 34	IC[b], ICFA[c]	IC magnitude and angle	04, 05
30, 32, 34	IN[b], INFA[c]	IN magnitude and angle	06, 07
30, 32, 34	VA[d], VAFA[c]	VA magnitude (kV) and angle. Contains VAB magnitude and angle when PTCONN = Delta.	08, 09
30, 32, 34	VB[d], VBFA[c]	VB magnitude (kV) and angle. Contains VBC magnitude and angle when PTCONN = Delta.	10, 11
30, 32, 34	VC[d], VCFA[c]	VC magnitude (kV) and angle. Contains VCA magnitude and angle when PTCONN = Delta.	12, 13
30, 32, 34	VAB[d], VABFA[c]	VAB magnitude (kV) and angle	–
30, 32, 34	VBC[d], VBCFA[c]	VBC magnitude (kV) and angle	–
30, 32, 34	VCA[d], VCAFA[c]	VCA magnitude (kV) and angle	–
30, 32, 34	VS[d], VSFA[c]	VS magnitude (kV) and angle	14, 15
30, 32, 34	IG[b], IGFA[c]	IG magnitude and angle	16, 17
30, 32, 34	3I0[b], 3I0FA[c]	3I0 magnitude and angle	–
30, 32, 34	I1[b], I1FA[c]	I1 magnitude and angle	18, 19
30, 32, 34	3I2[b], 3I2FA[c]	3I2 magnitude and angle	20, 21
30, 32, 34	3V0_MAG[c], 3V0FA[c]	3V0 magnitude (kV) and angle	22, 23
30, 32, 34	V1[c], V1FA[c]	V1 magnitude (kV) and angle	24, 25
30, 32, 34	V2[d], V2FA[c]	V2 magnitude (kV) and angle	26, 27
30, 32, 34	MWA[e], MWB[e], MWC[e], MW3[e]	MW A, B, C and 3 phase	28–31
30, 32, 34	MVARA[e], MVARB[e], MVARC[e], MVAR3[e]	MVAR A, B, C and 3 phase	32–35
30, 32, 34	PFA[c], PFB[c], PFC[c], PF3[c]	Power factor A, B, C and 3 phase	36–39
30, 32, 34	FREQ[c]	Frequency	40
30, 32, 34	VDC[f]	VDC	41
30, 32, 34	MWHAI[e], MWHAO[e]	A phase MWhr in and out	42, 43
30, 32, 34	MWHBI[e], MWHBO[e]	B phase MWhr in and out	44, 45
30, 32, 34	MWHCI[e], MWHCO[e]	C phase MWhr in and out	46, 47
30, 32, 34	MWH3I[e], MWH3O[e]	3 phase MWhr in and out	48, 49
30, 32, 34	MVRHAI[e], MVRHAO[e]	A phase MVARhr in and out	50, 51

Table L.10 DNP3 Reference Data Map (Sheet 4 of 6)

Obj. Type	Label	Description	Index (for firmware prior to R500)
30, 32, 34	MVRHBI[e], MVRHBO[e]	B phase MVARhr in and out	52, 53
30, 32, 34	MVRHCI[e], MVRHCO[e]	C phase MVARhr in and out	54, 55
30, 32, 34	MVRH3I[e], MVRH3O[e]	3 phase MVARhr in and out	56, 57
30, 32, 34	IADEM[b], IBDEM[b], ICDEM[b], INDEM[b], IGDEM[b], 3I2DEM[b]	Demand IA, IB, IC, IN, IG, and 3I2 magnitudes	58–63
30, 32, 34	MWADI[e], MWBDI[e], MWCDI[e], MW3DI[e]	A, B, C and 3 phase demand MW in	64–67
30, 32, 34	MVRADI[e], MVRBDI[e], MVRCDI[e], MVR3DI[e]	A, B, C and 3 phase demand MVAR in	68–71
30, 32, 34	MWADO[e], MWBDO[e], MWCDO[e], MW3DO[e]	A, B, C and 3 phase demand MW out	72–75
30, 32, 34	MVRADO[e], MVRBDO[e], MVRCDO[e], MVR3DO[e]	A, B, C and 3 phase demand MVAR out	76–79
30, 32, 34	IAPK[b], IBPK[b], ICPK[b], INPK[b], IGPK[b], 3I2PK[b]	Peak demand IA, IB, IC, IN, IG, and 3I2 magnitudes	80–85
30, 32, 34	MWAPI[e], MWBPI[e], MWCPI[e], MW3PI[e]	A, B, C and 3 phase peak demand MW in	86–89
30, 32, 34	MVRAPI[e], MVRBPI[e], MVRCPI[e], MVR3PI[e]	A, B, C and 3 phase peak demand MVAR in	90–93
30, 32, 34	MWAPO[e], MWBPO[e], MWCPO[e], MW3PO[e]	A, B, C and 3 phase peak demand MW out	94–97
30, 32, 34	MVRAPO[e], MVRBPO[e], MVRCPO[e], MVR3PO[e]	A, B, C and 3 phase peak demand MVAR out	98–101
30, 32, 34	IAHT, IBHT, ICHT[e]	Phase (A, B, C) current total harmonic distortion (THD)	–
30, 32, 34	INHT[e]	Neutral (channel IN) current total harmonic distortion (THD)	–
30, 32, 34	IAHR, IBHR, ICHR[b]	Phase (A, B, C) current rms magnitude	–
30, 32, 34	INHR[b]	Neutral (channel IN) current rms magnitude	–
30, 32, 34	IAH01, IBH01, ICH01[b]	Phase (A, B, C) current fundamental magnitude (harmonic metering)	–
30, 32, 34	INH01[b]	Neutral (channel IN) current fundamental magnitude (harmonic metering)	–
30, 32, 34	VAHT, VBHT, VCHT[e]	Phase (A, B, C) voltage total harmonic distortion (THD). When PTCONN = DELTA, VA ← V_{AB}, VB ← 0, VC ← V_{BC}.	–
30, 32, 34	VSHT[e]	Channel VS voltage total harmonic distortion (THD)	–
30, 32, 34	VAHR, VBHR, VCHR[d]	Phase (A, B, C) voltage rms magnitude (kV). When PTCONN = DELTA, VA ← V_{AB}, VB ← 0, VC ← V_{BC}.	–
30, 32, 34	VSHR[d]	Channel VS voltage rms magnitude (kV)	–
30, 32, 34	VAH01, VBH01, VCH01[d]	Phase (A, B, C) voltage fundamental magnitude (kV) (harmonic metering). When PTCONN = DELTA, VA ← V_{AB}, VB ← 0, VC ← V_{BC}.	–
30, 32, 34	VSH01[d]	Channel VS voltage fundamental magnitude (kV) (harmonic metering)	–
30, 32, 34	WEARA, WEARB, WEARC	Breaker contact wear percentage (A, B, C)	102–104
30, 32, 34	MAXWEAR	Greatest wear of WEARA, WEARB, or WEARC	–
30, 32, 34	EOTTRAAV[e]	Average electrical trip operating time, A-phase	–

Table L.10 DNP3 Reference Data Map (Sheet 5 of 6)

Obj. Type	Label	Description	Index (for firmware prior to R500)
30, 32, 34	EOTTRBAV[e]	Average electrical trip operating time, B-phase	–
30, 32, 34	EOTTRCAV[e]	Average electrical trip operating time, C-phase	–
30, 32, 34	EOTCLAAV[e]	Average electrical close operating time, A-phase	–
30, 32, 34	EOTCLBAV[e]	Average electrical close operating time, B-phase	–
30, 32, 34	EOTCLCAV[e]	Average electrical close operating time, C-phase	–
30, 32, 34	MOTTRAV[e]	Average mechanical trip operating time	–
30, 32, 34	MOTCLAV[e]	Average mechanical close operating time	–
30, 32, 34	FTYPE[g]	Fault type	105
30, 32, 34	FTYPE16[g]	Fault type (formatted as a 16-bit signed value)	–
30, 32, 34	FLOC[e,g]	Fault location	106
30, 32, 34	FI[b,g]	Maximum-phase fault current	107
30, 32, 34	FIA[b,g]	A-phase fault current, A primary	–
30, 32, 34	FIB[b,g]	B-phase fault current, A primary	–
30, 32, 34	FIC[b,g]	C-phase fault current, A primary	–
30, 32, 34	FIG[b,g]	Residual-ground fault current, A primary	–
30, 32, 34	FIN[b,g]	IN channel fault current, A primary	–
30, 32, 34	FIQ[b,g]	Negative-sequence fault current, A primary	–
30, 32, 34	FLI[b,g]	Highest phase Fault Locator current (largest of FLIA, FLIB, and FLIC)	–
30, 32, 34	FLIA[b,g]	Fault Locator phase A Fault current	–
30, 32, 34	FLIB[b,g]	Fault Locator phase B Fault current	–
30, 32, 34	FLIC[b,g]	Fault Locator phase C Fault current	–
30, 32, 34	FLIG[b,g]	Fault Locator Ground Fault current	–
30, 32, 34	FLIN[b,g]	Fault Locator Neutral Fault current	–
30, 32, 34	FLIQ[b,g]	Fault Locator Negative-Sequence Fault current	–
30, 32, 34	FFREQ[c,g]	Fault frequency	108
30, 32, 34	FGRP[g]	Fault settings group (1–6)	109
30, 32, 34	FSHO[g]	Fault recloser shot counter	110
30, 32, 34	FTIMEH[g], FTIMEM[g], FTIMEL[g]	Fault time in DNP format (high, middle, and low 16 bits)	111–113
30, 32, 34	FTIMEH16[g,h], FTI-MEM16[g,h], FTIMEL16[g,h]	Fault time in DNP format (high, middle, and low 16 bits formatted as a 16-bit signed value)	–
30, 32, 34	FZ[c,g]	Fault impedance magnitude in ohms secondary	–
30, 32, 34	FZFA[c,g]	Fault impedance angle in degrees	–
30, 32, 34	TEMP[f]	Relay Internal Temperature	114
30, 32, 34	FUNR[g]	Number of unread Faults	115
30, 32, 34	51AP[b]	51AP setting in primary units	116
30, 32, 34	51BP[b]	51BP setting in primary units	117
30, 32, 34	51CP[b]	51CP setting in primary units	118
30, 32, 34	51PP[b,i]	51PP setting in primary units	119
30, 32, 34	51GP[b,i]	51GP setting in primary units	120
30, 32, 34	51G2P[b,i]	51G2P setting in primary units	–

Table L.10 DNP3 Reference Data Map (Sheet 6 of 6)

Obj. Type	Label	Description	Index (for firmware prior to R500)
30, 32, 34	51QP[b,i]	51QP setting in primary units	121
30, 32, 34	51NP[b,i]	51NP setting in primary units	122
30, 32, 34	LDPFA[a]	Power Factor Leading = 1, A-phase	–
30, 32, 34	LDPFB[a]	Power Factor Leading = 1, B-phase	–
30, 32, 34	LDPFC[a]	Power Factor Leading = 1, C-phase	–
30, 32, 34	LDPF3[a]	Power Factor Leading = 1, Three-phase	–
30, 32, 34	SNUMBL	Relay Serial Number, lowest four digits	–
30, 32, 34	SNUMBM	Relay Serial Number, middle four digits	–
30, 32, 34	SNUMBH	Relay Serial Number, highest four digits	–
Analog Outputs			
40, 41	ACTGRP[j]	Active settings group	0

[a] For Delta configuration (setting PTCONN = DELTA), the per-phase power values, power factors, and 3V0 are set to 0. Three-phase values are defined and valid.
[b] Scaled according to the DECPLA setting, deadband according to ANADBA setting.
[c] Scaled by 100, deadband according to ANADBM setting.
[d] Scaled according to the DECPLV setting, deadband according to ANADBV setting.
[e] Scaled according to the DECPLM setting, deadband according to ANADBM setting.
[f] Scaled by 10, deadband according to ANADBM setting.
[g] See *Event Data* on page L.35 for a detailed description of these labels.
[h] Required because the DNP library does not support unsigned 16-bit values. These registers are populated with VALUE when VALUE ≤ 32767 and with VALUE−65536 when VALUE ≥ 32767.
[i] Analog inputs are derived from the present active group settings. If the associated settings is set to off, the value will be reported as –1.
[j] The active settings group can be modified by writing the desired settings group number to ACTGRP. If any of the SELOGIC Group Switch equations SS1–SS6 are asserted, the write is accepted but the active group will not change.
[k] Any label not shown to be scaled by any other value has a scaling of 1.
[l] Any label not shown to be associated with a deadband setting is associated with the ANADBM setting.

Default Data Map

The default data map is a subset of the reference map. All data maps are initialized to the default values. *Table L.11* shows the SEL-351 default data map. If the default maps are not appropriate, you can also use the custom DNP mapping commands **SET D *n*** and **SHOW D *n***, where *n* is the map number, to edit or create the map required for your application.

Table L.11 DNP3 Default Data Map (Sheet 1 of 3)

DNP Setting	Object	Point Label	Index
BI_000	01, 02	52A	0
BI_001	01, 02	79RS	1
BI_002	01, 02	79LO	2
BI_003	01, 02	81	3
BI_004	01, 02	51	4
BI_005	01, 02	50	5
BI_006	01, 02	SOTF	6
BI_007	01, 02	COMM	7
BI_008	01, 02	INST	8
BI_009	01, 02	TRIP_LED	9

Table L.11 DNP3 Default Data Map (Sheet 2 of 3)

DNP Setting	Object	Point Label	Index
BI_010	01, 02	EN	10
BI_011	01, 02	LO	11
BI_012	01, 02	CY	12
BI_013	01, 02	RS	13
BI_014	01, 02	N	14
BI_015	01, 02	G	15
BI_016	01, 02	C	16
BI_017	01, 02	B	17
BI_018	01, 02	A	18
BI_019	01, 02	LDPF3	19
BI_020	01, 02	RLYDIS	20
BI_021	01, 02	STFAIL	21
BI_022	01, 02	STWARN	22
BI_023	01, 02	UNRDEV	23
BI_024–BI_199	01, 02	NA	24–199
BO_000–BO_015	10, 12	RB1–RB16	0–15
BO_016	10, 12	OC	16
BO_017	10, 12	CC	17
BO_018	10, 12	DRST_TAR	18
BO_019	10, 12	NXTEVE	19
BO_020–BO_070	10, 12	NA	20–70
AI_000	30, 32, 34	IA	0
AI_001	30, 32, 34	IAFA::500	1
AI_002	30, 32, 34	IB	2
AI_003	30, 32, 34	IBFA::500	3
AI_004	30, 32, 34	IC	4
AI_005	30, 32, 34	ICFA::500	5
AI_006	30, 32, 34	IN	6
AI_007	30, 32, 34	INFA::500	7
AI_008	30, 32, 34	VA	8
AI_009	30, 32, 34	VAFA::500	9
AI_010	30, 32, 34	VB	10
AI_011	30, 32, 34	VBFA::500	11
AI_012	30, 32, 34	VC	12
AI_013	30, 32, 34	VCFA::500	13
AI_014	30, 32, 34	VS	14
AI_015	30, 32, 34	VSFA::500	15
AI_016	30, 32, 34	IG	16
AI_017	30, 32, 34	IGFA::500	17
AI_018	30, 32, 34	MW3	18
AI_019	30, 32, 34	MVAR3	19

Table L.11 DNP3 Default Data Map (Sheet 3 of 3)

DNP Setting	Object	Point Label	Index
AI_020	30, 32, 34	PF3	20
AI_021	30, 32, 34	FREQ	21
AI_022	30, 32, 34	VDC	22
AI_023	30, 32, 34	MWH3I	23
AI_024	30, 32, 34	MWH3O	24
AI_025	30, 32, 34	MVRH3I	25
AI_026	30, 32, 34	MVRH3O	26
AI_027	30, 32, 34	WEARA	27
AI_028	30, 32, 34	WEARB	28
AI_029	30, 32, 34	WEARC	29
AI_030	30, 32, 34	FTYPE	30
AI_031	30, 32, 34	FLOC	31
AI_032	30, 32, 34	FI	32
AI_033	30, 32, 34	FFREQ	33
AI_034	30, 32, 34	FGRP	34
AI_035	30, 32, 34	FSHO	35
AI_036	30, 32, 34	FTIMEH	36
AI_037	30, 32, 34	FTIMEM	37
AI_038	30, 32, 34	FTIMEL	38
AI_039	30, 32, 34	FUNR	39
AI_040–AI_199	30, 32, 34	NA	40–199
AO_000	40, 41	ACTGRP	0
AO_001–AO_007	40, 41	NA	1–7
CO_000	20, 22	ACTGRP	0
CO_001	20, 22	INTTR	1
CO_002	20, 22	EXTTR	2
CO_003–CO_007	20, 22	NA	3–7

Configurable Data Mapping

One of the most powerful features of the SEL-351 implementation is the ability to remap DNP3 data and, for analog values, specify per-point scaling and deadbands. Remapping is the process of selecting data from the reference map and organizing it into a data subset optimized for your application. The SEL-351 uses object and point labels, rather than point indices, to streamline the remapping process. This enables you to quickly create a custom map without having to search for each point index in a large reference map.

You can use any of the three available DNP3 maps simultaneously with as many as six unique DNP3 masters. Each map is initially populated with default data points, as described in *Default Data Map* on page L.24. You can remap the points in a default map to create a custom map with as many as:

- 200 Binary Inputs
- 71 Binary Outputs

- 200 Analog Inputs
- 8 Analog Outputs
- 8 Counters

You can use the **SHOW D *x* <Enter>** command to view the DNP3 data map settings, where *x* is the DNP3 map number from 1 to 3. See *Figure L.3* for an example display of map 1.

```
=>>SHO D 1 <Enter>

DNP Map Settings 1
BI_000  = 52A     BI_001  = 79RS     BI_002  = 79LO     BI_003  = 81
BI_004  = 51      BI_005  = 50       BI_006  = SOTF     BI_007  = COMM
BI_008  = INST    BI_009  = TRIP_LED BI_010  = EN       BI_011  = LO
…
BI_196  = NA      BI_197  = NA       BI_198  = NA       BI_199  = NA

BO_000  = RB1              BO_001  = RB2              BO_002  = RB3
BO_003  = RB4              BO_004  = RB5              BO_005  = RB6
…
BO_069  = NA               BO_070  = NA

AI_000  = VA                     AI_001  = VAFA
AI_002  = VB                     AI_003  = VBFA
AI_004  = VC                     AI_005  = VCFA
AI_006  = VS                     AI_007  = VSFA
AI_008  = IA                     AI_009  = IAFA
…
AI_198  = NA                     AI_199  = NA

AO_000  = ACTGRP  AO_001  = NA       AO_002  = NA       AO_003  = NA
AO_004  = NA      AO_005  = NA       AO_006  = NA       AO_007  = NA

CO_000  = ACTGRP        CO_001  = INTTR         CO_002  = EXTTR
CO_003  = NA            CO_004  = NA            CO_005  = NA
CO_006  = NA            CO_007  = NA
=>>
```

Figure L.3 Sample Response to SHO D Command

You can use the command **SET D *x***, where *x* is the map number, to edit or create custom DNP3 data maps. You can also use the ACSELERATOR QuickSet SEL-5030 Software, which is recommended for this purpose.

The following are valid entries if you choose to use the **SET D** command to create or edit custom maps:

- Binary Inputs—Any Relay Word bit label or additional DNP Binary Input (see *Binary Inputs* on page L.32), the values 0 or 1, or NA
- Binary Outputs—Any Remote bit label or pair, Breaker bit label or pair, or additional DNP Binary Output (see *Binary Outputs* on page L.32), or NA
- Analog Inputs—Any Analog Input Quantity (see *Analog Inputs* on page L.34) with scaling and/or deadband value, e.g., IA:0.1:50 (see below), the values 0 or 1, or NA
- Analog Outputs—Any Analog Output label (see *Table L.10*), NOOP, or NA
- Counter Inputs—Any counter label (see *Counter Inputs* on page L.34)

For the above custom map settings, a label of 0 or 1 yields the label value when the point is polled. A NOOP can be used as a placeholder for analog outputs—control of a point with this label does not change any relay values nor respond with an error message. Any gaps left in the custom map between labels (NA) will be removed and the contents packed.

You can customize the DNP3 analog input map with per-point scaling and deadband settings. Class scaling (DECPLA, DECPLV, and DECPLM) and deadband (ANADBA, ANADBV, and ANADBM) settings are applied to indices that do not have per-point entries. Per-point scaling and deadband settings override class scaling and deadband settings. Unlike per-point scaling, class-level scaling is specified by an integer in the range 0–3 (inclusive), which indicates the number of decimal place shifts. In other words, you should select 0 to multiply by 1, 1 for 10, 2 for 100, or 3 for 1000.

Per-point scaling factors allow you to overcome the limitations imposed, by default, of the integer nature of Objects 30 and 32. For example, DNP in the SEL-351, by default, truncates a value of 11.4 A to 11 A. You may use per-point scaling to include decimal point values by multiplying by a power of 10. For example, if you use 10 as a scaling factor, 11.4 A will be transmitted as 114. You must divide the value by 10 in the master to see the original value including one decimal place.

You can also use per-point scaling to avoid overflowing the 16-bit maximum integer value of 32767. For example, if you have a value that can reach 157834, you cannot send it using DNP3 16-bit analog object variations. You could use a scaling factor of 0.1 so that the maximum value reported is 15783. You can then multiply the value by 10 in the master to see a value of 157830. You will lose some precision as the last digit is truncated off in the scaling process, but you can transmit the scaled value using the default variations for DNP3 Objects 30 and 32.

If your DNP3 master has the capability to request floating-point analog input variations, the SEL-351 will support them. These floating-point variations, 5 and 6 for Object 30 and 5 through 8 for Object 32, allow the transmission of 16- or 32-bit floating-point values to DNP3 masters. When implemented, these variations eliminate the need for scaling and still maintain the resolution of the relay analog values. Note that this support is greater than DNP3 Level 4 functionality, so you must confirm that your DNP3 master can work with these variations before you consider using unscaled analog values.

If it is important to maintain tight data coherency (that is, all data read of a certain type was sampled or calculated at the same time), then you should group that data together within your custom map. For example, if you want all the currents to be coherent, you should group points IA_MAG, IB_MAG, IC_MAG, and IN_MAG together in the custom map. If points are not grouped together, they might not come from the same data sample.

The following example describes how to create a custom DNP3 map by point type. The example demonstrates the SEL ASCII command **SET D** for each point type, but the entire configuration may be completed without saving changes between point types. To do this, you simply continue entering data and save the entire map at the end. Alternately, you can use the QuickSet software to simplify custom data map creation.

Consider a case where you want to set the AI points in a map as shown in *Table L.12*.

Table L.12 Sample Custom DNP3 AI Map (Sheet 1 of 2)

Desired Point Index	Description	Label	Scaling	Deadband
0	IA magnitude	IA	default	default
1	IB magnitude	IB	default	default
2	IC magnitude	IC	default	default
3	IN magnitude	IN	default	default

Table L.12 Sample Custom DNP3 AI Map (Sheet 2 of 2)

Desired Point Index	Description	Label	Scaling	Deadband
4	3 Phase Real Power	MW3	5	default
5	A Phase-to-Neutral Voltage Magnitude	VA	default	default
6	A Phase-to-Neutral Voltage Angle	VAFA	1	15
7	Frequency	FREQ	.01	1

To set these points as part of custom map 1, you can use the command **SET D 1 AI_000 TERSE <Enter>** as shown in *Figure L.4*.

```
=>>SET D 1 AI_000 TERSE <Enter>

DNP Map Settings 1

Analog Input Map
  (DNP Analog Input Label:Scale Factor:Deadband):
DNP Analog Input Label Name
AI_000  = NA
     ? IA <Enter>

DNP Analog Input Label Name
AI_001  = NA
     ? IB::4 <Enter>

DNP Analog Input Label Name
AI_002  = NA
     ? IC <Enter>

DNP Analog Input Label Name
AI_003  = NA
     ? IN <Enter>

DNP Analog Input Label Name
AI_004  = NA
     ? MW3:5 <Enter>

DNP Analog Input Label Name
AI_005  = NA
     ? VA <Enter>

DNP Analog Input Label Name
AI_006  = NA
     ? VAFA:1:15 <Enter>

DNP Analog Input Label Name
AI_007  = NA
     ? FREQ:0.01:1 <Enter>

DNP Analog Input Label Name
AI_008  = NA
     ? end <Enter>

Save changes (Y/N) ? Y <Enter>

=>>
```

Figure L.4 Sample Custom DNP3 AI Map Settings

You can also use QuickSet to enter the above AI map settings as shown in *Figure L.5*. To enter scaling and deadband setting, double-click the AI point and enter the values in the pop-up dialog, as shown in *Figure L.7*.

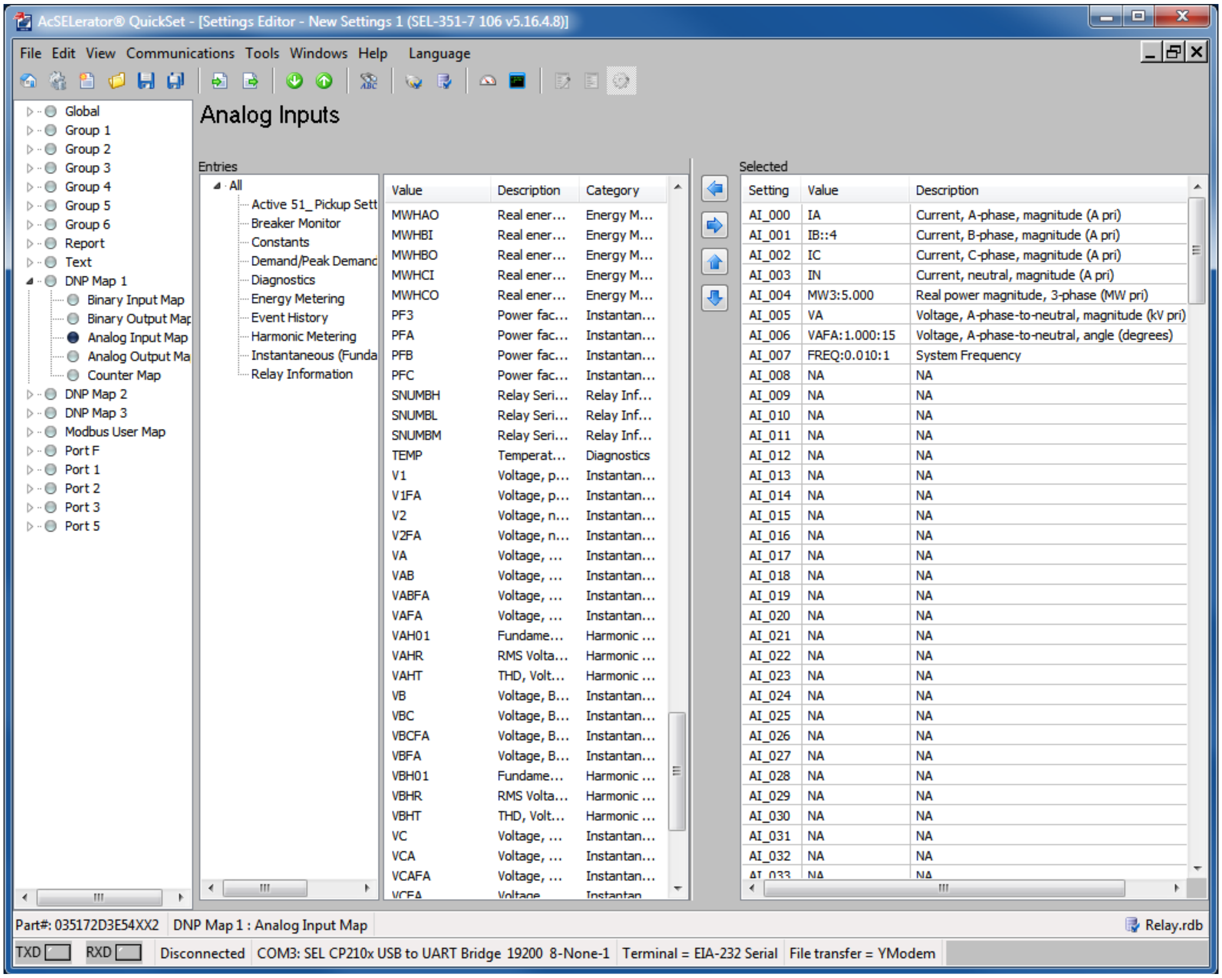

Figure L.5 Analog Input Map Entry in QuickSet

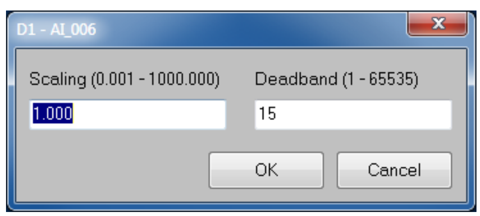

Figure L.6 AI Point Label, Scaling and Deadband in QuickSet

The **SET D x CO_000 TERSE <Enter>** command allows you to populate the DNP counter map with per-point deadbands. Entering these settings is similar to defining the analog input map settings.

You can use the command **SET D *x* BO_000 TERSE <Enter>** to change the binary output map *x* as shown in *Figure L.7*. You may populate the custom BO map with any of the 32 remote bits (RB1–RB32), breaker bits (OC, CC), data reset bits (DRST_DEM, DRST_PDM, DRST_BK, DRST_HIS, DRST_ENE, DRST_MML, DRST_TAR, DRST_HAL, DRSTDNPE), or the NXTEVE and SINGEVE bits. You can define bit pairs for remote bits or breaker bits in BO maps by including a colon (:) between the bit labels. Paired mode allows the mapping of two remote bits into a single binary output to send trip/close command codes to the same binary output while operating on two separate remote bits in the relay.

```
=>>SET D 1 BO_000 TERSE <Enter>

DNP Map Settings 1

Binary Output Map:
DNP Binary Output Label Name
BO_000   = NA
     ? RB1 <Enter>

DNP Binary Output Label Name
BO_001   = NA
     ? RB2 <Enter>

DNP Binary Output Label Name
BO_002   = NA
     ? RB3:RB4 <Enter>

DNP Binary Output Label Name
BO_003   = NA
     ? RB5:RB6 <Enter>

DNP Binary Output Label Name
BO_004   = NA
     ? END <Enter>

Save Changes(Y/N)? Y <Enter>
=>>
```

Figure L.7 Sample Custom DNP3 BO Map Settings

You can also use QuickSet to enter the BO map settings as shown in *Figure L.8*.

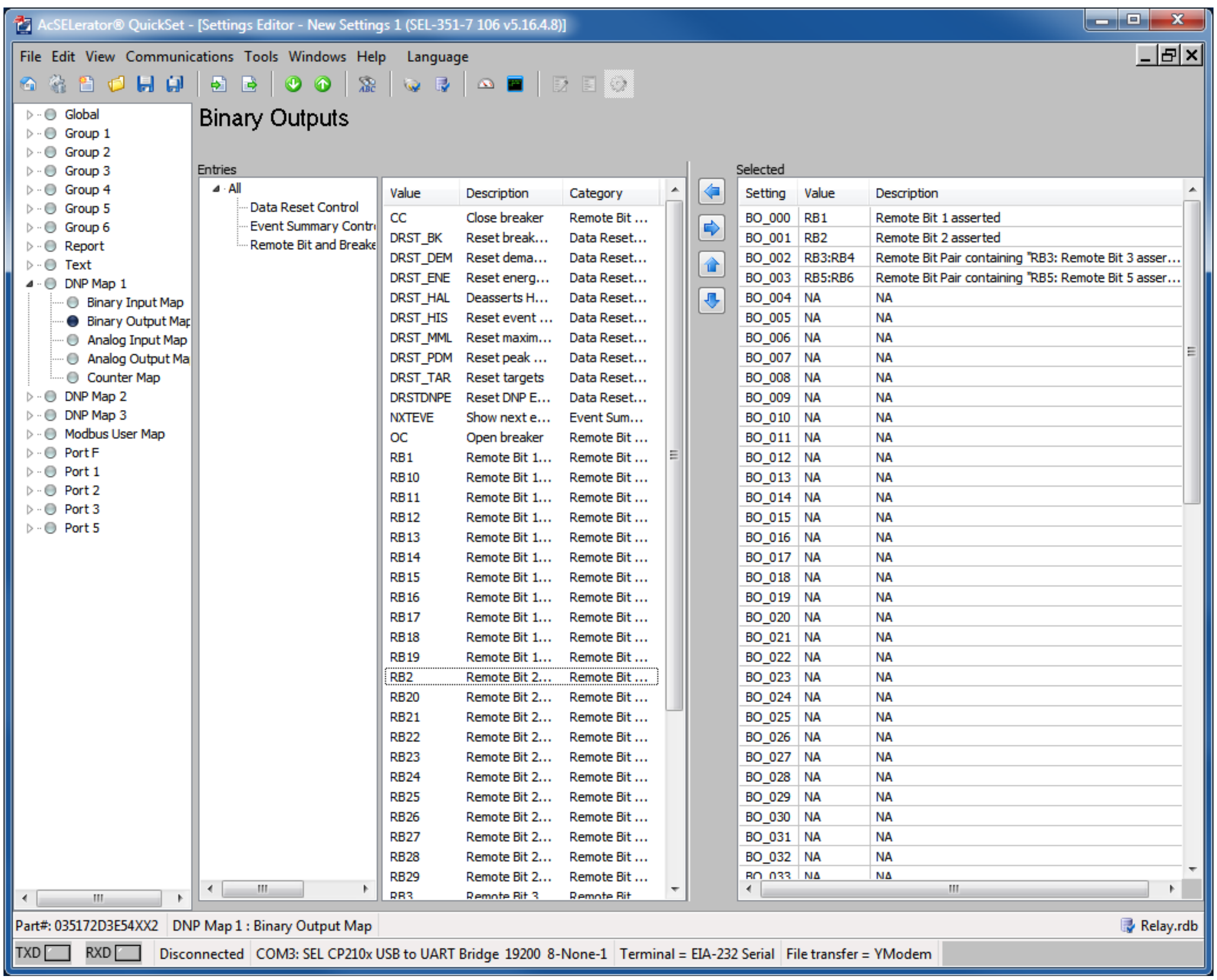

Figure L.8 Binary Output Map Entry in QuickSet

The binary input (BI) maps are modified in a similar manner, but pairs are not allowed.

Binary Inputs

Binary Inputs (objects 1 and 2) are supported as defined in *Table L.9* and *Table L.10*. The default variation for both static and event inputs is 2. Only the Read function code (1) is allowed with these objects. All variations are supported. Object 2, variation 3 will be responded to, but will contain no data.

Binary Inputs are scanned approximately once per second to generate events. When time is reported with these event objects, it is the time at which the scanner observed the bit change. This may be significantly delayed from when the original source changed and should not be used for sequence-of-events determination. Binary inputs registered with SER are derived from the SER and carry the time stamp of actual occurrence. Some additional binary inputs are available only to DNP: RLYDIS is derived from the relay status variable; STWARN and STFAIL are derived from the diagnostic task data; UNRDEV and NUNREV are derived from the event queue. Another binary input, STSET, is derived from the SER and carries the time stamp of actual occurrence. Static reads of this input will always show 0.

Binary Outputs

Binary Outputs are supported as defined in *Table L.9* and *Table L.10*. Binary Output status (Object 10, variation 2) is supported. Static reads of points RB1–RB32 respond with the on-line bit set and the state of the requested bit. Reads of NXTEVE respond with the online bit set and a state of 1 if Event Summary Data are being read in Multiple-Event FIFO mode and a state of 0 otherwise. Reads of SINGEVE respond with the online bit set and a state of 1 when Event Summary Data are being read in Single-Event mode and a state of 0 when Event Summary Data are being read in Multiple-Event mode. Reads from OC, CC and control-only binary output points (such as the data reset controls DRST_DEM, DRST_ENE, etc.) respond with the online bit set and a state of 0 (or tripped) because of the pulse only control operation of these points.

Control Relay Output Block (CROB) objects (object 12, variations 1, 2, and 3) are supported. The control relays correspond to the remote bits and other labels as shown in *Table L.13* through *Table L.16*. The Trip/Close bits take precedence over the control field. CROB operations are not guaranteed to occur during the same processing interval.

Operation of the binary outputs is controlled by the Global settings BOOPTCC and BOOPPUL. BOOPTCC controls how binary outputs respond to Close and Trip operations. BOOPPUL controls how the binary outputs respond to Pulse On operations. Each setting has two choices, SET and PULSE. The response of various outputs for different settings of BOOPTCC and BOOPPUL is shown in *Table L.13* through *Table L.16*. Note that the operation of remote bit and OC:CC pairs is not affected by these settings, nor is the operation of any binary outputs for Latch On and Latch Off operations.

Table L.13 BOOPTCC = PULSE, BOOPPUL = PULSE

Label	Close (0x4X)	Trip (0x8X)	Latch On (3)	Latch Off (4)	Pulse On (1)	Pulse Off (2)
RBx	Pulse	Pulse	Set	Clear	Pulse	Clear
OC and CC	Pulse	Pulse	Pulse	Do nothing	Pulse	Do Nothing
Resets[a]	Pulse	Pulse	Pulse	Do nothing	Pulse	Do Nothing
NXTEVE	Read Oldest	Read Oldest	Read Oldest	Read Newest	Read Oldest	Read Newest
SINGEVE	Pulse	Pulse	Pulse	Do nothing	Pulse	Do Nothing
RBx:RBy	Pulse RB*y*	Pulse RB*x*	Pulse RB*y*	Pulse RB*x*	Pulse RB*y*	Pulse RB*x*
OC:CC	Pulse CC	Pulse OC	Pulse CC	Pulse OC	Pulse CC	Pulse OC

[a] DRST_DEM, DRST_ENE, DRST_BK, DRST_MML, DRST_HIS, DRST_PDM, DRST_TAR, DRST_HAL, and DRSTDNPE.

Table L.14 BOOPTCC = SET, BOOPPUL = PULSE

Label	Close (0x4X)	Trip (0x8X)	Latch On (3)	Latch Off (4)	Pulse On (1)	Pulse Off (2)
RBx	Set	Clear	Set	Clear	Pulse	Clear
OC and CC	Pulse	Do Nothing	Pulse	Do nothing	Pulse	Do Nothing
Resets[a]	Pulse	Do Nothing	Pulse	Do nothing	Pulse	Do Nothing
NXTEVE	Read Oldest	Read Newest	Read Oldest	Read Newest	Read Oldest	Read Newest
SINGEVE	Pulse	Do Nothing	Pulse	Do nothing	Pulse	Do Nothing
RBx:RBy	Pulse RB*y*	Pulse RB*x*	Pulse RB*y*	Pulse RB*x*	Pulse RB*y*	Pulse RB*x*
OC:CC	Pulse CC	Pulse OC	Pulse CC	Pulse OC	Pulse CC	Pulse OC

[a] DRST_DEM, DRST_ENE, DRST_BK, DRST_MML, DRST_HIS, DRST_PDM, DRST_TAR, DRST_HAL, and DRSTDNPE.

Table L.15 BOOPTCC = PULSE, BOOPPUL = SET

Label	Close (0x4X)	Trip (0x8X)	Latch On (3)	Latch Off (4)	Pulse On (1)	Pulse Off (2)
RBx	Pulse	Pulse	Set	Clear	Set	Clear
OC and CC	Pulse	Pulse	Pulse	Do nothing	Pulse	Do Nothing
Resets[a]	Pulse	Pulse	Pulse	Do nothing	Pulse	Do Nothing
NXTEVE	Read Oldest	Read Oldest	Read Oldest	Read Newest	Read Oldest	Read Newest
SINGEVE	Pulse	Pulse	Pulse	Do nothing	Pulse	Do Nothing
RBx:RBy	Pulse RB*y*	Pulse RB*x*	Pulse RB*y*	Pulse RB*x*	Pulse RB*y*	Pulse RB*x*
OC:CC	Pulse CC	Pulse OC	Pulse CC	Pulse OC	Pulse CC	Pulse OC

[a] DRST_DEM, DRST_ENE, DRST_BK, DRST_MML, DRST_HIS, DRST_PDM, DRST_TAR, DRST_HAL, and DRSTDNPE.

Table L.16 BOOPTCC = SET, BOOPPUL = SET

Label	Close (0x4X)	Trip (0x8X)	Latch On (3)	Latch Off (4)	Pulse On (1)	Pulse Off (2)
RBx	Set	Clear	Set	Clear	Set	Clear
OC and CC	Pulse	Do Nothing	Pulse	Do nothing	Pulse	Do Nothing
Resets[a]	Pulse	Do Nothing	Pulse	Do nothing	Pulse	Do Nothing
NXTEVE	Read Oldest	Read Newest	Read Oldest	Read Newest	Read Oldest	Read Newest
SINGEVE	Pulse	Do Nothing	Pulse	Do nothing	Pulse	Do Nothing
RBx:RBy	Pulse RB*y*	Pulse RB*x*	Pulse RB*y*	Pulse RB*x*	Pulse RB*y*	Pulse RB*x*
OC:CC	Pulse CC	Pulse OC	Pulse CC	Pulse OC	Pulse CC	Pulse OC

[a] DRST_DEM, DRST_ENE, DRST_BK, DRST_MML, DRST_HIS, DRST_PDM, DRST_TAR, DRST_HAL, and DRSTDNPE.

The Status field is used exactly as defined. All other fields are ignored. A pulse operation is asserted for a single processing interval. A maximum of ten operations can be performed for a single command. If more than ten operations are attempted, the relay will respond with `Too Many Operations` to each attempt in excess of ten. If the relay is disabled, remote bit operations are not performed. If the relay is disabled or the breaker jumper is not installed, OC and CC operations are not performed.

Control Point Operation

You can define any two RB points as a pair for Trip/Close or Code Selection operations with Object 12 control device output block command messages. The SEL-351 assigns some special operations to the code portion of the control device output block command. Because the SEL-351 allows only one control bit to be pulsed at a time, you should send consecutive control bits in consecutive messages. Pulse operations provide a pulse with duration of one processing interval.

Table L.17 Example Object 12 Trip/Close or Code Selection Operation (BOOPTCC = PULSE and BOOPPUL = PULSE)

Control Points	Trip/Close		Code Selection Operation			
	Close (0x4X)	Trip (0x8X)	Latch On (3)	Latch Off (4)	Pulse On (1)	Pulse Off (2)
RB1:RB2	PULSE RB2	PULSE RB1	PULSE RB2	PULSE RB1	PULSE RB2	PULSE RB1
RB3	PULSE RB3	PULSE RB3	SET RB3	CLEAR RB3	PULSE RB3	CLEAR RB3
RB4	PULSE RB4	PULSE RB4	SET RB4	CLEAR RB4	PULSE RB4	CLEAR RB4
RB5:RB6	PULSE RB6	PULSE RB5	PULSE RB6	PULSE RB5	PULSE RB6	PULSE RB5
RB7	PULSE RB7	PULSE RB7	SET RB7	CLEAR RB7	PULSE RB7	CLEAR RB7
RB8	PULSE RB8	PULSE RB8	SET RB8	CLEAR RB8	PULSE RB8	CLEAR RB8
RB14:RB15	PULSE RB15	PULSE RB14	PULSE RB15	PULSE RB14	PULSE RB15	PULSE RB14
RB18:RB21	PULSE RB21	PULSE RB18	PULSE RB21	PULSE RB18	PULSE RB21	PULSE RB18

Counter Inputs

Counters (object 20) and Counter Change Events (object 22) are supported as defined in *Table L.9* and *Table L.10*. Supported variations are shown in *Table L.9*. Event class messages are generated whenever a counter changes beyond the value given by the appropriate deadband setting. For example, with a deadband of 1 and a starting value of 5, when the counter changes from 5 to 6, no event will be generated. When the value changes from 6 to 7, an event will be generated and the new starting value will be 7. The default counter deadband setting is 0. A per-point deadband can be applied to a counter object by adding the deadband after the object label in the DNP map (i.e., INTTR:2). The per-point deadband overrides the default deadband. Counters are scanned at approximately a one-second rate and are time-stamped with the time the scan was initiated.

Analog Inputs

Analog Inputs (object 30) and Analog Change Events (object 32) are supported as defined in *Table L.9* and *Table L.10*, with the default variation based on the serial port setting DVARAI and the Ethernet port setting DVARAI*n*, where *n* denotes the Ethernet session being used. Analog values are reported in primary units. See *Appendix E: Analog Quantities* for a list of all available analog inputs, and the DNP Reference map (*Table L.10*) for default scaling and deadbands. A deadband check is done after any scaling has been applied. Event class messages are generated whenever an input changes beyond the value given by the appropriate deadband setting. Analog inputs are scanned at approximately a 1 second rate, except for the Fault analog inputs discussed in *Event Data* on page L.35. The ANADBA setting applies to the same values as the DECPLA settings. The ANADBV setting applies to the same values as the DECPLV setting. The ANADBM setting applies to all other analog input items. All events generated during a scan will use the time the scan was initiated.

Event Data

The following Fault Analog Inputs are derived from the history queue data for the most recently read event: FTYPE, FTYPE16, FLOC, FI, FIA, FIB, FIC, FIG, FIN, FIQ, FFREQ, FGRP, FSHO, FTIMEH, FTIMEM, FTIMEL, FTIMEH16, FTIMEM16, FTIMEL16, FUNR, FLI, FLIA, FLIB, FLIC, FLIG, FLIN, FLIQ, FZ, and FZFA. These quantities, also referred to as the DNP relay event registers, shall generate DNP3 analog change events (Object 32). Because these DNP relay event registers refer to the same event summary record, the relay creates analog change events for all of these DNP relay event registers when any one of the registers exceeds its deadband. Events for these inputs will use the time the scan was initiated. Current quantities FI, FIA, FIB, FIC, FIG, FIN, and FIQ are populated with currents from the maximum fault row. Current quantities FLI, FLIA, FLIB, FLIC, FLIG, FLIN, and FLIQ are populated with fault locator currents. For more details on fault currents and location, see *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*.

Analog input FLOC is the Fault Location value. If this field contains "$$$$$$" (undetermined location) or is blank (when EFLOC = N), the relay will set the internal value of FLOC to –999.9 for DNP3. As with most of the event register values, FLOC is subject to scaling by the DECPLM setting (1 by default). So by default, a DNP3 poll of this value under the above conditions would yield a value of –9999.0 at the master. This value was chosen to represent an undetermined or blank FLOC that would not create nuisance alarms by presenting an over-range value to a DNP3 master. Note that if DECPLM is changed, this will change the end value of this point at the DNP3 master. If DECPLM is changed, you should set per-point scaling to 1 for FLOC to override the DECPLM scaling and ensure that it is transmitted as expected.

Analog input FTYPE is a 16-bit composite value where the upper byte value indicates an event cause, as shown in *Table L.18* and the lower byte indicates a fault type, as shown in *Table L.19*. The upper and lower byte will be the sum of the applicable event cause and fault types. For example, a FTYPE value of 3079 decimal would translate to 0C07 hex, and indicate a Trip and an ER element Event Cause (4 + 8 = 12 or 0C hex) on A-phase, B-phase, and C-phase (1 + 2 + 4 = 7 or 07 hex). If input FTYPE is 0, fault information has not yet been read and the fault analog inputs do not contain valid event data.

Table L.18 Fault Type Upper Byte: Event Cause

Value	Event Cause
1	Trigger command
2	Pulse command
4	Trip element
8	ER element

Table L.19 Fault Type Lower Byte: Fault Type

Value	Fault Type
0	Indeterminate
1	A Phase
2	B Phase
4	C Phase
8	Ground

In some instances, the values in the FTIME*x* registers and FTYPE register may contain a value greater than 32767, which can be read correctly using Object 30 variation 1 or 3 (32 bit value). However, some DNP masters cannot read a 32 bit value, so the 16 bit variations (2 and 4) clamp the value and variation 2 reports an over range flag. FTYPE16, FTIMEH16, FTIMEM16, and FTIMEL16 contain a 16 bit signed value that can be read using variation 2 or 4. The FTIMEx16 and FTYPE16 registers contain the FTIMEx or FTYPE value minus 65536 if the value is greater than 32767. The value is reported as a negative number without an over range flag.

Settings Data

Analog inputs 51AP, 51BP, 51CP, 51PP, 51GP, 51G2P, 51QP, and 51NP are derived from the present active group settings. If the associated setting is set to off, the value will be reported as –1. Please note that these values are subject to scaling by the DECPLA setting (i.e., you will see a value of –10 for OFF with the default DECPLA setting.) You can override the default scaling by applying per-point scaling to these values in a custom DNP map.

Reading Relay Event Data

The SEL-351 provides protective relay event history information in either single or multiple-event mode. *Event Data* on page L.35 describes the analog DNP relay event registers that are updated for the most recently read event from the event history. When in single-event mode, the relay makes event data available in the DNP relay event registers as described in *Single-Event Mode* on page L.37. When in multiple-event mode, the relay makes event data available in the DNP relay event registers as described in *Multiple-Event Mode* on page L.38.

Each DNP session starts up in the mode specified by Port setting EVEMODE upon the relay turning on, DNP port settings change, DNP map change, or SER settings change. When EVEMODE = SINGLE, the relay starts up in single-event mode. When EVEMODE = MULTI, the relay starts up in multiple-event mode.

The reporting method can also be changed by asserting a binary output control point. The relay changes to multiple-event mode on a per-session basis if the NXTEVE control point is operated on. The relay changes to single-event mode on a per-session basis if the SINGEVE control point is operated on. A relay turning on, DNP port settings change, DNP map change, or SER settings change returns the reporting method to the mode specified by EVEMODE. When switching from multiple-event mode to single-event mode, the DNP relay event registers are set to zero.

Analog input FUNR represents the number of unread relay events and is derived from the history queue. For single-event mode, all registers except FUNR update when a new event occurs. For multiple-event mode, the only register that will update when a new event occurs is FUNR. DNP3 masters configured to use multiple-event mode must monitor at least one of the analog DNP relay event registers to detect if the relay has transitioned to single-event mode. If only one of the registers is monitored, that register cannot be FUNR because FUNR does not update for single-event mode. If changes are detected in the analog DNP relay event registers, the DNP3 master should latch on or latch off NXTEVE to put the relay into multiple-event mode.

Event summary data are only generated for events that have occurred since the last power-up, within the limits of the event buffer. Upon an initial switch from single-event mode to multiple-event mode, all existing events since power-up are considered unread. Once an event is read via FIFO, it is no longer available via LIFO and vice-versa. FIFO and LIFO are discussed in *Multiple-Event Mode* on page L.38. The user cannot traverse event summaries forward, then backwards. After the initial switch from single-event mode to multiple-event mode, when switching to single-event mode by operating SINGEVE, the DNP relay event registers are set to zero but the event buffer is not reset. For example, if the relay is in single-event mode, three events occur, and the relay is switched to multiple-event mode by latching on NXTEVE, a read of the analog DNP relay event registers will show data for the oldest event and FUNR will be equal to 2. If the relay is switched to single-event mode by operating SINGEVE, a read of the analog DNP relay event registers will show that they are all zero but the event buffer will still contain two unread events. This can be seen by latching on NXTEVE to switch back to multiple-event mode. Once in multiple-event mode, a read of the analog DNP relay event registers will show data for the oldest event and FUNR will be equal to 1, indicating that there is still one unread event in the event buffer. Note that the switching between modes is not normal behavior for a DNP master and is only discussed here to illustrate the event buffer functionality when switching modes.

Port setting RPEVTYP controls the type of events that are reported to the relay DNP event summary. When Port setting RPEVTYP = TRIP, only TRIP events are reported in the DNP event summary data. When Port setting RPEVTYP = ALL, all events are reported in the DNP event summary data.

The Port settings MINDIST and MAXDIST can be used to limit fault summary data to only data within a certain fault distance. If MINDIST and MAXDIST are set to a numeric value, DNP events will only be generated when the fault location is within these setting values. If MINDIST is set to OFF, there is no lower limit for the fault location distance. If MAXDIST is set to OFF, there is no upper limit for the fault location distance. If the fault location is undetermined, the event is displayed regardless of the MINDIST and MAXDIST settings but is constrained by the RPEVTYP setting.

SELOGIC control equation RSTDNPE is used to clear the DNP relay event registers and the DNP event buffer for both single-event mode and multiple-event mode for all DNP sessions. When RSTDNPE is evaluated to one, the DNP relay event registers are set to zero and the DNP event buffer is cleared. The DNP binary output DRSTDNPE is similar in function to RSTDNPE and can also be used to clear the DNP relay event registers and the DNP event buffer when the relay is in single-event mode or multiple-event mode on a per-session basis.

Single-Event Mode

Single-event mode provides the most recent event report summary data as they occur in the relay. When a new event report is triggered (TRIP, ER assert, TRI, etc.), the new event data are stored in DNP relay event registers as long as the Port settings RPEVTYP, MINDIST, and MAXDIST criteria are satisfied. When the DNP relay event registers are updated, a DNP3 event is generated. The event report summary values are locked into the DNP relay event registers for the time determined by Global setting EVELOCK. Additional event reports triggered before the EVELOCK timer expires are ignored by DNP3. EVELOCK = 0 defeats the lock function, and allows the DNP relay event registers to be updated as soon as a new event report is triggered. EVELOCK has no effect when the session is in multiple-event mode.

Multiple-Event Mode

Multiple-event mode provides the most recent event report summary data when the master sends a latch-on or latch-off control to NXTEVE. Anytime there are unread event data, UNRDEV will be asserted and FUNR will represent the number of unread event reports.

When the session DNP3 master sends a latch-on control to NXTEVE, the oldest unread event summary data are transferred to the DNP relay event registers. To check for more available unread event summary data, read the UNRDEV binary input. If UNRDEV is asserted, then more event data exist. Use the NXTEVE binary output and UNRDEV binary input to create an event summary data FIFO. If UNRDEV is asserted, send a latch-on control to NXTEVE, read the event summary data, and read UNRDEV again. Repeat until UNRDEV is cleared. Sending a latch-on control to NXTEVE while UNRDEV is cleared sets the analog event data registers to zero.

When the session DNP3 master sends a latch-off control to NXTEVE, the newest unread event summary data are transferred to the DNP relay event registers. To check for more available unread event summary data, read the UNRDEV binary input. If UNRDEV is asserted, then more event data exist. This sequence steps through the event summary data from newest to oldest, forming an LIFO. It is possible that, while stepping through the event summary data from newest to oldest, a new event will be triggered. In that case, the binary input NUNREV asserts, and the next event summary is from the most recently triggered event. Subsequent latch-off controls to NXTEVE resume with the next newest unread event summary, skipping all the event summaries already read. Sending a latch-off control to NXTEVE while UNRDEV is cleared sets the analog event data registers to zero.

In either FIFO or LIFO mode, if the session DNP master latches NXTEVE more often than once per two seconds, some DNP events may not be generated by the new event summary data, and event summary data may be lost.

DNP Settings Sheets

DNP Map Settings (SET D n Command)

Use the **SET D *n*** command with *n* = 1, 2, or 3 to create as many as three DNP User Maps. Refer to *Default Data Map* on page L.24 for details.

This is DNP Map 1 (DNP Map 2 and DNP Map 3 tables are identical to DNP Map 1 table).

Binary Input Map

DNP Binary Input Label Name	**BI_000 :=** ____________
DNP Binary Input Label Name	**BI_001 :=** ____________
DNP Binary Input Label Name	**BI_002 :=** ____________
DNP Binary Input Label Name	**BI_003 :=** ____________
DNP Binary Input Label Name	**BI_004 :=** ____________
DNP Binary Input Label Name	**BI_005 :=** ____________
DNP Binary Input Label Name	**BI_006 :=** ____________
DNP Binary Input Label Name	**BI_007 :=** ____________
DNP Binary Input Label Name	**BI_008 :=** ____________
DNP Binary Input Label Name	**BI_009 :=** ____________
DNP Binary Input Label Name	**BI_010 :=** ____________
DNP Binary Input Label Name	**BI_011 :=** ____________
DNP Binary Input Label Name	**BI_012 :=** ____________
DNP Binary Input Label Name	**BI_013 :=** ____________
DNP Binary Input Label Name	**BI_014 :=** ____________
DNP Binary Input Label Name	**BI_015 :=** ____________
DNP Binary Input Label Name	**BI_016 :=** ____________
DNP Binary Input Label Name	**BI_017 :=** ____________
DNP Binary Input Label Name	**BI_018 :=** ____________
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DNP Binary Input Label Name	**BI_071 :=** ______________
DNP Binary Input Label Name	**BI_072 :=** ______________
DNP Binary Input Label Name	**BI_073 :=** ______________
DNP Binary Input Label Name	**BI_074 :=** ______________
DNP Binary Input Label Name	**BI_075 :=** ______________
DNP Binary Input Label Name	**BI_076 :=** ______________
DNP Binary Input Label Name	**BI_077 :=** ______________
DNP Binary Input Label Name	**BI_078 :=** ______________
DNP Binary Input Label Name	**BI_079 :=** ______________
DNP Binary Input Label Name	**BI_080 :=** ______________
DNP Binary Input Label Name	**BI_081 :=** ______________
DNP Binary Input Label Name	**BI_082 :=** ______________
DNP Binary Input Label Name	**BI_083 :=** ______________
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DNP Binary Input Label Name	**BI_099 :=** ______________
DNP Binary Input Label Name	**BI_100 :=** ______________
DNP Binary Input Label Name	**BI_101 :=** ______________

DNP Binary Input Label Name	**BI_102 :=** ____________
DNP Binary Input Label Name	**BI_103 :=** ____________
DNP Binary Input Label Name	**BI_104 :=** ____________
DNP Binary Input Label Name	**BI_105 :=** ____________
DNP Binary Input Label Name	**BI_106 :=** ____________
DNP Binary Input Label Name	**BI_107 :=** ____________
DNP Binary Input Label Name	**BI_108 :=** ____________
DNP Binary Input Label Name	**BI_109 :=** ____________
DNP Binary Input Label Name	**BI_110 :=** ____________
DNP Binary Input Label Name	**BI_111 :=** ____________
DNP Binary Input Label Name	**BI_112 :=** ____________
DNP Binary Input Label Name	**BI_113 :=** ____________
DNP Binary Input Label Name	**BI_114 :=** ____________
DNP Binary Input Label Name	**BI_115 :=** ____________
DNP Binary Input Label Name	**BI_116 :=** ____________
DNP Binary Input Label Name	**BI_117 :=** ____________
DNP Binary Input Label Name	**BI_118 :=** ____________
DNP Binary Input Label Name	**BI_119 :=** ____________
DNP Binary Input Label Name	**BI_120 :=** ____________
DNP Binary Input Label Name	**BI_121 :=** ____________
DNP Binary Input Label Name	**BI_122 :=** ____________
DNP Binary Input Label Name	**BI_123 :=** ____________
DNP Binary Input Label Name	**BI_124 :=** ____________
DNP Binary Input Label Name	**BI_125 :=** ____________
DNP Binary Input Label Name	**BI_126 :=** ____________
DNP Binary Input Label Name	**BI_127 :=** ____________
DNP Binary Input Label Name	**BI_128 :=** ____________
DNP Binary Input Label Name	**BI_129 :=** ____________
DNP Binary Input Label Name	**BI_130 :=** ____________
DNP Binary Input Label Name	**BI_131 :=** ____________
DNP Binary Input Label Name	**BI_132 :=** ____________
DNP Binary Input Label Name	**BI_133 :=** ____________
DNP Binary Input Label Name	**BI_134 :=** ____________
DNP Binary Input Label Name	**BI_135 :=** ____________
DNP Binary Input Label Name	**BI_136 :=** ____________
DNP Binary Input Label Name	**BI_137 :=** ____________
DNP Binary Input Label Name	**BI_138 :=** ____________
DNP Binary Input Label Name	**BI_139 :=** ____________

DNP Binary Input Label Name	**BI_140 :=** ____________
DNP Binary Input Label Name	**BI_141 :=** ____________
DNP Binary Input Label Name	**BI_142 :=** ____________
DNP Binary Input Label Name	**BI_143 :=** ____________
DNP Binary Input Label Name	**BI_144 :=** ____________
DNP Binary Input Label Name	**BI_145 :=** ____________
DNP Binary Input Label Name	**BI_146 :=** ____________
DNP Binary Input Label Name	**BI_147 :=** ____________
DNP Binary Input Label Name	**BI_148 :=** ____________
DNP Binary Input Label Name	**BI_149 :=** ____________
DNP Binary Input Label Name	**BI_150 :=** ____________
DNP Binary Input Label Name	**BI_151 :=** ____________
DNP Binary Input Label Name	**BI_152 :=** ____________
DNP Binary Input Label Name	**BI_153 :=** ____________
DNP Binary Input Label Name	**BI_154 :=** ____________
DNP Binary Input Label Name	**BI_155 :=** ____________
DNP Binary Input Label Name	**BI_156 :=** ____________
DNP Binary Input Label Name	**BI_157 :=** ____________
DNP Binary Input Label Name	**BI_158 :=** ____________
DNP Binary Input Label Name	**BI_159 :=** ____________
DNP Binary Input Label Name	**BI_160 :=** ____________
DNP Binary Input Label Name	**BI_161 :=** ____________
DNP Binary Input Label Name	**BI_162 :=** ____________
DNP Binary Input Label Name	**BI_163 :=** ____________
DNP Binary Input Label Name	**BI_164 :=** ____________
DNP Binary Input Label Name	**BI_165 :=** ____________
DNP Binary Input Label Name	**BI_166 :=** ____________
DNP Binary Input Label Name	**BI_167 :=** ____________
DNP Binary Input Label Name	**BI_168 :=** ____________
DNP Binary Input Label Name	**BI_169 :=** ____________
DNP Binary Input Label Name	**BI_170 :=** ____________
DNP Binary Input Label Name	**BI_171 :=** ____________
DNP Binary Input Label Name	**BI_172 :=** ____________
DNP Binary Input Label Name	**BI_173 :=** ____________
DNP Binary Input Label Name	**BI_174 :=** ____________
DNP Binary Input Label Name	**BI_175 :=** ____________
DNP Binary Input Label Name	**BI_176 :=** ____________
DNP Binary Input Label Name	**BI_177 :=** ____________

DNP Binary Input Label Name **BI_178 :=** ____________
DNP Binary Input Label Name **BI_179 :=** ____________
DNP Binary Input Label Name **BI_180 :=** ____________
DNP Binary Input Label Name **BI_181 :=** ____________
DNP Binary Input Label Name **BI_182 :=** ____________
DNP Binary Input Label Name **BI_183 :=** ____________
DNP Binary Input Label Name **BI_184 :=** ____________
DNP Binary Input Label Name **BI_185 :=** ____________
DNP Binary Input Label Name **BI_186 :=** ____________
DNP Binary Input Label Name **BI_187 :=** ____________
DNP Binary Input Label Name **BI_188 :=** ____________
DNP Binary Input Label Name **BI_189 :=** ____________
DNP Binary Input Label Name **BI_190 :=** ____________
DNP Binary Input Label Name **BI_191 :=** ____________
DNP Binary Input Label Name **BI_192 :=** ____________
DNP Binary Input Label Name **BI_193 :=** ____________
DNP Binary Input Label Name **BI_194 :=** ____________
DNP Binary Input Label Name **BI_195 :=** ____________
DNP Binary Input Label Name **BI_196 :=** ____________
DNP Binary Input Label Name **BI_197 :=** ____________
DNP Binary Input Label Name **BI_198 :=** ____________
DNP Binary Input Label Name **BI_199 :=** ____________

Binary Output Map

DNP Binary Output Label Name **BO_000 :=** ____________
DNP Binary Output Label Name **BO_001 :=** ____________
DNP Binary Output Label Name **BO_002 :=** ____________
DNP Binary Output Label Name **BO_003 :=** ____________
DNP Binary Output Label Name **BO_004 :=** ____________
DNP Binary Output Label Name **BO_005 :=** ____________
DNP Binary Output Label Name **BO_006 :=** ____________
DNP Binary Output Label Name **BO_007 :=** ____________
DNP Binary Output Label Name **BO_008 :=** ____________
DNP Binary Output Label Name **BO_009 :=** ____________
DNP Binary Output Label Name **BO_010 :=** ____________
DNP Binary Output Label Name **BO_011 :=** ____________
DNP Binary Output Label Name **BO_012 :=** ____________
DNP Binary Output Label Name **BO_013 :=** ____________

DNP Binary Output Label Name	**BO_014 :=** ____________
DNP Binary Output Label Name	**BO_015 :=** ____________
DNP Binary Output Label Name	**BO_016 :=** ____________
DNP Binary Output Label Name	**BO_017 :=** ____________
DNP Binary Output Label Name	**BO_018 :=** ____________
DNP Binary Output Label Name	**BO_019 :=** ____________
DNP Binary Output Label Name	**BO_020 :=** ____________
DNP Binary Output Label Name	**BO_021 :=** ____________
DNP Binary Output Label Name	**BO_022 :=** ____________
DNP Binary Output Label Name	**BO_023 :=** ____________
DNP Binary Output Label Name	**BO_024 :=** ____________
DNP Binary Output Label Name	**BO_025 :=** ____________
DNP Binary Output Label Name	**BO_026 :=** ____________
DNP Binary Output Label Name	**BO_027 :=** ____________
DNP Binary Output Label Name	**BO_028 :=** ____________
DNP Binary Output Label Name	**BO_029 :=** ____________
DNP Binary Output Label Name	**BO_030 :=** ____________
DNP Binary Output Label Name	**BO_031 :=** ____________
DNP Binary Output Label Name	**BO_032 :=** ____________
DNP Binary Output Label Name	**BO_033 :=** ____________
DNP Binary Output Label Name	**BO_034 :=** ____________
DNP Binary Output Label Name	**BO_035 :=** ____________
DNP Binary Output Label Name	**BO_036 :=** ____________
DNP Binary Output Label Name	**BO_037 :=** ____________
DNP Binary Output Label Name	**BO_038 :=** ____________
DNP Binary Output Label Name	**BO_039 :=** ____________
DNP Binary Output Label Name	**BO_040 :=** ____________
DNP Binary Output Label Name	**BO_041 :=** ____________
DNP Binary Output Label Name	**BO_042 :=** ____________
DNP Binary Output Label Name	**BO_043 :=** ____________
DNP Binary Output Label Name	**BO_044 :=** ____________
DNP Binary Output Label Name	**BO_045 :=** ____________
DNP Binary Output Label Name	**BO_046 :=** ____________
DNP Binary Output Label Name	**BO_047 :=** ____________
DNP Binary Output Label Name	**BO_048 :=** ____________
DNP Binary Output Label Name	**BO_049 :=** ____________
DNP Binary Output Label Name	**BO_050 :=** ____________
DNP Binary Output Label Name	**BO_051 :=** ____________

DNP Binary Output Label Name	**BO_052 :=** ________________
DNP Binary Output Label Name	**BO_053 :=** ________________
DNP Binary Output Label Name	**BO_054 :=** ________________
DNP Binary Output Label Name	**BO_055 :=** ________________
DNP Binary Output Label Name	**BO_056 :=** ________________
DNP Binary Output Label Name	**BO_057 :=** ________________
DNP Binary Output Label Name	**BO_058 :=** ________________
DNP Binary Output Label Name	**BO_059 :=** ________________
DNP Binary Output Label Name	**BO_060 :=** ________________
DNP Binary Output Label Name	**BO_061 :=** ________________
DNP Binary Output Label Name	**BO_062 :=** ________________
DNP Binary Output Label Name	**BO_063 :=** ________________
DNP Binary Output Label Name	**BO_064 :=** ________________
DNP Binary Output Label Name	**BO_065 :=** ________________
DNP Binary Output Label Name	**BO_066 :=** ________________
DNP Binary Output Label Name	**BO_067 :=** ________________
DNP Binary Output Label Name	**BO_068 :=** ________________
DNP Binary Output Label Name	**BO_069 :=** ________________
DNP Binary Output Label Name	**BO_070 :=** ________________

Analog Input Map

Entry format for Analog Inputs: Analog Label [: optional scaling factor 0.001–1000 : optional deadband 0–65535]. Enter NA to clear a setting.

DNP Analog Input Label Name	**AI_000 :=** ________________
DNP Analog Input Label Name	**AI_001 :=** ________________
DNP Analog Input Label Name	**AI_002 :=** ________________
DNP Analog Input Label Name	**AI_003 :=** ________________
DNP Analog Input Label Name	**AI_004 :=** ________________
DNP Analog Input Label Name	**AI_005 :=** ________________
DNP Analog Input Label Name	**AI_006 :=** ________________
DNP Analog Input Label Name	**AI_007 :=** ________________
DNP Analog Input Label Name	**AI_008 :=** ________________
DNP Analog Input Label Name	**AI_009 :=** ________________
DNP Analog Input Label Name	**AI_010 :=** ________________
DNP Analog Input Label Name	**AI_011 :=** ________________
DNP Analog Input Label Name	**AI_012 :=** ________________
DNP Analog Input Label Name	**AI_013 :=** ________________
DNP Analog Input Label Name	**AI_014 :=** ________________
DNP Analog Input Label Name	**AI_015 :=** ________________

DNP Analog Input Label Name	**AI_016 :=** ________________
DNP Analog Input Label Name	**AI_017 :=** ________________
DNP Analog Input Label Name	**AI_018 :=** ________________
DNP Analog Input Label Name	**AI_019 :=** ________________
DNP Analog Input Label Name	**AI_020 :=** ________________
DNP Analog Input Label Name	**AI_021 :=** ________________
DNP Analog Input Label Name	**AI_022 :=** ________________
DNP Analog Input Label Name	**AI_023 :=** ________________
DNP Analog Input Label Name	**AI_024 :=** ________________
DNP Analog Input Label Name	**AI_025 :=** ________________
DNP Analog Input Label Name	**AI_026 :=** ________________
DNP Analog Input Label Name	**AI_027 :=** ________________
DNP Analog Input Label Name	**AI_028 :=** ________________
DNP Analog Input Label Name	**AI_029 :=** ________________
DNP Analog Input Label Name	**AI_030 :=** ________________
DNP Analog Input Label Name	**AI_031 :=** ________________
DNP Analog Input Label Name	**AI_032 :=** ________________
DNP Analog Input Label Name	**AI_033 :=** ________________
DNP Analog Input Label Name	**AI_034 :=** ________________
DNP Analog Input Label Name	**AI_035 :=** ________________
DNP Analog Input Label Name	**AI_036 :=** ________________
DNP Analog Input Label Name	**AI_037 :=** ________________
DNP Analog Input Label Name	**AI_038 :=** ________________
DNP Analog Input Label Name	**AI_039 :=** ________________
DNP Analog Input Label Name	**AI_040 :=** ________________
DNP Analog Input Label Name	**AI_041 :=** ________________
DNP Analog Input Label Name	**AI_042 :=** ________________
DNP Analog Input Label Name	**AI_043 :=** ________________
DNP Analog Input Label Name	**AI_044 :=** ________________
DNP Analog Input Label Name	**AI_045 :=** ________________
DNP Analog Input Label Name	**AI_046 :=** ________________
DNP Analog Input Label Name	**AI_047 :=** ________________
DNP Analog Input Label Name	**AI_048 :=** ________________
DNP Analog Input Label Name	**AI_049 :=** ________________
DNP Analog Input Label Name	**AI_050 :=** ________________
DNP Analog Input Label Name	**AI_051 :=** ________________
DNP Analog Input Label Name	**AI_052 :=** ________________
DNP Analog Input Label Name	**AI_053 :=** ________________

DNP Analog Input Label Name	**AI_054 :=** ______________
DNP Analog Input Label Name	**AI_055 :=** ______________
DNP Analog Input Label Name	**AI_056 :=** ______________
DNP Analog Input Label Name	**AI_057 :=** ______________
DNP Analog Input Label Name	**AI_058 :=** ______________
DNP Analog Input Label Name	**AI_059 :=** ______________
DNP Analog Input Label Name	**AI_060 :=** ______________
DNP Analog Input Label Name	**AI_061 :=** ______________
DNP Analog Input Label Name	**AI_062 :=** ______________
DNP Analog Input Label Name	**AI_063 :=** ______________
DNP Analog Input Label Name	**AI_064 :=** ______________
DNP Analog Input Label Name	**AI_065 :=** ______________
DNP Analog Input Label Name	**AI_066 :=** ______________
DNP Analog Input Label Name	**AI_067 :=** ______________
DNP Analog Input Label Name	**AI_068 :=** ______________
DNP Analog Input Label Name	**AI_069 :=** ______________
DNP Analog Input Label Name	**AI_070 :=** ______________
DNP Analog Input Label Name	**AI_071 :=** ______________
DNP Analog Input Label Name	**AI_072 :=** ______________
DNP Analog Input Label Name	**AI_073 :=** ______________
DNP Analog Input Label Name	**AI_074 :=** ______________
DNP Analog Input Label Name	**AI_075 :=** ______________
DNP Analog Input Label Name	**AI_076 :=** ______________
DNP Analog Input Label Name	**AI_077 :=** ______________
DNP Analog Input Label Name	**AI_078 :=** ______________
DNP Analog Input Label Name	**AI_079 :=** ______________
DNP Analog Input Label Name	**AI_080 :=** ______________
DNP Analog Input Label Name	**AI_081 :=** ______________
DNP Analog Input Label Name	**AI_082 :=** ______________
DNP Analog Input Label Name	**AI_083 :=** ______________
DNP Analog Input Label Name	**AI_084 :=** ______________
DNP Analog Input Label Name	**AI_085 :=** ______________
DNP Analog Input Label Name	**AI_086 :=** ______________
DNP Analog Input Label Name	**AI_087 :=** ______________
DNP Analog Input Label Name	**AI_088 :=** ______________
DNP Analog Input Label Name	**AI_089 :=** ______________
DNP Analog Input Label Name	**AI_090 :=** ______________
DNP Analog Input Label Name	**AI_091 :=** ______________

DNP Analog Input Label Name	**AI_092 :=** ________
DNP Analog Input Label Name	**AI_093 :=** ________
DNP Analog Input Label Name	**AI_094 :=** ________
DNP Analog Input Label Name	**AI_095 :=** ________
DNP Analog Input Label Name	**AI_096 :=** ________
DNP Analog Input Label Name	**AI_097 :=** ________
DNP Analog Input Label Name	**AI_098 :=** ________
DNP Analog Input Label Name	**AI_099 :=** ________
DNP Analog Input Label Name	**AI_100 :=** ________
DNP Analog Input Label Name	**AI_101 :=** ________
DNP Analog Input Label Name	**AI_102 :=** ________
DNP Analog Input Label Name	**AI_103 :=** ________
DNP Analog Input Label Name	**AI_104 :=** ________
DNP Analog Input Label Name	**AI_105 :=** ________
DNP Analog Input Label Name	**AI_106 :=** ________
DNP Analog Input Label Name	**AI_107 :=** ________
DNP Analog Input Label Name	**AI_108 :=** ________
DNP Analog Input Label Name	**AI_109 :=** ________
DNP Analog Input Label Name	**AI_110 :=** ________
DNP Analog Input Label Name	**AI_111 :=** ________
DNP Analog Input Label Name	**AI_112 :=** ________
DNP Analog Input Label Name	**AI_113 :=** ________
DNP Analog Input Label Name	**AI_114 :=** ________
DNP Analog Input Label Name	**AI_115 :=** ________
DNP Analog Input Label Name	**AI_116 :=** ________
DNP Analog Input Label Name	**AI_117 :=** ________
DNP Analog Input Label Name	**AI_118 :=** ________
DNP Analog Input Label Name	**AI_119 :=** ________
DNP Analog Input Label Name	**AI_120 :=** ________
DNP Analog Input Label Name	**AI_121 :=** ________
DNP Analog Input Label Name	**AI_122 :=** ________
DNP Analog Input Label Name	**AI_123 :=** ________
DNP Analog Input Label Name	**AI_124 :=** ________
DNP Analog Input Label Name	**AI_125 :=** ________
DNP Analog Input Label Name	**AI_126 :=** ________
DNP Analog Input Label Name	**AI_127 :=** ________
DNP Analog Input Label Name	**AI_128 :=** ________
DNP Analog Input Label Name	**AI_129 :=** ________

DNP Analog Input Label Name	**AI_130 :=** ______________
DNP Analog Input Label Name	**AI_131 :=** ______________
DNP Analog Input Label Name	**AI_132 :=** ______________
DNP Analog Input Label Name	**AI_133 :=** ______________
DNP Analog Input Label Name	**AI_134 :=** ______________
DNP Analog Input Label Name	**AI_135 :=** ______________
DNP Analog Input Label Name	**AI_136 :=** ______________
DNP Analog Input Label Name	**AI_137 :=** ______________
DNP Analog Input Label Name	**AI_138 :=** ______________
DNP Analog Input Label Name	**AI_139 :=** ______________
DNP Analog Input Label Name	**AI_140 :=** ______________
DNP Analog Input Label Name	**AI_141 :=** ______________
DNP Analog Input Label Name	**AI_142 :=** ______________
DNP Analog Input Label Name	**AI_143 :=** ______________
DNP Analog Input Label Name	**AI_144 :=** ______________
DNP Analog Input Label Name	**AI_145 :=** ______________
DNP Analog Input Label Name	**AI_146 :=** ______________
DNP Analog Input Label Name	**AI_147 :=** ______________
DNP Analog Input Label Name	**AI_148 :=** ______________
DNP Analog Input Label Name	**AI_149 :=** ______________
DNP Analog Input Label Name	**AI_150 :=** ______________
DNP Analog Input Label Name	**AI_151 :=** ______________
DNP Analog Input Label Name	**AI_152 :=** ______________
DNP Analog Input Label Name	**AI_153 :=** ______________
DNP Analog Input Label Name	**AI_154 :=** ______________
DNP Analog Input Label Name	**AI_155 :=** ______________
DNP Analog Input Label Name	**AI_156 :=** ______________
DNP Analog Input Label Name	**AI_157 :=** ______________
DNP Analog Input Label Name	**AI_158 :=** ______________
DNP Analog Input Label Name	**AI_159 :=** ______________
DNP Analog Input Label Name	**AI_160 :=** ______________
DNP Analog Input Label Name	**AI_161 :=** ______________
DNP Analog Input Label Name	**AI_162 :=** ______________
DNP Analog Input Label Name	**AI_163 :=** ______________
DNP Analog Input Label Name	**AI_164 :=** ______________
DNP Analog Input Label Name	**AI_165 :=** ______________
DNP Analog Input Label Name	**AI_166 :=** ______________
DNP Analog Input Label Name	**AI_167 :=** ______________

DNP Analog Input Label Name	**AI_168 :=** ________________
DNP Analog Input Label Name	**AI_169 :=** ________________
DNP Analog Input Label Name	**AI_170 :=** ________________
DNP Analog Input Label Name	**AI_171 :=** ________________
DNP Analog Input Label Name	**AI_172 :=** ________________
DNP Analog Input Label Name	**AI_173 :=** ________________
DNP Analog Input Label Name	**AI_174 :=** ________________
DNP Analog Input Label Name	**AI_175 :=** ________________
DNP Analog Input Label Name	**AI_176 :=** ________________
DNP Analog Input Label Name	**AI_177 :=** ________________
DNP Analog Input Label Name	**AI_178 :=** ________________
DNP Analog Input Label Name	**AI_179 :=** ________________
DNP Analog Input Label Name	**AI_180 :=** ________________
DNP Analog Input Label Name	**AI_181 :=** ________________
DNP Analog Input Label Name	**AI_182 :=** ________________
DNP Analog Input Label Name	**AI_183 :=** ________________
DNP Analog Input Label Name	**AI_184 :=** ________________
DNP Analog Input Label Name	**AI_185 :=** ________________
DNP Analog Input Label Name	**AI_186 :=** ________________
DNP Analog Input Label Name	**AI_187 :=** ________________
DNP Analog Input Label Name	**AI_188 :=** ________________
DNP Analog Input Label Name	**AI_189 :=** ________________
DNP Analog Input Label Name	**AI_190 :=** ________________
DNP Analog Input Label Name	**AI_191 :=** ________________
DNP Analog Input Label Name	**AI_192 :=** ________________
DNP Analog Input Label Name	**AI_193 :=** ________________
DNP Analog Input Label Name	**AI_194 :=** ________________
DNP Analog Input Label Name	**AI_195 :=** ________________
DNP Analog Input Label Name	**AI_196 :=** ________________
DNP Analog Input Label Name	**AI_197 :=** ________________
DNP Analog Input Label Name	**AI_198 :=** ________________
DNP Analog Input Label Name	**AI_199 :=** ________________

Analog Output Map

DNP Analog Output Label Name	**AO_000 :=** ________________
DNP Analog Output Label Name	**AO_001 :=** ________________
DNP Analog Output Label Name	**AO_002 :=** ________________
DNP Analog Output Label Name	**AO_003 :=** ________________

DNP Analog Output Label Name	**AO_004 :=** ______________
DNP Analog Output Label Name	**AO_005 :=** ______________
DNP Analog Output Label Name	**AO_006 :=** ______________
DNP Analog Output Label Name	**AO_007 :=** ______________

Counter Map

DNP Counter Label Name	**CO_000 :=** ______________
DNP Counter Label Name	**CO_001 :=** ______________
DNP Counter Label Name	**CO_002 :=** ______________
DNP Counter Label Name	**CO_003 :=** ______________
DNP Counter Label Name	**CO_004 :=** ______________
DNP Counter Label Name	**CO_005 :=** ______________
DNP Counter Label Name	**CO_006 :=** ______________
DNP Counter Label Name	**CO_007 :=** ______________

APPENDIX M

Fast SER Protocol

Overview

This appendix describes special binary Fast Sequential Events Recorder (SER) messages that are not included in *Section 10: Communications*. Devices with embedded processing capability can use these messages to enable and accept unsolicited binary Fast SER messages from the SEL-351 Relay. Unsolicited Fast SER messages can be enabled on multiple serial and Ethernet ports simultaneously.

SEL relays and communications processors have two separate data streams that share the same serial port. The normal serial interface consists of ASCII character commands and reports that are intelligible using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information, and then allow the ASCII data stream to continue. This mechanism allows a single communications channel to be used for ASCII communications (e.g., transmission of a long event report) interleaved with short bursts of binary data to support fast acquisition of metering or SER data. To exploit this feature, the device connected to the other end of the link requires software that uses the separate data streams. The binary commands and ASCII commands can also be accessed by a device that does not interleave the data streams.

Sequential Events Recorder (SER) Storage Considerations

The relay captures a record in the Sequential Events Recorder (SER) event report for any change of state in any one of the elements listed in the SER1, SER2, or SER3 trigger settings. Nonvolatile memory is used to store the latest 1024 rows of the SER event report so they can be retained during power loss. The nonvolatile memory is rated for a finite number of writes. Exceeding the limit can result in an EEPROM self-test failure. *An average of one state change every three minutes can be made for a 25-year relay service life*.

The Fast SER event buffer stores the most recent 512 events in volatile memory. If the relay loses power and event messages have not been sent, Fast SER will not send those messages upon power up. An enable message must be sent to the relay to begin the transmission of Fast SER messages.

Recommended Message Usage

Use the following sequence of commands to enable unsolicited binary Fast SER messaging in the SEL-351:

1. On initial connection, send the **SNS** command (see *Appendix J: Configuration, Fast Meter, and Fast Operate Commands*) to retrieve and store the ASCII names for the digital I/O points assigned to trigger SER records.

   The order of the ASCII names matches the point indices in the unsolicited binary Fast SER messages. Send the "Enable Unsolicited Fast SER Data Transfer" message to enable the SEL-351 to transmit unsolicited binary Fast SER messages.
2. When SER records are triggered in the SEL-351, the relay responds with an unsolicited binary Fast SER message. If this message has a valid checksum, it must be acknowledged by sending an acknowledge message with the same response number as contained in the original message. The relay will wait approximately 100 ms to 500 ms to receive an acknowledge message, at which time the relay will resend the same unsolicited Fast SER message with the same response number five times before suspending the message transmission. An enable message must be sent to the relay to begin sending the Fast SER messages again.
3. Upon receiving an acknowledge message with a matching response number, the relay increments the response number, and continues to send and seek acknowledgment for unsolicited Fast SER messages, if additional SER records are available. When the response number reaches three it wraps around to zero on the next increment.

Functions and Function Codes

In the messages shown below, all numbers are in hexadecimal, unless otherwise noted.

01—Function Code: Enable Unsolicited Fast SER Data Transfer, Sent From Master to Relay

Upon power-up, the SEL-351 disables its own unsolicited transmissions. This function enables the SEL-351 to begin sending unsolicited data to the device that sent the enable message, if the SEL-351 has such data to transfer. The message format for function code 01 is shown in *Table M.1*.

Table M.1 Function Code 01 Message Format (Sheet 1 of 2)

Data	Description
A546	Message header
12	Message length in bytes (18 decimal)
0000000000	Five bytes reserved for future use as a routing address
YY	Status byte (LSB = 1 indicates an acknowledge is requested)
01	Function code

Table M.1 Function Code 01 Message Format (Sheet 2 of 2)

Data	Description
C0	Sequence byte (Always C0. Other values are reserved for future use in multiple frame messages.)
XX	Response number (XX = 00, 01, 02, 03, 00, 01...).
18	Function to enable (18—unsolicited SER messages)
0000	Reserved for future use as function code data
nn	Maximum number of SER records per message, 01–20 hex
cccc	Two byte CRC-16 check code for message

The SEL-351 verifies the message by checking the header, length, function code, and enabled function code against the expected values. It also checks the entire message against the CRC-16 field. If any of the checks fail, except the function code or the function to enable, the message is ignored.

If an acknowledge is requested as indicated by the least significant bit of the status byte, the relay transmits an acknowledge message with the same response number received in the enable message.

The “nn” field is used to set the maximum number of SER records per message. The relay checks for SER records approximately every 500 ms. If there are new records available, the relay immediately creates a new unsolicited Fast SER message and transmits it. If there are more than “nn” new records available, or if the first and last record are separated by more than 16 seconds, the relay will break the transmission into multiple messages so that no message contains more than “nn” records, and the first and last record of each message are separated by no more than 16 seconds.

If the function to enable is not 18 or the function code is not recognized, the relay responds with an acknowledge message containing a response code 01 (function code unrecognized), and no functions are enabled. If the SER triggers are disabled (SER1, SER2, and SER3 are all set to NA), the unsolicited Fast SER messages are still enabled, but the only SER records generated are the result of settings changes and power being applied to the relay. If the SER1, SER2, or SER3 settings are subsequently changed to any non-NA value and SER entries are triggered, unsolicited SER messages will be generated with the new SER records.

02—Function Code: Disable Unsolicited Fast SER Data Transfer, Sent From Master to Relay

This function disables the SEL-351 from transferring unsolicited data. The message format for function code 02 is shown in *Table M.2*.

Table M.2 Function Code 02 Message Format (Sheet 1 of 2)

Data	Description
A546	Message header
10	Message length (16 decimal)
0000000000	Five bytes reserved for future use as a routing address.
YY	Status byte (LSB = 1 indicates an acknowledge is requested)
02	Function code

Table M.2 Function Code 02 Message Format (Sheet 2 of 2)

Data	Description
C0	Sequence byte (Always C0. Other values are reserved for future use in multiple frame messages.)
XX	Response number (XX = 00, 01, 02, 03, 01, 02...)
18	Function to disable (18 = Unsolicited SER)
00	Reserved for future use as function code data
cccc	Two byte CRC-16 check code for message

The SEL-351 verifies the message by checking the header, length, function code, and disabled function code against the expected values, and checks the entire message against the CRC-16 field. If any of the checks fail, except the function code or the function to disable, the message is ignored.

If an acknowledge is requested as indicated by the least significant bit of the status byte, the relay transmits an acknowledge message with the same response number received in the enable message.

If the function to disable is not 18 or the function code is not recognized, the relay responds with an acknowledge message containing the response code 01 (function code unrecognized) and no functions are disabled.

18—Function: Unsolicited Fast SER Response, Sent From Relay to Master

The function 18 is used for the transmission of unsolicited Fast Sequential Events Recorder (SER) data from the SEL-351. This function code is also passed as data in the “Enable Unsolicited Data Transfer” and the “Disable Unsolicited Data Transfer” messages to indicate which type of unsolicited data should be enabled or disabled. The message format for function code 18 is shown in *Table M.3*.

Table M.3 Function Code 18 Message Format (Sheet 1 of 2)

Data	Description
A546	Message header
ZZ	Message length (As long as 34 + 4 • *nn* decimal, where *nn* is the maximum number of SER records allowed per message as indicated in the “Enable Unsolicited Data Transfer” message.)
0000000000	Five bytes reserved for future use as a routing address.
YY	Status Byte (01 = need acknowledgment; 03 = settings changed and need acknowledgment. If YY=03, the master should re-read the SNS data because the element index list may have changed.)
18	Function code
C0	Sequence byte (Always C0. Other values are reserved for future use in multiple frame messages.)
XX	Response number (XX = 00, 01, 02, 03, 01, 02...)
00000000	Four bytes reserved for future use as a return routing address.
dddd	Two-byte day of year (1–366)
yyyy	Two-byte, four-digit year (e.g., 2009 or 07D9 hex)
mmmmmmmm	Four-byte time of day in milliseconds since midnight
XX	1st element index (match with the response to the SNS command; 00 for 1st element, 01 for second element, and so on)

Table M.3 Function Code 18 Message Format (Sheet 2 of 2)

Data	Description
uuuuuu	Three-byte time tag offset of 1st element in microseconds since time indicated in the time of day field.
XX	2nd element index
uuuuuu	Three-byte time tag offset of 2nd element in microseconds since time indicated in the time of day field.
• • •	
xx	last element index
uuuuuu	Three-byte time tag offset of last element in microseconds since time indicated in the time of day field.
FFFFFFFE	Four-byte end-of-records flag
ssssssss	Packed four-byte element status for as many as 32 elements (LSB for the 1st element)
cccc	Two-byte CRC-16 checkcode for message

If the relay determines that SER records have been lost, it sends a message with the following format:

Table M.4 Message Format for Lost SER Records

Data	Description
A546	Message header
22	Message length (34 decimal)
0000000000	Five bytes reserved for future use as a routing address.
YY	Status Byte (01 = need acknowledgment; 03 = settings changed and need acknowledgment)
18	Function code
C0	Sequence byte (Always C0. Other values are reserved for future use in multiple frame messages.)
XX	Response number (XX = 00, 01, 02, 03, 00, 01, ...)
00000000	Four bytes reserved for future use as a return routing address.
dddd	Two-byte day of year (1–366) of overflow message generation
yyyy	Two-byte, four-digit year (e.g., 2009 or 07D9 hex) of overflow message generation.
mmmmmmmm	Four-byte time of day in milliseconds since midnight
FFFFFFFE	Four-byte end-of-records flag
00000000	Element status (unused)
cccc	Two byte CRC-16 checkcode for message

Acknowledge Message Sent from Master to Relay, and From Relay to Master

The acknowledge message is constructed and transmitted for every received message that contains a status byte with the LSB set (except another acknowledge message), and that passes all other checks, including the CRC. The acknowledge message format is shown in *Table M.5*.

Table M.5 Acknowledge Message Format

Data	Description
A546	Message header
0E	Message length (14 decimal)
0000000000	Five bytes reserved for future use as a routing address.
00	Status byte (always 00)
XX	Function code, echo of acknowledged function code with MSB set.
RR	Response code (see below)
XX	Response number (XX = 00, 01, 02, 03, 00, 01, ...) must match response number from message being acknowledged.)
cccc	Two byte CRC-16 checkcode for message

The SEL-351 supports the response codes in *Table M.6*.

Table M.6 Supported Response Codes

RR	Response
00	Success.
01	Function code not recognized.

Examples

1. Successful acknowledge for "Enable Unsolicited Fast SER Data Transfer" message from a relay with at least one of SER1, SER2, or SER3 not set to NA:

   A5 46 0E 00 00 00 00 00 00 81 00 XX cc cc (XX is the same as the Response Number in the "Enable Unsolicited Data Transfer" message to which it responds)

2. Unsuccessful acknowledge for "Enable Unsolicited Fast SER Data Transfer" message from a relay with all of SER1, SER2, and SER3 set to NA:

   A5 46 0E 00 00 00 00 00 00 81 02 XX cc cc (XX is the same as the response number in the "Enable Unsolicited Data Transfer" message to which it responds.)

3. Disable Unsolicited Fast SER Data Transfer message, acknowledge requested:

   A5 46 10 00 00 00 00 00 01 02 C0 XX 18 00 cc cc (XX = 0, 1, 2, 3)

4. Successful acknowledge from the relay for the "Disable Unsolicited Fast SER Data Transfer" message:

   A5 46 0E 00 00 00 00 00 00 82 00 XX cc cc (XX is the same as the response number in the "Disable Unsolicited Fast SER Data Transfer" message to which it responds.)

5. Successful acknowledge message from the master for an unsolicited Fast SER message:

   A5 46 0E 00 00 00 00 00 00 98 00 XX cc cc (XX is the same as the response number in the unsolicited Fast SER message to which it responds.)

Notes

Once the relay receives an acknowledge with response code 00 from the master, it will clear the settings changed bit (bit 1) in its status byte, if that bit is asserted, and it will clear the settings changed bit in Fast Meter, if that bit is asserted.

An element index of FE indicates that the SER record is the result of power up. An element index of FF indicates that the SER record is the result of a setting change. An element index of FD indicates that the element identified in this SER record is no longer in the SER trigger settings. There are other non-Relay Word bits that appear in the SER that are not transmitted in a Fast SER message. These are shown in *Table 12.5*.

When the relay sends an SER message packet, it will put a sequential number (0, 1, 2, 3, 0, 1, ...) into the response number. If the relay does not receive an acknowledge from the master before approximately 500 ms, the relay will resend the same message packet as many as five times with the same response number until it receives an acknowledge message with that response number. For the next SER message, the relay will increment the response number (it will wrap around to zero from three).

A single Fast SER message packet from the relay can have a maximum number of 32 records and the data may span a time period of no more than 16 seconds. The master can limit the number of records in a packet with the third byte of function code data in the “Enable Unsolicited Data Transfer” message (function code 01). The relay can generate an SER packet with fewer than the requested number of records, if the record time stamps span more than 16 seconds.

The relay always requests acknowledgment in unsolicited Fast SER messages (LSB of the status byte is set).

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APPENDIX N

Synchrophasors

Overview

The SEL-351 provides Phasor Measurement Unit (PMU) capabilities when connected to a suitable IRIG-B time source. Synchrophasor is used as a general term that can refer to data or protocol.

This section covers the following topics:

See *IRIG-B Time-Code Input* on page 2.19 for the requirements of the IRIG-B time source. Synchrophasors are still measured if the high-accuracy time source is not connected, however, the data are not time-synchronized to any external reference, as indicated by Relay Word bits TSOK = logical 0 and PMDOK = logical 0.

Introduction

The word synchrophasor is derived from two words: synchronized and phasor. Synchrophasor measurement refers to the concept of providing measurements taken on a synchronized schedule in multiple locations. A high-accuracy clock, commonly a Global Positioning System (GPS) receiver such as the SEL-2407 Satellite-Synchronized Clock, makes synchrophasor measurement possible.

The availability of an accurate time reference over a large geographic area allows multiple devices, such as a number of SEL-351 Relays, to synchronize the gathering of power system data. The accurate clock allows precise event report triggering and other off-line analysis functions.

The SEL-351 Global settings contain the synchrophasor settings, including the choice of synchrophasor protocol and the synchrophasor data set the relay will transmit. The Port settings select which serial port(s) are reserved for synchrophasor protocol use and enables synchrophasors on Ethernet ports. See *Settings for IEEE C37.118 Protocol Synchrophasors* on page N.5.

The SEL-351 generates time status Relay Word bits and time-quality information that is important for synchrophasor measurement. Some protection SELogic variables and programmable digital trigger information (C37.118 protocol only) are also added to the Relay Word bits for synchrophasors—see *Synchrophasor Relay Word Bits* on page N.17.

The value of synchrophasor data increases greatly when the data can be shared over a communications network in real time. Two synchrophasor protocols are available in the SEL-351 that allow for a centralized device to collect data efficiently from several phasor measurement units (PMUs). Some possible uses of a system-wide synchrophasor system include the following:

- ➤ Power-system state measurement
- ➤ Wide-area network protection and control schemes
- ➤ Small-signal analysis
- ➤ Power-system disturbance analysis

In any installation, the SEL-351 can use only one of the synchrophasor protocols, SEL Fast Message Synchrophasor, or C37.118, as selected by Global setting MFRMT. When MFRMT = FM, SEL Fast Message synchrophasor data are available on multiple serial ports when the port setting PROTO = SEL. When MFRMT = C37.118, IEEE C37.118 compliant synchrophasor data are available on multiple serial ports when the port setting PROTO = PMU and on Ethernet Ports when port setting EPMIP = Y. Use either SEL or C37.118 protocol to create control schemes by making port setting FASTOP = Y.

You can view synchrophasor data over a serial port set to PROTO = SEL, see *View Synchrophasors by Using the MET PM Command* on page N.18.

SEL Fast Message synchrophasor protocol is able to share the same physical port with separate data streams (see *Overview* on page J.1).

Synchrophasor Measurement

NOTE: The synchrophasor data stream is separate from the other protection and metering functions.

The phasor measurement unit in the SEL-351 measures four voltages and four currents on a constant-time basis. These samples are synchronized to the high-accuracy IRIG-B time source, and occur at a fixed frequency of either 60 Hz or 50 Hz, depending on Global setting NFREQ. The relay then filters the measured samples according to Global setting PMAPP = F or N—see *PMAPP* on page N.7. The phase angle is measured relative to an absolute reference, which is represented by a cosine function in *Figure N.1*. The time-of-day is shown for the two time marks.

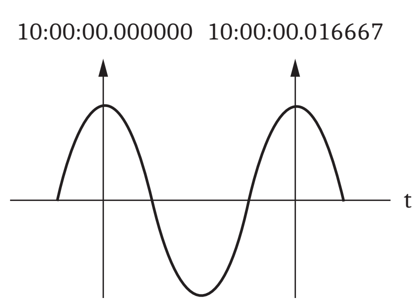

Figure N.1 High-Accuracy Clock Controls Reference Signal (60 Hz System)

The instrument transformers (PTs or CTs) and the interconnecting cables may introduce a time shift in the measured signal. Global settings VPCOMP, VSCOMP, IPCOMP, and INCOMP, entered in degrees, are added to the measured phasor angles to create the corrected phasor angles, as shown in *Figure N.2*. The VPCOMP, VSCOMP, IPCOMP, and INCOMP settings may be positive or negative values. The corrected angles are displayed in the **MET PM** command and transmitted as part of synchrophasor messages.

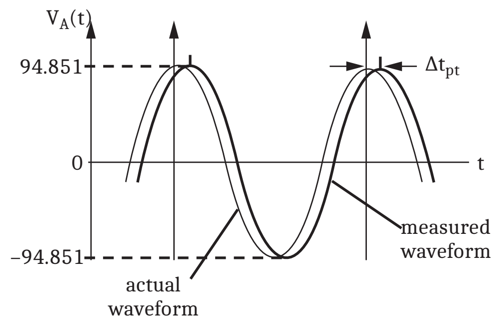

Figure N.2 Waveform at Relay Terminals May Have Phase Shift

$$\text{Compensation Angle} = \frac{\Delta t_{pt}}{\left(\frac{1}{\text{freq}}\right)} \bullet 360^\circ$$
$$= \Delta t_{pt} \bullet \text{freq} \bullet 360^\circ$$

Equation N.1

If the time shift on the pt measurement path Δt_{pt} = 0.784 ms and the nominal frequency, $freq_{nominal}$ = 60Hz, use *Equation N.2* to obtain the correction angle:

$$0.784 \bullet 10^{-3}\text{s} \bullet 60\text{s}^{-1} \bullet 360^\circ = 16.934^\circ$$

Equation N.2

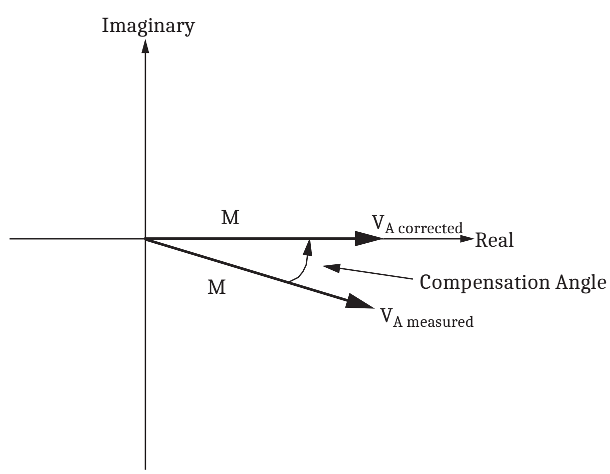

Figure N.3 Correction of Measured Phase Angle

For a sinusoidal signal, the phasor magnitude is calculated as shown in *Equation N.3*. The phasors are rms values scaled in primary units, as determined by Group settings PTR, PTRS, CTR, and CTRN. The SEL-351 then calculates the positive-sequence voltage and currents.

$$\text{Magnitude M} = \frac{V_{pk}}{\sqrt{2}} \bullet \text{PTR}_{\text{setting}}$$

Equation N.3

With PTR = 2000, and the signal in *Figure N.2* (with peak voltage V_{pk} = 94.851 V), use *Equation N.4* to obtain the magnitude, VA_MAG:

$$\begin{aligned} \text{VA\_MAG} &= \frac{94.851}{\sqrt{2}} \bullet 2000 \\ &= 134140 \text{ V} \\ &= 134.140 \text{ kV} \end{aligned}$$

Equation N.4

Finally, the magnitude and angle pair for each synchrophasor is converted to a real and imaginary pair using *Equation N.5* and *Equation N.6*. For example, analog quantities VA_MAG and VA_ANG are converted to VA_REAL and VA_IMG. An example phasor with an angle measurement of 104.400° is shown in *Figure N.4*.

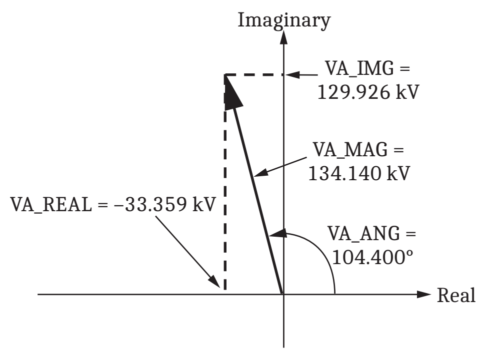

Figure N.4 Example Calculation of Real and Imaginary Components of Synchrophasor

$$\text{Real part} = \text{M} \bullet \cos(\text{angle})$$

Equation N.5

$$\text{Imaginary part} = \text{M} \bullet \sin(\text{angle})$$

Equation N.6

Using the magnitude M from *Equation N.5*, the real part is given in *Equation N.7*.

$$\begin{aligned} \text{VA\_REAL} &= 134.140 \text{ kV} \bullet \cos 104.400° \\ &= -33.359 \text{ kV} \end{aligned}$$

Equation N.7

Similarly, the imaginary part is calculated in *Equation N.8*

$$\begin{aligned} \text{VA\_IMG} &= 134.140 \text{ kV} \bullet \sin 104.400° \\ &= 129.926 \text{ kV} \end{aligned}$$

Equation N.8

Because the sampling reference is based on the GPS clock (IRIG-B signal) and not synchronized to the power system, an examination of successive synchrophasor data sets will almost always show some angular change between samples of the same signal. This is not a malfunction of the relay or the power system, but is merely a result of viewing data from one system with an instrument with an independent time base. In other words, a power system has a nominal frequency of either 50 or 60 Hz, but on closer examination, it is usually running a little faster or slower than nominal.

Settings for IEEE C37.118 Protocol Synchrophasors

NOTE: IEEE C37.118 protocol is recommended for all new applications.

The phasor measurement unit (PMU) settings are listed in *Table N.1*. Make these settings when you want to use the C37.118 synchrophasor protocol.

The Global enable setting EPMU must be set to Y before the remaining SEL-351 synchrophasor settings are available. No synchrophasor data collection can take place when EPMU = N.

You must make the port settings in *Table N.4* or *Table N.5* to transmit data with synchrophasor protocol. It is possible to set EPMU = Y without using any ports for synchrophasor protocols. For example, the serial port **MET PM** ASCII command can still be used.

The Global settings for the SEL Fast Message synchrophasor protocol are a subset of the *Table N.1* settings, and are listed separately (see *SEL Fast Message Synchrophasor Protocol* on page N.22).

Table N.1 PMU Settings in the SEL-351 (Global Settings) (Sheet 1 of 2)

Global Settings	Description	Default
EPMU	Enable Synchronized Phasor Measurement (Y, N)	N[a]
MFRMT	Message Format (C37.118, FM)[b,c]	C37.118
MRATE	Messages per Second {1, 2, 5, 10, 25, or 50 when NFREQ = 50} {1, 2, 4, 5, 10, 12, 15, 20, 30, or 60 when NFREQ = 60}	2
PMAPP	PMU Application (F = Fast Response, N = Narrow Bandwidth)	N
PHCOMP	Frequency-Based Phasor Compensation (Y, N)	Y
PMSTN	Station Name (16 characters, mixed case)	STATION A
PMID	PMU Hardware ID (1–65534)	1
PHDATAV	Phasor Data Set, Voltages (V1, PH, ALL, NA when PTCONN = WYE or DELTA; ALL or NA when PTCONN = SINGLE)	V1
VPCOMP	Phase Voltage Angle Compensation Factor (–179.99 to 180 degrees)	0.00
VSCOMP	VS Voltage Angle Compensation Factor (–179.99 to 180 degrees)	0.00
PHDATAI	Phasor Data Set, Currents (I1, PH, ALL, NA)	NA
IPCOMP	Phase Current Angle Compensation Factor (–179.99 to 180 degrees)	0.00
INCOMP	Neutral Current Angle Compensation Factor (–179.99 to 180 degrees)	0.00
PHNR[d]	Phasor Numeric Representation (I = Integer, F = Floating point)	I

Table N.1 PMU Settings in the SEL-351 (Global Settings) (Sheet 2 of 2)

Global Settings	Description	Default
PHFMT[d]	Phasor Format (R = Rectangular coordinates, P = Polar coordinates)	R
FNR	Frequency Numeric Representation (I = Integer, F = Float)	I
NUMDSW	Number of 16-bit Digital Status Words (0, 1)	1

[a] Set EPMU = Y to access the remaining settings
[b] C37.118 = IEEE C37.118 Standard; FM = SEL Fast Message—see *Table N.19*.
[c] When PTCONN = SINGLE or DELTA, MFRMT cannot be set to FM.
[d] Setting hidden when PHDATAV = NA and PHDATAI = NA or MFRMT = FM.

Table N.2 PMU Settings in the SEL-351 (Logic Settings)

Logic Settings	Description	Default
TREA1	Trigger Reason Bit 1 (SELOGIC Control Equation)	0
TREA2	Trigger Reason Bit 2 (SELOGIC Control Equation)	0
TREA3	Trigger Reason Bit 3 (SELOGIC Control Equation)	0
TREA4	Trigger Reason Bit 4 (SELOGIC Control Equation)	0
PMTRIG	Trigger (SELOGIC Control Equation)	0

Descriptions of Synchrophasor Settings

Definitions for the settings in *Table N.1* are as follows:

MFRMT

Selects the message format for synchrophasor data streaming on serial ports.

SEL recommends the use of MFRMT = C37.118 for any new PMU applications because of increased setting flexibility and the availability of software and hardware for synchrophasor concentration, processing, and control. The SEL-351 includes the MFRMT = FM setting choice to maintain compatibility in any systems presently using SEL Fast Message synchrophasors.

MRATE

Selects the message rate in messages per second for synchrophasor data streaming on serial ports.

Choose the MRATE setting that suits the needs of your PMU application. This setting is one of six settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size. See *Communications Bandwidth for C37.118 Protocol* on page N.15 for detailed information.

PMAPP

Selects the type of digital filters used in the synchrophasor algorithm:

- The Narrow Bandwidth setting (N) represents filters with a cutoff frequency approximately ¼ of MRATE. The response in the frequency domain is narrower, and response in the time domain is slower. This method results in synchrophasor data that are free of aliasing signals and well suited for post-disturbance analysis.
- The Fast Response setting (F) represents filters with a higher cutoff frequency. The response in frequency domain is wider and the response in the time domain is faster. This method results in synchrophasor data that can be used in synchrophasor applications requiring more speed in tracking system parameters.

PHCOMP

Enables or disables frequency-based compensation for synchrophasors.

For most applications, set PHCOMP = Y to activate the algorithm that compensates for the magnitude and angle errors of synchrophasors for frequencies that are off nominal. Use PHCOMP = N if you are concentrating the SEL-351 synchrophasor data with other PMU data that do not employ frequency compensation.

PMSTN and PMID

Defines the name and number of the PMU.

NOTE: The PMSTN setting is not the same as the SEL-351 Group setting TID (Terminal Identifier), even though they share the same factory default value.

The PMSTN setting is an ASCII string with as many as 16 characters. The PMID setting is a numeric value. Use your utility or synchrophasor data concentrator naming convention to determine these settings.

PHDATAV, VPCOMP, and VSCOMP

PHDATAV selects which voltage synchrophasors to include in the data packet. Consider the burden on your synchrophasor processor and offline storage requirements when deciding how much data to transmit. This setting is one of six settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth for C37.118 Protocol* on page N.15 for detailed information.

- PHDATAV = V1 will transmit only positive-sequence voltage, V_1
- PHDATAV = PH will transmit VA, VB, and VC when PTCONN = WYE
- PHDATAV = PH will transmit VAB, VBC, and VCA when PTCONN = DELTA

NOTE: When PTCONN = SINGLE, the VA synchrophasor is the voltage connected between the VA terminal (Z09) and the N terminal (Z12). Global setting PHANTV has no effect on synchrophasors.

- PHDATAV = ALL will transmit V1, VA, VB, VC, and VS when PTCONN = WYE
- PHDATAV = ALL will transmit V1, VAB, VBC, VCA, and VS when PTCONN = DELTA
- PHDATAV = ALL will transmit VS and the voltage connected between terminals VA and N when PTCONN = SINGLE
- PHDATAV = NA will not transmit any voltages

Table N.3 describes the order of synchrophasors inside the data packet.

The VPCOMP and VSCOMP settings allow correction for any steady-state voltage phase errors (from the potential transformers or wiring characteristics). VPCOMP corrects the VA, VB, VC, and V1 voltages for phase angle error. VSCOMP corrects the VS voltage for phase angle error. See *Synchrophasor Measurement* on page N.2 for details on this setting.

PHDATAI, IPCOMP, and INCOMP

PHDATAI selects which current synchrophasors to include in the data packet. Consider the burden on your synchrophasor processor and offline storage requirements when deciding how much data to transmit. This setting is one of six settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth for C37.118 Protocol* on page N.15 for detailed information.

- PHDATAI = I1 will transmit only positive-sequence current, I_1
- PHDATAI = PH will transmit IA, IB, and IC
- PHDATAI = ALL will transmit I_1, I_A, I_B, I_C, and I_N
- PHDATAI = NA will not transmit any currents

The IPCOMP and INCOMP settings allow correction for any steady-state phase errors (from the current transformers or wiring characteristics). See *Synchrophasor Measurement* on page N.2 for details on these settings.

Table N.3 describes the order of synchrophasors inside the data packet. Synchrophasors are transmitted in the order indicated from the top to the bottom of the table. When PHFMT = R, real values are transmitted first and imaginary values are transmitted second. When PHFMT = P, magnitude values are transmitted first and angle values are transmitted second. Synchrophasors are only transmitted if specified to be included by the PHDATAV and PHDATAI settings. For example, if PHDATAV = ALL and PHDATAI = I1, phase voltages will be transmitted first, followed by VS input voltage, positive-sequence voltage, and positive-sequence current.

Table N.3 Synchrophasor Order in Data Stream (Voltages and Currents)

Synchrophasors[a]	Scaling[b]	Channel Name
Phase A Current	CTR	IAPM
Phase B Current	CTR	IBPM
Phase C Current	CTR	ICPM
Neutral Current	CTRN	INPM
Phase A or AB Voltage[c]	PTR	VAPM
Phase B or BC Voltage[c]	PTR	VBPM
Phase C or CA Voltage[c]	PTR	VCPM
VS Input Voltage	PTRS	VSPM
Positive-Sequence Current	CTR	I1PM
Positive-Sequence Voltage	PTR	V1PM

[a] Synchrophasors are included in the order shown (for example phase currents, if selected, will always precede phase voltage).

[b] Synchrophasors are transmitted as primary values. Relay settings CTR, CTRN, PTR, PTRS are used to scale the values as shown.

[c] When PHDATAV = PH or ALL and PTCONN = WYE, phase voltages VA, VB, and VC are transmitted. Phase voltages VAB, VBC, and VCA are transmitted when PTCONN = DELTA. The voltage connected between terminals VA and N is transmitted when PTCONN = SINGLE.

PHNR

Selects the numeric representation of voltage and current phasor data in the synchrophasor data stream.

This setting is one of six settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth for C37.118 Protocol* on page N.15 for detailed information.

The choices for this setting depend on synchrophasor processor requirements.

Setting PHNR = I sends each voltage and/or current synchrophasor as 2 two-byte integer values.

Setting PHNR = F sends each voltage and/or current synchrophasor as 2 four-byte floating-point values.

PHFMT

Selects the phasor representation of voltage and current phasor data in the synchrophasor data stream.

The choices for this setting depend on synchrophasor processor requirements.

Setting PHFMT = R (rectangular) sends each voltage or current synchrophasor as a pair of signed real and imaginary values.

Setting PHFMT = P (polar) sends each voltage or current synchrophasor as a magnitude and angle pair. The angle is in radians when PHNR = F, and in radians • 10^4 when PHNR = I. The range is as follows:

$-\pi < \text{angle} \leq \pi$.

In both the rectangular and polar representations, the values are scaled in rms (root mean square) units. For example, a synchrophasor with a magnitude of 1.0 at an angle of –30 degrees will have a real component of 0.866, and an imaginary component of –0.500. See *Synchrophasor Measurement* on page N.2 for an example of conversion between polar and rectangular coordinates.

FNR

Selects the numeric representation of the two frequency values in the synchrophasor data stream.

This setting is one of six settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth for C37.118 Protocol* on page N.15 for detailed information.

The choices for this setting depend on synchrophasor processor requirements.

Setting FNR = I sends the frequency data as a difference from nominal frequency, NFREQ, with the following formula:

$(\text{FREQ}_{\text{measured}} - \text{NFREQ}) \bullet 1000$,

represented as a signed, two-byte value.

Setting FNR = I also sends the rate-of-change-of-frequency data with scaling.

$\text{DFDT}_{\text{measured}} \bullet 100$,

represented as a signed, two-byte value.

Setting FNR = F sends the measured frequency data and rate-of-change of frequency as two four-byte, floating-point values.

NUMDSW

Selects the number of user-definable digital status words to be included in the synchrophasor data stream.

This setting is one of six settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth for C37.118 Protocol* on page N.15 for detailed information.

The choices for this setting depend on the synchrophasor system design. The inclusion of digital data can help indicate breaker status or other operational data to the synchrophasor processor. For example, because VS channel synchrophasors are IEEE C37.118 Level 1 compliant only when the frequency is the same as the Phase A voltage, it may be desirable to monitor breaker position to indicate when there might be a frequency difference. See *IEEE C37.118 PMU Setting Example* on page N.19 for a suggested use of the digital status word fields.

Setting NUMDSW = 0 sends no user-definable digital status words.

Setting NUMDSW = 1 sends the user-definable digital status words containing Relay Word bits SV1 through SV16.

The digital status words are sent after positive-sequence current in the synchrophasor data packet starting with SV1 and continuing through SV16.

TREA1, TREA2, TREA3, TREA4, and PMTRIG

Defines the programmable trigger bits as allowed by IEEE C37.118.

Each of the four Trigger Reason settings, TREA1–TREA4, and the PMU Trigger setting, PMTRIG, are SELOGIC control equations in Logic settings. The SEL-351 evaluates these equations and places the results in Relay Word bits with the same names: TREA1–TREA4, and PMTRIG.

NOTE: The PM Trigger function is not associated with the SEL-351 Event Report Trigger ER, a SELOGIC control equation in Logic settings.

The trigger reason equations represent the Trigger Reason bits in the STAT field of the data packet, according to *Table N.6*. After the trigger reason bits are set to convey a message, the PMTRIG Equation should be asserted for a reasonable amount of time, to allow the synchrophasor processor to read the TREA1–TREA4 fields.

The IEEE C37.118 standard defines the first eight of 16 binary combinations of these trigger reason bits (bits 0–3). The remaining eight binary combinations are available for user definition.

The SEL-351 does not automatically set the TREA1–TREA4 or PMTRIG Relay Word bits—these bits must be programmed even for the eight combinations defined by IEEE C37.118.

These bits may be used to send various messages at a low bandwidth via the synchrophasor message stream. Digital Status Words may also be used to send binary information directly, without the need to manage the coding of the trigger reason messages in SELOGIC.

Use these Trigger Reason bits if your synchrophasor system design requires these bits. The SEL-351 synchrophasor processing and protocol transmission are not affected by the status of these bits.

Serial Port Settings for IEEE C37.118 Synchrophasors

IEEE C37.118 compliant synchrophasors are available via serial or Ethernet port. The associated serial port settings are shown in *Table N.4*.

Table N.4 SEL-351 Serial Port Settings for Synchrophasors

Setting	Description	Default
EPORT	Enable Port (Y, N)	Y[a]
MAXACC	Maximum Access Level (0, 1, B, 2, C)	2
PROTO	Protocol (SEL, LMD, DNP, MOD, MBA, MBB, MB8A, MB8B, PMU)[b]	SEL[c]
SPEED	Data Speed (300 to 57600)	9600
STOPBIT	Stop Bits (1, 2)	1
RTSCTS	Enable Hardware Handshaking (Y, N)	N
FASTOP	Fast Operate Enable (Y, N)[d]	N

[a] Set EPORT = Y to access the remaining settings.
[b] Some of the other PROTO setting choices may not be available.
[c] Set PROTO = PMU to enable C37.118 synchrophasor protocol on this port.
[d] See *Synchrophasor Protocols and SEL Fast Operate Commands* on page N.32.

The serial port settings for PROTO = PMU, shown in *Table N.4*, do not include the settings BITS and PARITY; these two settings are internally fixed as BITS = 8, PARITY = N.

Serial port setting PROTO cannot be set to PMU (see *Table N.4*) when Global setting EPMU = N. Synchrophasors must be enabled (EPMU = Y) before PROTO can be set to PMU. If the PROTO setting for any serial port is PMU, EMPU cannot be set to N.

If you use a computer terminal session or ACSELERATOR QuickSet SEL-5030 software connected to a serial port, and then set that same serial port PROTO setting to PMU, you will lose the ability to communicate with the relay through ASCII commands. If this happens, either connect via another serial port (that has PROTO = SEL) or use the front-panel HMI SET/SHOW screen to change the port PROTO setting back to SEL.

Ethernet Port Settings for IEEE C37.118 Synchrophasors

IEEE C37.118 compliant synchrophasors are available via serial or Ethernet port. The associated Ethernet port settings are shown in *Table N.5*.

Two PMU Ethernet Output sessions are available, except when IEC 61850 is enabled. When Port 5 setting E61850 = Y, only one PMU Ethernet output can be used.

Table N.5 SEL-351 Ethernet Port Settings for Synchrophasors (Sheet 1 of 2)

Setting	Description	Default
EPMIP[a]	Enable PMU Processing (Y,N)	N[b]
PMOTS1	PMU Output 1 Transport Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U)	OFF

Table N.5 SEL-351 Ethernet Port Settings for Synchrophasors (Sheet 2 of 2)

Setting	Description	Default
PMOIPA1	PMU Output 1 Client IP (Remote) Address (www.xxx.yyy.zzz)	192.168.1.3
PMOTCP1	PMU Output 1TCP/IP (Local) Port Number (1–65534)	4712
PMOUDP1	PMU Output 1 UDP/IP Data (Remote) Port Number (1–65534)	4713
PMOTS2[c]	PMU Output 2 Transport Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U)	OFF
PMOIPA2[c]	PMU Output 2 Client IP (Remote) Address (www.xxx.yyy.zzz)	192.168.1.4
PMOTCP2[c]	PMU Output 2 TCP/IP (Local) Port Number (1–65534)	4722
PMOUDP2[c]	PMU Output 2 UDP/IP Data (Remote) Port Number (1–65534)	4713

[a] Setting is hidden when EPMU = N or when EPMU = Y and MFRMT = FM.

[b] Set EPMIP = Y to access other settings and to enable IEEE C37.118 protocol synchrophasors on this port. Setting EPMIP is not available when Global setting EPMU is set to N. EPMU cannot be set to N if EPMIP = Y on any Ethernet port.

[c] PMU Output 2 settings are not available when IEC 61850 functions are enabled.

Descriptions of Ethernet Synchrophasor Settings

Definitions for some of the settings in *Table N.5* are as follows.

EPMIP

Setting this to Y enables synchrophasor data transmission over Ethernet port. Setting this to N disables the synchrophasor data transmission over Ethernet port.

Ethernet port setting EPMIP cannot be set to Y (see *Table N.5*) when Global setting EPMU = N or when EPMU = Y and MFRMT = FM. Synchrophasors must be enabled (EPMU = Y) before EPMIP can be set to Y. If EPMIP = Y for any Ethernet port, EPMU cannot be set to N.

PMOTS1 and PMOTS2

Selects the PMU Output transport scheme for Session 1 and 2, respectively.

➤ PMOTS*n* = TCP establishes a single, persistent TCP socket for transmitting and receiving synchrophasor messages (both commands and data), as illustrated in *Figure N.5*.

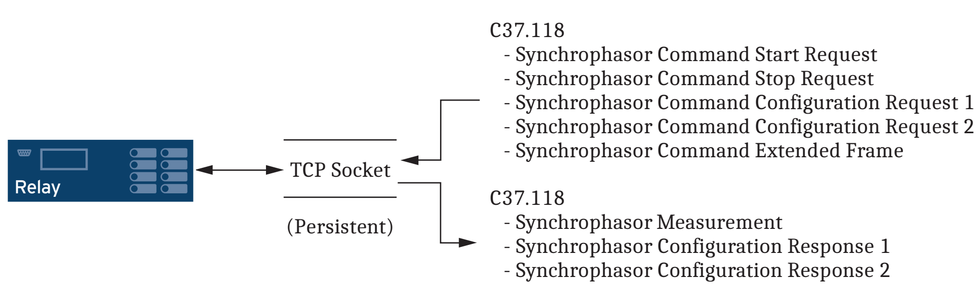

Figure N.5 TCP Connection

- PMOTS*n* = UDP_T establishes two socket connections. A nonpersistent TCP connection is used for receiving synchrophasor command messages as well as transmitting synchrophasor configuration messages. A persistent UDP socket is used to transmit synchrophasor data messages. *Figure N.6* depicts the UDP_T connection.
- PMOTS*n* = UDP_U uses the same connection scheme as the UDP_T except the synchrophasor configuration messages are sent over the UDP socket, as shown in *Figure N.6*.

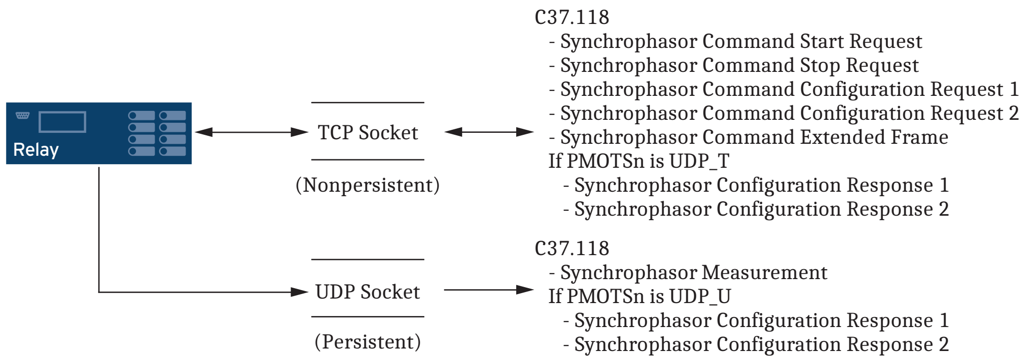

Figure N.6 UDP_T and UDP_U Connections

- PMOTS*n* = UDP_S establishes a single persistent UDP socket to transmit synchrophasor messages. Synchrophasor data are transmitted whenever new data are read. With this communication scheme, the relay sends a `Synchrophasor Configuration Response 2` once every minute, as shown in *Figure N.7*.

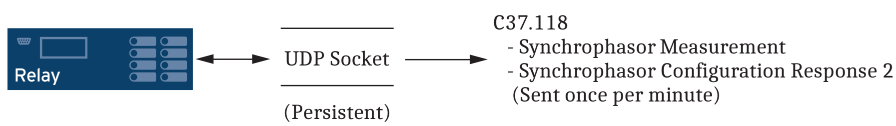

Figure N.7 UDP_S Connection

PMOIPA1 and PMOIPA2

Defines the PMU Output Client IP address for Session 1 and 2, respectively.

PMOTCP1 and PMOTCP2

Defines the TCP/IP (Local) port number for Session 1 and 2, respectively. These port numbers, as well as all servers running on the relay, must have unique local port numbers.

PMOUDP1 and PMOUDP2

Defines the UDP/IP (Remote) port number for Session 1 and 2, respectively.

C37.118 Synchrophasor Protocol

The SEL-351 complies with *IEEE C37.118, Standard for Synchrophasors for Power Systems*, when Global setting MFRMT = C37.118.

The protocol is available on serial ports 1, 2, 3, and F by setting the corresponding Port setting PROTO = PMU. The protocol is available on any Ethernet port when EPMIP = Y.

This subsection does not cover the details of the protocol, but highlights some of the important features and options that are available.

Settings Affect Message Contents

The SEL-351 allows several options for transmitting synchrophasor data. These are controlled by Global settings described in *Settings for IEEE C37.118 Protocol Synchrophasors* on page N.5. You can select how often to transmit the synchrophasor messages (MRATE), which synchrophasors to transmit (PHDATAV and PHDATAI), which numeric representation to use (PHNR), and which coordinate system to use (PHFMT).

The SEL-351 automatically includes the frequency and rate-of-change of frequency in the synchrophasor messages. Global setting FNR selects the numeric format to use for these two quantities.

The relay can include 16 digital status values, as controlled by Global setting NUMDSW.

The SEL-351 always includes the results of four synchrophasor trigger reason SELOGIC control equations TREA1, TREA2, TREA3, and TREA4, and the trigger SELOGIC control equation result PMTRIG, in the synchrophasor message. *Table N.6* shows the contents of the SEL-351 Data Frame.

Table N.6 C37.118 Data Frame (Sheet 1 of 2)

Field	Size (Bytes)	Description
SYNC	2	Bits 15 to 8—0xAA Bit 7—Reserved Always set to 0 Bits 6 to 4—Frame identifier 000 for data frames 001 for header frames 010 for configuration 1 frames 011 for configuration 2 frames 100 for command frames Bits 3 to 0—Version of synchrophasor spec, set to 001
FRAMESIZE	2	Number of bytes in frame, 16 bit unsigned integer
IDCODE	2	PMID setting, 16 bit unsigned integer
SOC	4	Time stamp, 32 bit unsigned second of century from January 1, 1970

Table N.6 C37.118 Data Frame (Sheet 2 of 2)

Field	Size (Bytes)	Description
FRACSEC	4	Bit 31—Reserved. Always set to 0 Bit 30—Leap second direction, 0 for add, 1 for delete Bit 29—Leap second occurred. Set on the falling edge of leap second pending bit (LPSECP) if TIRIG = 1. Once set, Bit 29 remains set for 24 hours. Bit 28—Leap second pending. Follows LPSECP Bits 27 to 24—Time quality flags. TQUAL1 through TQUAL4 Bits 23 to 0—Fractions of a second 16777215 • Message index for current second/MRATE
STAT	2	Bit 15—Data Valid. Always set to 0 Bit 14—PMU error flag. Follows !PMDOK Bit 13—PMU Sync flag. Follows !TSOK Bit 12—Data sorting flag. Always set to 0. Bit 11—PMU trigger detected flag. Follows PMTRIG Bit 10—Configuration changed flag Bits 9 to 6—Reserved. Always set to 0 Bits 5 and 4—Time error 00= best quality, synchronized. TSOK = 1 or TSOK = 0 for 10 seconds or less 01= TSOK = 0 for 10 seconds to not more than 100 seconds 10= TSOK = 0 for 100 seconds but less than 1000 seconds 11= TSOK = 0 for 1000 seconds or longer Bits 3 to 0—Trigger reason Bit 3 follows TREA4 Bit 2 follows TREA3 Bit 1 follows TREA2 Bit 0 follows TREA1
PHASORS	See *Table N.3* and *Table N.7*	Phasor data
FREQ	2 or 4	(Measured frequency-NFREQ) • 100 if FNR=INT, Measured Frequency if FNR=FLOAT
DFREQ	2 or 4	Rate-of-change of frequency • 100 if FNR=INT, Rate-of-change of frequency if FNR=FLOAT
ANALOG	0	No analog data are transmitted
DIGITAL	0 or 2	2 • NUMDSW
CHK	2	

Communications Bandwidth for C37.118 Protocol

A phasor measurement unit (PMU) that is configured to transmit a single synchrophasor (positive-sequence voltage, for example) at a message rate of once per second places little burden on the communications channel. As more synchrophasors or digital status words are added, or if the message rate is increased, some communications channel restrictions come into play.

If the SPEED setting on any serial port set with PROTO = PMU is insufficient for the PMU Global settings, the SEL-351 or QuickSet will display an error message and fail to save settings until the error is corrected.

NOTE: There are no limitations placed on the number of bytes in the synchrophasor message and the message rate if only the Ethernet port is enabled for synchrophasors.

The C37.118 synchrophasor message format always includes 18 bytes for the message header and terminal ID, time information, and status bits. The selection of synchrophasor data, numeric format, and programmable digital data will add to the byte requirements. *Table N.7* can be used to calculate the number of bytes in a synchrophasor message.

Table N.7 Size of a C37.118 Synchrophasor Message

Item	Possible Number of Quantities	Bytes per Quantity	Minimum Number of Bytes	Maximum Number of Bytes
Fixed			18	18
Synchrophasors	0, 1, 2, 3, 4, 5, 6, 8, or 10	4 {PHNR = I} 8 {PHNR = F}	0	80
Frequency	2 (fixed)	2 {FNR = I} 4 {FNR = F}	4	8
Digital Status Words	0–1	2	0	2
Total (Minimum and Maximum)			22	108

Table N.8 lists the baud settings available on any SEL-351 serial port (setting SPEED), and the maximum message size that can fit within the port bandwidth. Blank entries indicate bandwidths of less than 20 bytes.

Table N.8 Serial Port Bandwidth for Synchrophasors (in Bytes)

Global Setting MRATE	Port Setting SPEED							
	300	1200	2400	4800	9600	19200	38400	57600
1	25	103	207	414	829	1658	3316	4974
2		51	103	207	414	829	1658	2487
4 (60 Hz only)		25	51	103	207	414	829	1243
5		20	41	82	165	331	663	994
10			20	41	82	165	331	497
12 (60 Hz only)				34	69	138	276	414
15 (60 Hz only)				27	55	110	221	331
20 (60 Hz only)				20	41	82	165	248
25 (50 Hz only)					33	66	132	198
30 (60 Hz only)					27	55	110	165
50 (50 Hz only)						33	66	99
60 (60 Hz only)						27	55	82

Referring to *Table N.7* and *Table N.8*, it is clear that the lower SPEED settings are very restrictive.

The smallest practical synchrophasor message would be comprised of one synchrophasor, and this message would consume between 26 and 34 bytes, depending on the numeric format settings. This type of message could be sent at any message rate (MRATE) when SPEED = 38400 or 57600, as fast as MRATE = 50 or 30 when SPEED = 19200, and as fast as MRATE = 25 or 20 when SPEED = 9600.

Another example application has messages comprised of ten synchrophasors and one digital status word. This type of message would consume between 64 and 108 bytes, depending on the numeric format settings. The 64-byte version, using integer numeric representation, could be sent at any message rate (MRATE) when SPEED = 57600. The 108-byte version, using floating-point numeric representation, could be sent as fast as MRATE = 25 or 30 when SPEED = 57600, to MRATE = 20 or 25 when SPEED = 38400, and to MRATE = 10 or 12 when SPEED = 19200.

Protocol Operation

The SEL-351 will only transmit synchrophasor messages over serial ports that have setting PROTO = PMU. The connected device will typically be a synchrophasor processor, such as the SEL-3378 Synchrophasor Vector Processor. The synchrophasor processor controls the PMU functions of the SEL-351, with IEEE C37.118 commands, including commands to start and stop synchrophasor data transmission, and commands to request a configuration block from the relay, so the synchrophasor processor can automatically build a database structure.

Transmit Mode Control

The SEL-351 will not begin transmitting synchrophasors until an enable message is received from the synchrophasor processor. The relay will stop synchrophasor transmission when the appropriate command is received from the synchrophasor processor. The SEL-351 can also indicate when a configuration change occurs, so the synchrophasor processor can request a new configuration block and keep its database up-to-date.

The SEL-351 will only respond to configuration block request messages when it is in the non-transmitting mode.

Independent Ports

Each serial port with the PROTO = PMU setting is independently configured and enabled for synchrophasor commands. The ports are not required to have the same SPEED setting, although the slowest SPEED setting on a PROTO = PMU port will affect the maximum Global MRATE setting that can be used.

Synchrophasor Relay Word Bits

Table N.9 and *Table N.10* list the SEL-351 Relay Word bits that are related to synchrophasor measurement.

The Synchrophasor Trigger Relay Word bits in *Table N.9* follow the state of the SELOGIC control equations of the same name, listed in *Table N.2*. These Relay Word bits are included in the IEEE C37.118 synchrophasor data frame STAT field. See *Table N.3* for standard definitions for these settings.

Table N.9 Synchrophasor Trigger Relay Word Bits (Sheet 1 of 2)

Name	Description
PMTRIG	Trigger (SELOGIC Control Equation)
TREA4	Trigger Reason Bit 4 (SELOGIC Control Equation)
TREA3	Trigger Reason Bit 3 (SELOGIC Control Equation)

Table N.9 Synchrophasor Trigger Relay Word Bits (Sheet 2 of 2)

Name	Description
TREA2	Trigger Reason Bit 2 (SELOGIC Control Equation)
TREA1	Trigger Reason Bit 1 (SELOGIC Control Equation)

The Time-Synchronization Relay Word bits in *Table N.10* indicate the present status of the high-accuracy timekeeping function of the SEL-351. See *Configuring High-Accuracy Timekeeping* on page N.28.

Table N.10 Time-Synchronization Relay Word Bits

Name	Description
TIRIG	Asserts while relay time is based on IRIG-B time source.
TSOK	Time synchronization OK. Asserts while time is based on high-accuracy IRIG-B time source of sufficient accuracy for synchrophasor measurement.
PMDOK	Phasor measurement data OK. Asserts when the SEL-351 is enabled, synchrophasors are enabled (Global Setting EPMU = Y), Relay Word bit TSOK = 1, the frequency is 40–65 Hz, and the positive-sequence voltage[a] V1 > 10 V secondary. A few seconds may be necessary for PMDOK to assert when the relay is first powered, after any of the settings in *Table N.1* are changed, or when an IRIG-B time signal is first connected.

[a] When Global setting PTCONN = SINGLE, the single-phase voltage connected to terminals VA-N must be greater than 10 V secondary.

View Synchrophasors by Using the MET PM Command

The **MET PM** serial port ASCII command may be used to view the SEL-351 synchrophasor measurements. See ***MET** (Metering Data)* on page 10.55 for general information on the **MET** command.

There are multiple ways to use the **MET PM** command:

- As a test tool, to verify connections, phase rotation, and scaling
- As an analytical tool, to capture synchrophasor data at an exact time, in order to compare this information with similar data captured in other phasor measurement unit(s) at the same time.
- As a method of periodically gathering synchrophasor data through a communications processor.

The **MET PM** command displays the same set of analog synchrophasor information, regardless of the Global settings MFRMT, PHDATAV and PHDATAI. The **MET PM** command can function even when no ports are sending synchrophasor data.

The **MET PM** command only displays data when the Relay Word bit TSOK = logical 1. *Figure N.8* shows a sample **MET PM** command response. The synchrophasor data are also available in the QuickSet HMI and have a similar format to *Figure N.8*.

The **MET PM *time*** command can be used to direct the **SEL-351** to display the synchrophasor for an exact specified time, in 24-hour format. For example, entering the command **MET PM 14:14:12** will result in a response similar to *Figure N.8* occurring just after 14:14:12, with the time stamp 14:14:12.000.

This method of data capture always reports from the exact second, even if the time parameter is entered with fractional seconds. For example, entering **MET PM 14:14:12.200** results in the same data capture as **MET PM 14:14:12**, because the relay ignored the fractional seconds.

See ***MET PM****—Synchrophasor Metering* on page 10.62 for complete command options, and error messages.

When PTCONN = WYE, voltages V1, VA, VB, VC, and VS are displayed, as shown in *Figure N.8*. When PTCONN = DELTA, voltages V1, VAB, VBC, VCA, and VS are displayed. When PTCONN = SINGLE, VS and the voltage connected between terminals VA and N are displayed.

NOTE: The values reported by the **MET PM HIS** command are only valid if settings are not changed after the trigger.

MET PM HIS recalls the most recently triggered synchrophasor meter report. This is useful when synchrophasor data from multiple relays must be captured on a single PC. For example, connect to each relay and issue the **MET PM 14:14:00** command. At 14:14, each relay will issue a response similar to *Figure N.8*. After 14:14, connect to each relay, issue the **MET PM HIS** command, and capture the results. Because **MET PM HIS** recalls the last MET PM report, the data captured from every relay will be from the same time. Values displayed reflect present relay settings, not settings in effect at the time of the original **MET PM** command.

```
=>MET PM <Enter>

FEEDER 1                          Date: 12/01/08    Time: 10:33:59.000
STATION A

                                                                 PMDOK = 1
Time Quality   Maximum time synchronization error:     0.000 (ms)  TSOK = 1

Synchrophasors
                   Phase Voltages          Synch Voltage    Pos.-Seq. Voltage
               VA        VB        VC          VS                V1
MAG (kV)       12.045    12.037    12.038       12.042            12.040
ANG (DEG)     139.563    19.756  -100.109      140.066           139.737

                   Phase Currents         Neutral Current   Pos.-Seq. Current
               IA        IB        IC          IN                I1
MAG (A)       120.865   121.026   120.477       0.625           106.448
ANG (DEG)     140.109    20.452  -159.931      139.213           121.169

FREQ (Hz) 59.991
Rate-of-change of FREQ (Hz/s)    0.00

Digitals

SV1    SV2    SV3    SV4    SV5    SV6    SV7    SV8
 0      0      0      0      0      0      0      0
SV9    SV10   SV11   SV12   SV13   SV14   SV15   SV16
 0      0      0      0      0      0      0      0

=>
```

Figure N.8 Sample MET PM Command Response When PTCONN = WYE

IEEE C37.118 PMU Setting Example

A utility is upgrading its distribution system to use the SEL-351 for feeder protection. The utility also wants to install phasor measurement units (PMUs) in each substation to collect data to monitor voltages and currents throughout the system.

The PMU data collection requirements call for the following data, collected at 10 messages per second:

- ➤ Frequency
- ➤ Positive-sequence voltage from the bus in each substation
- ➤ Three-phase, positive-sequence, and neutral current for each line
- ➤ Indication when the breaker is open
- ➤ Indication when the voltage or frequency information is unusable

The utility is able to meet the requirements with the SEL-351 for each line, an SEL-2407 Satellite-Synchronized Clock, and an SEL-3306 Synchrophasor Processor in each substation.

This example will cover the PMU settings in one of the SEL-351 Relays.

Some system details:

- ➤ The nominal frequency is 60 Hz.
- ➤ The bus PTs and wiring have a phase error of 4.20 degrees (lagging) at 60 Hz.
- ➤ The breaker CTs and wiring have a phase error of 3.50 degrees (lagging) at 60 Hz.
- ➤ The neutral CTs and wiring have a phase error of 5.50 degrees (lagging) at 60 Hz.
- ➤ The synchrophasor data will be using Port 3, and the maximum baud allowed is 19200.
- ➤ The system designer specified floating-point numeric representation for the synchrophasor data, and rectangular coordinates.
- ➤ The system designer specified integer numeric representation for the frequency data.
- ➤ The system designer specified fast synchrophasor response, because the data are being used for system monitoring.

The protection settings will not be shown.

Determining Settings

The protection engineer performs a bandwidth check, using *Table N.7*, and determines the required message size. The system requirements, in order of appearance in *Table N.7*, are:

- ➤ Six synchrophasors, in floating-point representation
- ➤ Integer representation for the frequency data
- ➤ Three digital status bits, which require one status word

The message size is 18 + 6 • 8 + 2 • 2 + 1 • 2 = 72 bytes. Using *Table N.8*, the engineer verifies that the port baud of 19200 is adequate for the message, at 10 messages per second.

The Protection SELOGIC Variables SV14, SV15, and SV16 will be used to transmit the breaker status, loss-of-potential alarm, and frequency measurement status, respectively.

Make the Global settings as shown in *Table N.11*.

Table N.11 Example Synchrophasor Global Settings

Setting	Description	Value
NFREQ	Nominal System Frequency (50, 60 Hz)	60
EPMU	Enable Synchronized Phasor Measurement (Y, N)	Y
MFRMT	Message Format (C37.118, FM)	C37.118
MRATE	Messages per Second (1, 2, 4, 5, 10, 12, 15, 20, 30, 60)	10
PMAPP	PMU Application (F = Fast Response, N = Narrow Bandwidth)	F
PHCOMP	Frequency-Based Phasor Compensation (Y, N)	Y
PMSTN	Station Name (16 characters, mixed case)	SAMPLE1
PMID	PMU Hardware ID (1–65534)	14
PHDATAV	Phasor Data Set, Voltages (V1, PH, ALL, NA)	V1
VCOMP	Phase Voltage Angle Compensation Factor (–179.99 to 180 degrees)	4.20
VSCOMP	VS Voltage Angle Compensation Factor (–179.99 to 180.00 degrees)	0.00
PHDATAI	Phasor Data Set, Currents (I1, PH, ALL, NA)	ALL
IPCOMP	Phase Current Angle Compensation Factor (–179.99 to 180 degrees)	3.50
INCOMP	Neutral Current Angle Compensation Factor (–179.99 to 180 degrees)	5.50
PHNR	Phasor Numeric Representation (I = Integer, F = Floating point)	F
PHFMT	Phasor Format (R = Rectangular coordinates, P = Polar coordinates)	R
FNR	Frequency Numeric Representation (I = Integer, F = Float)	I
NUMDSW	Number of 16-bit Digital Status Words (0 or 1)	1

Table N.12 Example Synchrophasor Logic Settings

Logic Setting	Description	Value
TREA1	Trigger Reason Bit 1 (SELOGIC Control Equation)	NA
TREA2	Trigger Reason Bit 2 (SELOGIC Control Equation)	NA
TREA3	Trigger Reason Bit 3 (SELOGIC Control Equation)	NA
TREA4	Trigger Reason Bit 4 (SELOGIC Control Equation)	NA
PMTRIG	Trigger (SELOGIC Control Equation)	NA

The three Relay Word bits required in this example must be placed in certain SELOGIC variables. Make the settings in *Table N.13* in all six setting groups.

Table N.13 Example Synchrophasor SELOGIC Settings

Setting	Value
SV14	52A
SV15	LOP
SV16	FREQOK

Make the *Table N.14* settings for serial port 3, using the **SET P 3** command.

Table N.14 Example Synchrophasor Port Settings

Setting	Description	Value
EPORT	Enable Port (Y, N)	Y
MAXACC	Maximum Access Level (0, 1, B, 2, C)	1
PROTO	Protocol (SEL, DNP, MBA, MBB, RTD, PMU)	PMU
SPEED	Data Speed (300 to 57600)	19200
STOPBIT	Stop Bits (1, 2 bits)	1
RTSCTS	Enable Hardware Handshaking (Y, N)	N
FASTOP	Fast Operate Enable (Y, N)	N

SEL Fast Message Synchrophasor Protocol

SEL Fast Message Unsolicited Write (synchrophasor) messages are general Fast Messages (A546h) that transport measured synchrophasor information. Fast Message synchrophasors are available through the serial ports, but not through the Ethernet ports. Use Global settings PHDATAV and PHDATAI to select the voltage and current data to include in the Fast Message. *Table N.21* lists analog quantities included in the Fast Message for various Global settings (frequency is included in all messages). Not all messages are supported at all data speeds. If the selected data rate is not sufficient for the given message length, the relay responds with an error message.

Table N.15 lists the Synchrophasor Fast Message Write function codes and the actions the relay takes in response to each command.

Table N.15 Fast Message Command Function Codes for Synchrophasor Fast Write

Function Code (Hex)	Function	Relay Action
01h	Enable unsolicited transfer	Relay transmits Fast Message command acknowledged message (Function Code 81). Relay transmits Synchrophasor Measured Quantities (function to enable: Unsolicited Write broadcast, Function Code 20)
02h	Disable unsolicited transfer	Relay sends Fast Message command acknowledge message (Function Code 82) and discontinues transferring unsolicited synchrophasor messages (function to disable: Unsolicited Write broadcast, Function Code 20)

Fast Message Synchrophasor Implementation

One of the differences between the C37.118 and SEL Fast Message formats relates to data transmission speed. When the C37.118 format is used, Global Setting MRATE determines the message rate—the synchrophasor processor cannot request a data rate via the enable message.

In the SEL Fast Message format, the synchrophasor processor must request a particular data message period, which is embedded in the enable message. If the requested message period can be supported, the SEL-351 will acknowledge the request (if an acknowledge was requested) and begin transmitting synchrophasors. If the requested message period is not permitted, the SEL-351 will respond with a bad data message (if an acknowledge was requested), and will not transmit any synchrophasor data.

Transmit Mode Control

The relay stops synchrophasor transmission on a particular serial port when the disable command is received from the connected device, or when the relay settings are changed. The SEL-351 responds to configuration block request messages regardless of the present transmit status, waiting only as long as it takes for any partially sent messages to be completely transmitted.

Table N.16–Table N.18 list the Synchrophasor Fast Message protocol formats, including the specific construction of the enable and disable messages. SEL Application Guide *AG2002-08, Using SEL-421 Relay Synchrophasors in Basic Applications* provides additional information on the SEL Fast Message Synchrophasor protocol and example applications. This application guide refers to the SEL-421 Relay and differs slightly from the SEL-351 implementation.

Table N.16 SEL Fast Message Protocol Format

Field	Description	Hex Data
Header	Synchrophasor Fast Message	A546
Frame Size	Synchrophasor Data Size[a]	XX
Routing	Must be 0000000000 for this application	0000000000
Status Byte	Must be 00 for this application	00
Function Code	20h Code for unsolicited write messages	20
Sequence	C0 for single frame messages. Maximum frame size 255 bytes	C0
Response Number	Response Number (always 00)	00
PM Data Address	Address of Synchrophasor Measurement Data (PMID setting)	00000000
Register Count	Data size in registers (1 Register = 2 Bytes)	XXXX
Sample Number	0-based index into SOC of this packet	0000
SOC	Second of century[b]	XXXXXXXX
Frequency	IEEE 32-bit floating point[c]	XXXXXXXX
Phasor Mag.	Synchrophasor Data Magnitude (IEEE 32-bit floating point)[d]	XXXXXXXX
Phasor Angle	Synchrophasor Data Angle ±180° (IEEE 32-bit floating point)[d]	XXXXXXXX
Digital Data	TSOK, Time Synchronization OK. PMDOK, Phasor Measurement Data OK. SV3–SV16 bits	XXXX
Check Word	2-byte CRC-16 check code for message	XXXX

[a] The synchrophasor data size is dependent on the PHDATAV and PHDATAI settings as shown in *Table N.21*.
[b] Provided as an offset referenced to 1900 A.D.
[c] From ANSI/IEEE Std. 754-1985, The IEEE Standard for Binary Floating-Point Arithmetic.
[d] The number and transmit order of Magnitude and Angle data values are determined by the PHDATAV and PHDATAI setting as shown in *Table N.21*.

Table N.17 Unsolicited Fast Message Enable Packet (Sheet 1 of 2)

Field	Description	Hex Data
Header	Synchrophasor Fast Message	A546
Frame Size	18 bytes	12
Routing	Must be 0000000000 for this application	0000000000
Status Byte	YY = 00 acknowledge is not requested YY = 01 acknowledge is requested	YY
Function Code	01h Enable unsolicited write messages	01

Table N.17 Unsolicited Fast Message Enable Packet (Sheet 2 of 2)

Field	Description	Hex Data
Sequence	C0 for single frame message. Maximum frame size 255 bytes	C0
Response Number	XX = 00, 01, 02, 03	XX
Application (first byte)	20h Synchrophasor	20
Application (second byte)	Must be 00 for this application	00
Message Period	Data message period	nnnn[a]
Check Word	2-byte CRC-16 check code for message	XXXX

[a] See *Table N.19* for permissible data message period values.

Table N.18 Unsolicited Fast Message Disable Packet

Field	Description	Hex Data
Header	Synchrophasor Fast Message	A546
Frame Size	16 bytes	10
Routing	Must be 0000000000 for this application	0000000000
Status Byte	YY = 00 acknowledge is not requested YY = 01 acknowledge is requested	YY
Function Code	02h Disable unsolicited write messages	02
Sequence	C0 for single frame message. Maximum frame size 255 bytes	C0
Response Number	XX = 00, 01, 02, 03	XX
Application (first byte)	20h Synchrophasor	20
Application (second byte)	Must be 00 for this application	00
Check Word	2-byte CRC-16 check code for message	XXXX

In the SEL Fast Message format, the synchrophasor processor must request a particular data message period, which is embedded in the enable message. If the requested message period can be supported, the SEL-351 will acknowledge the request (if an acknowledgment was requested) and begin transmitting synchrophasors. If the requested message period is not permitted, the SEL-351 will respond with a bad data message (if an acknowledge was requested), and will not transmit any synchrophasor data. *Table N.19* lists the permissible data message periods that can be requested by the enable message. Note that each Fast Message is transmitted at a fixed time after the beginning of each minute.

The SEL-351 will only transmit synchrophasor messages over serial ports that have setting PROTO = SEL. The connected device will typically be a synchrophasor processor or a communications processor, such as the SEL-2032. The connected device controls the PMU functions of the SEL-351 with SEL Fast Message commands, including commands to start and stop synchrophasor data transmission.

Table N.19 Permissible Message Periods Requested by Enable Message

Message Period (Hex)	Fast Messages Sent This Number of Seconds After the Top of Each Minute	Number of Fast Messages per Minute
0064h	0,1,2,3,4,5,...,59	60
00C8h	0,2,4,6,8,10,...58	30
012Ch	0,3,6,9,12,15,...57	20
0190h	0,4,8,12,15,...56	15
01F4h	0,5,10,15,20,...55	12
0258h	0,6,12,18,24,...54	10
03E8h	0,10,20,30,40,50	6
05DCh	0,15,30,45	4
07D0h	0,20,40	3
0BB8h	0,30	2
1770h	0	1

The SEL Fast Message Synchrophasor protocol is able to share the same physical port with separate data streams (see *Overview* on page J.1).

SEL-351 Fast Message Synchrophasor Settings

The settings for SEL Fast Message synchrophasors are listed in *Table N.20*. Many of these settings are identical to the settings for the C37.118 format.

Table N.20 PMU Settings in the SEL-351 for SEL Fast Message Protocol (Global Settings)

Setting	Description	Default
EPMU	Enable Synchronized Phasor Measurement (Y, N)	N[a]
MFRMT	Message Format (C37.118, FM)[b]	C37.118
PMID	PMU Hardware ID (0–4294967295)	1
PHDATAV	Phasor Data Set, Voltages (V1, ALL)	V1
VCOMP	Voltage Angle Compensation Factor (–179.99 to 180 degrees)	0.00
PHDATAI[c]	Phasor Data Set, Currents (ALL, NA)	NA
ICOMP	Current Angle Compensation Factor (–179.99 to 180 degrees)	0.00

[a] Set EPMU = Y to access the remaining settings.
[b] C37.118 = IEEE C37.118 Standard—see *Table N.1*; FM = SEL Fast Message. Set MFRMT = FM to enter the Fast Message settings. MFRMT cannot be set to FM when PTCONN = DELTA or SINGLE.
[c] When PHDATAV = V1, this setting is forced to NA and cannot be changed.

Descriptions of Fast Message Synchrophasor Settings

Definitions of the settings in *Table N.20* follow.

EPMU

This setting enables synchrophasor operation.

MFRMT

Selects the message format for synchrophasor data streaming on serial ports. SEL recommends the used of MFRMT = C37.118 for any new PMU applications because of increasing setting flexibility and the expected availability of software for synchrophasor processors. The SEL-351 still includes the MFRMT = FM setting choice to maintain compatibility in any system presently using SEL Fast Message synchrophasors.

PMID

This setting defines the four-byte destination address used in the SEL Fast Message Unsolicited Write message.

The PMID setting is a 32-bit numeric value.

When connected to an SEL-2032 or an SEL-2030 Communications Processor, the PMID specifies the memory location for data storage. In this case the uppermost byte indicates the communications processor port and the lower two bytes specify the user region address for that port. See the *SEL-2032 Communications Processor Instruction Manual* for more details.

PHDATAV and VCOMP

PHDATAV selects which voltage synchrophasors to include in the Fast Message data packet. Consider the synchrophasor processor burden and offline storage requirements when deciding how much data to transmit. PHDATAV and PHDATAI determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Table N.21*.

- ➤ PHDATAV = V1 will transmit only positive-sequence voltage, V1
- ➤ PHDATAV = ALL will transmit V1, VA, VB, and VC

Note that VS is *not* included when PHDATAV = ALL and MFRMT = FM.

Table N.21 describes the order of synchrophasors inside the data packet.

The VCOMP setting allows correction for any steady-state voltage phase errors (from the potential transformer or wiring characteristics).

PHDATAI and ICOMP

PHDATAI selects which current synchrophasors to include in the data packet. Consider the synchrophasor processor burden and offline storage requirements when deciding how much data to transmit. PHDATAV and PHDATAI determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Table N.21*.

- ➤ PHDATAI = ALL will transmit I1, IA, IB, and IC
- ➤ PHDATAI = NA will not transmit any currents

Note that IN is *not* included when PHDATAI = ALL and MFRMT = FM.

Table N.21 describes the order of synchrophasors inside the data packet.

The ICOMP setting allows correction for any steady-state phase errors (from the current transformers or wiring characteristics).

Other Settings Not Present

The SEL Fast Message format does not require the following settings: MRATE, PMAPP, PHCOMP, PMSTN, VPCOMP, VSCOMP, IPCOMP, INCOMP, PHNR, PHFMT, FNR, NUMDSW, TREA1–TREA4, and PMTRIG.

The SEL Fast Message synchrophasor protocol always calculates synchrophasors once per second, uses a Narrow Bandwidth filter (equivalent to PMAPP = N) and no frequency-based compensation (equivalent to PHCOMP = N). The SEL Fast Message synchrophasor protocol always includes the frequency information in floating-point representation, and 14 user-programmable SELOGIC variables SV3 through SV16.

Communications Bandwidth for Fast Message Protocol

A phasor measurement unit (PMU) that is configured to transmit a single synchrophasor quantity (positive-sequence voltage, for example) at a message period of one second places little burden on the communications channel. As more synchrophasors or interleaved protocols are added, some communications channel restrictions come into play.

The SPEED setting on any serial port set with PROTO = SEL should be set as high as possible to allow for the largest possible number of message period requests to be successful.

The SEL-351 Fast Message synchrophasor format always includes 32 bytes for the message header and terminal ID, time information, frequency, and status bits. The selection of synchrophasor data will add to the byte requirements. Each synchrophasor quantity will add eight bytes to the message length. *Table N.21* shows the effect that adding synchrophasor quantities has on the minimum allowed SPEED setting.

The number of interleaved protocols sharing the same physical port will also impact the minimum allowed SPEED setting. *Table N.21* shows the setting if the Fast Message Synchrophasor format is the only data stream transmitted; additional data streams will necessitate a higher SPEED setting.

Table N.21 SEL Fast Message Voltage and Current Selections Based on PHDATAV and PHDATAI

Global Settings	Number of Synchrophasor Magnitude and Angle Pairs Transmitted	Synchrophasor Magnitude and Angle Pairs to Transmit, and the Transmit Order	Synchrophasor Data Size (Bytes)	Minimum Baud Rate (SPEED Setting) at One Second Message Period
PHDATAV = V1 PHDATAI = NA	1	V1	40	1200 Baud
PHDATAV = ALL PHDATAI = NA	4	VA, VB, VC, V1	64	2400 Baud
PHDATAV = ALL PHDATAI = ALL	8	VA, VB, VC, V1, IA, IB, IC, I1	96	4800 Baud

Independent Ports

Each serial port with the PROTO = SEL setting is independently configured and enabled for synchrophasor commands. For example, if there are two serial ports set to PROTO = SEL, the status of one port has no effect on the other port. One port might be commanded to start transmitting synchrophasor messages, while the other port is idle, responding to a configuration block or Fast Operate request, or transmitting synchrophasors. The ports are not required to have the same

SPEED setting, although the SPEED setting on each PROTO = SEL port will affect the minimum synchrophasor message data period that can be used on that port.

Configuring High-Accuracy Timekeeping

The SEL-351 features high-accuracy timekeeping when supplied with an IRIG-B signal. When the supplied clock signal is sufficiently accurate, the SEL-351 can act as a Phasor Measurement Unit (PMU) and transmit synchrophasor data representative of the power system at fixed time periods to an external data processor. The relay can also record event report data using the high-accuracy time stamp (see *Synchrophasor-Level Accuracy in Event Reports* on page 12.16).

IRIG Standard 200-04 defines many different types of time-code formats. IRIG-B002, or standard IRIG-B provides time data once per second. The time data are formatted as second of the minute, minute of the hour, hour of the day, and day of the year. IRIG-B000, or extended IRIG-B, adds control functions which are defined based on the application. In this manual, IRIG-B000 is used to identify a time signal containing the control functions defined by IEEE C37.118 Standard for Synchrophasors for Power Systems. These control functions include the year, leap second, daylight-saving time information, UTC offset, time quality indicator codes, and a parity bit.

IRIG-B

In a standard shipment, the SEL-351 has two input connectors that accept IRIG-B demodulated time-code format: the IRIG-B pins of Serial Port 2, and the IRIG-B BNC connector. The optional SEL-2812 compatible fiber port can also provide an IRIG-B signal if connected to a fiber-optic transceiver that transmits IRIG-B or the fiber-optic port of an SEL-2407 clock.

The BNC connector and Port 2 connections can be used for high-accuracy time-keeping purposes, with as great as 1 µs accuracy with an appropriate time source. Any of the three inputs can be used for general-purpose timekeeping, and the relay will have as great as 5 ms accuracy. The SEL-2812 compatible fiber-optic port is not suitable for high-accuracy timekeeping. See *Table N.22* for SEL-351 timekeeping mode details.

Table N.22 SEL-351 Timekeeping Modes

Item	Internal Clock	Normal Accuracy IRIG	Holdover	High-Accuracy IRIG
Best accuracy (condition)	Depends on last method of setting, plus internal clock drift[a]	5 ms (when IRIG-B signal not meeting requirements for high-accuracy IRIG is connected)		1 µs (when time source jitter is less than 500 ns, and time error is less than 1 µs)[b]
IRIG-B Connection Required	None	BNC connector (preferred), Serial Port 2, or fiber-optic Serial Port 1		BNC connector (preferred) or Serial Port 2
Relay Word bits	TIRIG = logical 0 TSOK = logical 0	TIRIG = logical 1 TSOK = logical 0	TIRIG = logical 0 TSOK = logical 1	TIRIG = logical 1 TSOK = logical 1

[a] The SEL-351 internal clock can be synchronized via SNTP, DNP3, SEL-2030 Communications Processor, or ASCII TIM command.
[b] The time-error check only applies when Global setting IRIGC = C37.118.

NOTE: If the time-code signal connected to a higher-priority source degrades in quality, the SEL-351 will not switch-over to a lower-priority source. The SEL-351 only switches to Serial Port 2 or fiber-optic serial Port 1 if the signal on the higher-priority source completely fails (e.g., the cable is un-plugged). Use the **TIME Q** command to determine which IRIG-B source is in use.

Only one IRIG-B time source can be used by the SEL-351. The relay uses IRIG-B signals from the three sources with the following priority:

- BNC input
- Serial Port 2 IRIG-B pins
- SEL-2812 compatible fiber-optic Port 1 (if present)

The SEL-351 determines the suitability of the IRIG-B signal for normal accuracy by applying several tests:

- Seconds, minutes, and day field is in range
- Time from two consecutive messages differs by one second, except for leap second or daylight-saving time transitions
- When IRIGC = C37.118, the signal contains the correct parity bit

The SEL-351 determines the suitability of the IRIG-B signal for high-accuracy timekeeping by applying two additional tests:

- The jitter between positive-transitions (rising edges) of the clock signal is less than 500 ns.
- The time error information contained in the IRIG-B control field indicates time error is less than 10^{-6} seconds (1 µs).

When IRIGC = C37.118 and an appropriate IRIG-B signal is connected, Relay Word bit TSOK only asserts when these two tests are met. When IRIGC = NONE, the relay asserts TSOK when only the first test is met.

The relay accepts C37.118 (IRIG-B000) signals with either odd or even parity. When an IRIG-B signal is connected, the relay detects whether the signal has odd or even parity and continues to check received IRIG-B messages for that parity. If a message is received with the opposite parity or no parity, the signal fails the parity test.

If your clock has programmable parity and the parity is changed, the relay disqualifies the IRIG-B signal for a few seconds until it detects that the parity change is not because of corrupt messages.

If the relay is in High Accuracy mode and either of the two tests fails, the relay enters Holdover mode. When in Holdover, the relay asserts TSOK, deasserts TIRIG, and holds Relay Word bits TQUAL1, TQUAL2, TQUAL3, and TQUAL 4 at their last state. The relay remains in Holdover mode for as long as 15 seconds, and reverts to High-Accuracy IRIG, Normal Accuracy IRIG, or internal clock, depending on conditions.

If you connect two IRIG-B sources, they should be of the same format (IRIG-B000 with C37.118 control extensions or IRIG-B002) and match the IRIGC setting. SEL does not recommend connecting different types of signals to different inputs (for example, an IRIG-B000 signal to the BNC input and an IRIG-B002 signal to Port 1 or Port 2) when IRIGC = C37.118. The IRIG-B002 signal provides neither the year nor the parity bit required for Normal Accuracy mode when IRIGC = C37.118. In this case, if the IRIG-B000 source fails, relay timekeeping reverts to the internal clock, but the relay year changes to 2000 and remains incorrect until the IRIG-B000 signal returns. The relay will update the time from the IRIG-B002 signal about once every 10 seconds, if the signal passes the remaining two tests for Normal Accuracy mode. Relay Word bit TIRIG asserts momentarily during the update.

NOTE: Set IRIGC=C37.118 only when an IRIG-B000 signal is connected to the relay. Set IRIGC=NONE when an IRIGB-B002 (standard IRIG) signal is connected.

Table N.23 Time and Date Management

Label	Prompt	Default Value
IRIGC[a]	IRIG-B Control Bits Definition (None, C37.118)	None

[a] When MFRMT = C37.118, IRIGC is forced to C37.118.

A time quality value is determined based on the four-bit Time Quality indicator code defined in the IEEE C37.118 standard. When Global setting IRIGC = C37.118, the raw time quality information from the IRIG-B signal is placed into four Relay Word bits TQUAL1, TQUAL2, TQUAL3, and TQUAL4. For example, if TQAUL1 = 1, TQUAL2 = 0, TQUAL3 = 1, and TQUAL4 = 0, the binary time quality indicator code received from the clock via the IRIG signal is 0101, which corresponds to 10 microseconds time error. See *Table N.24* for time quality decoding. The time quality is shown in the MET PM report beside the label `Time Quality   Maximum time synchronization error:` viewed with the **MET PM** command and in the **TIME Q** command.

Table N.24 Time Quality Decoding

TQUAL	Time Quality	TQUAL	Time Quality
0000	Locked	1000	10 milliseconds
0001	1 nanosecond	1001	100 milliseconds
0010	10 nanoseconds	1010	1 second
0011	100 nanoseconds	1011	10 seconds
0100	1 microsecond	1100	100 seconds
0101	10 microseconds	1101	1000 seconds
0110	100 microseconds	1110	10,000 seconds
0111	1 millisecond	1111	Fault

When IRIGC = C37.118, the relay also decodes Leap Second Pending, Leap Second Direction, Daylight Savings Pending, and Daylight Savings control bits that are present in the IRIG-B signal. The status of these control bits is reflected in Relay Word bits LPSECP, LPSEC, DSTP, and DST, respectively. The relay accepts C37.118 (IRIG-B000) signals with either even or odd parity.

When IRIGC = NONE, the TQUAL1, TQUAL2, TQUAL3, TQUAL4, LPSECP, LPSEC, DSTP, and DST Relay Word bits are not updated. When Global setting MFRMT = C37.118, IRIGC is forced to C37.118.

Connecting High-Accuracy Timekeeping

The procedure in the following steps assumes that you have a modern high-accuracy GPS receiver with a BNC connector output for an IRIG-B signal. Use a communications terminal to send commands and receive data from the relay.

This example assumes that you have successfully established communication with the relay. In addition, you must be familiar with relay access levels and passwords.

Step 1. Confirm that the relay is operating.

Step 2. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 3. Connect the cable.

Attach the IRIG-B signal with a BNC-to-BNC coaxial jumper cable from the GPS receiver IRIG-B output to the SEL-351 IRIG-B BNC connector.

Step 4. Confirm/Enable automatic detection of high-accuracy timekeeping.

a. Wait at least 20 seconds for the SEL-351 to acquire the clock signal, and then, at a communications terminal, type **TAR TIRIG <Enter>**

The relay will return one row from the Relay Word, as shown in *Figure N.9*. Only the state of the TIRIG and TSOK Relay Word bits are discussed in the troubleshooting steps below.

```
=>TAR TIRIG <Enter>

SAGAB   SAGBC   SAGCA   SWAB    SWBC    SWCA    TSOK    TIRIG
0       0       0       0       0       0       1       1
=>
```

Figure N.9 Confirming the High-Accuracy Timekeeping Relay Word Bits

b. The TIRIG and TSOK Relay Word bits should be asserted (logical 1), indicating that the relay is in the high-accuracy IRIG timekeeping mode.

If TSOK is not asserted, but TIRIG is asserted, the relay is in regular IRIG timekeeping mode. The **TIME Q** command shows which IRIG-B source is in use and the time quality. Here is a list of possible reasons for not entering high-accuracy mode:

- Global setting IRIGC = C37.118, but the IRIG-B clock does not use the IEEE C37.118 Control Bit assignments.
- The IRIG-B signal jitter is too high.
- The termination resistor, required by some IRIG clocks, is not installed.
- Global setting IRIGC = C37.118, but the time-source clock is reporting that its time error is greater than 1 µs.

If neither TSOK nor TIRIG are asserted, the relay is not in an IRIG time-source mode. Here is a list of possible reasons for not entering IRIG mode:

- The IRIG-B clock signal is not of sufficient accuracy or is improperly configured.
- The termination resistor, required by some IRIG clocks, is not installed.
- The time source clock is not connected to an antenna.

Synchrophasor Protocols and SEL Fast Operate Commands

The SEL-351 can be configured to process SEL Fast Operate commands received on serial ports that have Port setting PROTO = PMU, when the Port setting FASTOP = Y. Fast Operate commands can be interleaved with synchrophasor messages or contained within IEEE C37.118 extended frames.

This functionality can allow a host device to initiate control actions in the PMU without the need for a separate communications interface.

If port setting FASTOP = Y on a serial port set to PROTO = PMU, the SEL-351 will provide Fast Operate support. The host device can request a Fast Operate Configuration Block when the relay is in the nontransmitting mode, and the relay will respond with the message, which includes codes that define the circuit breaker and remote bit control points that are available via Fast Operate commands.

The SEL-351 will process Fast Operate requests regardless of whether synchrophasors are being transmitted, as long as serial port setting FASTOP = Y. When FASTOP = N, the relay will ignore Fast Operate commands. Use the FASTOP = N option to lockout any control actions from that serial port if required by your company operating practices.

The SEL-351 does not acknowledge received Fast Operate commands. However, it is easy to program one or more Relay Word bits to observe the controlled function. For example, a Fast Operate Circuit Breaker close command could be confirmed by monitoring the breaker status bit 52A by assigning SELOGIC setting LV32 = 52A.

Note that only the Fast Operate function is available on ports set to PROTO = PMU. The protocols SEL Fast Meter and SEL Fast SER are unavailable on PROTO = PMU ports.

APPENDIX O

Modbus RTU and TCP Communications

Overview

This appendix describes Modbus RTU and TCP communications features supported by the SEL-351 Protection System. Complete specifications for the Modbus protocol are available from the Modbus user's group website at modbus.org.

The SEL-351 allows as many as three simultaneous Modbus sessions. The number of Ethernet Modbus sessions is limited by the number of enabled Ethernet DNP sessions. See *Session Limits* on page 10.15

The SEL-351 Modbus communication allows a Modbus master device to do the following:

- Acquire metering, monitoring, and event data from the relay.
- Control SEL-351 output contacts and remote bits.
- Read and switch the Active Setting Group.
- Read and set the time and date.
- Reset targets, demand and peak data, energy data, breaker monitor, min/max, and event history data.

Enable Modbus TCP protocol with the Ethernet port setting EMODBUS. The master IP address for each session is selected with the Ethernet port settings MODIP1, MODIP2, and MODIP3. The Master IP address 0.0.0.0 is a valid entry and is used to accept a connection from any master. Use caution when using this address as any Modbus master may connect to the Ethernet port through this connection. When a Modbus TCP master attempts to connect, the relay will first search the valid master IP addresses. If no matching Modbus master IP address is found, and one of the MODIP*x* addresses is 0.0.0.0, the master will be allowed to connect through that connection. The TCP port number is the Modbus TCP registered port 502. Modbus TCP uses the device IP address as the Modbus identifier and accesses the data in the relay using the same function codes and data maps as Modbus RTU.

Modbus RTU is a binary protocol that permits communication between a single master device and multiple slave devices. The communication is half duplex—only one device transmits at a time. The master transmits a binary command that includes the address of the desired slave device. All of the slave devices receive the message, but only the slave device with the matching address responds. Enable Modbus RTU protocol with the serial port PROTO setting.

Communications Protocol

Modbus RTU Queries

Modbus master devices initiate all exchanges by sending a query. The query format for Modbus RTU consists of the fields shown in *Table O.1*.

Table O.1 Modbus Query Fields

Field	Number of Bytes
Slave Device Address	1 byte
Function Code	1 byte
Data Region	0–251 bytes
Cyclic Redundancy Check (CRC)	2 bytes

The SEL-351 serial port SLAVEID setting defines the device address. Set this value to a unique number for each device on the Modbus network. For Modbus RTU communication to operate properly, no two slave devices may have the same address.

The cyclic redundancy check detects errors in the received data. If an error is detected, the relay discards the packet.

Modbus TCP Queries

The Modbus request or response is encapsulated when carried on a Modbus TCP/IP network. A dedicated header used on TCP/IP identifies the Modbus Application Data Unit (ADU). The header, called the MBAP (Modbus Application Protocol header), contains the following fields:

Field	Number of Bytes
Transaction Identifier	2 Bytes
Protocol Identifier	2 Bytes (0 = MODBUS protocol)
Length	2 Bytes
Unit Identifier	1 Byte

The Modbus TCP Message consists of the MBAP Header, followed by the Modbus function code and the data supporting the function code. The Modbus TCP message does not contain the 2 byte CRC that is included in the RTU message, as the error checking is accomplished through TCP. Otherwise the data following the MBAP header is identical to the Modbus RTU message.

The remainder of this section will cover the Modbus Function codes in terms of the Modbus RTU protocol.

Modbus Responses

The slave device sends a response message after it performs the action the query specifies. If the slave cannot execute the query command for any reason, it sends an error response. Otherwise, the slave device response is formatted similarly to the query and includes the slave address, function code, data (if applicable), and a cyclic redundancy check value.

Supported Modbus Function Codes

The SEL-351 supports the Modbus function codes shown in *Table O.2*.

Table O.2 SEL-351 Modbus Function Codes

Codes	Description
01h	Read Discrete Output Coil Status
02h	Read Discrete Input Status
03h	Read Holding Registers
04h	Read Input Registers
05h	Force Single Coil
06h	Preset Single Register
08h	Diagnostic Command
10h	Preset Multiple Registers

Modbus Exception Responses

The SEL-351 sends an exception code under the conditions described in *Table O.3*.

Table O.3 SEL-351 Modbus Exception Codes

Exception Code	Error Type	Description
1	Illegal Function Code	The received function code is either undefined or unsupported.
2	Illegal Data Address	The received command contains an unsupported address in the data field.
3	Illegal Data Value	The received command contains a value that is out of range.
4	Device Error	The SEL-351 is in the wrong state for the function a query specifies. The relay is unable to perform the action specified by a query (i.e., cannot write to a read-only register, device is disabled, etc.).
6	Busy	The device is unable to process the command at this time because of a busy resource.

In the event that any of the errors listed in *Table O.3* occur, the relay assembles a response message that includes the exception code in the data field. The relay sets the most significant bit in the function code field to indicate to the master that the data field contains an error code, instead of the required data.

Cyclic Redundancy Check

The SEL-351 calculates a 2-byte CRC value through use of the device address, function code, and data region. It appends this value to the end of every Modbus RTU response. When the master device receives the response, it recalculates the CRC. If the calculated CRC matches the CRC sent by the SEL-351, the master device uses the data received. If there is no match, the check fails and the message is ignored. The devices use a similar process when the master sends queries.

Function Codes

01h Read Discrete Output Coil Status Command

Use function code 01h to read the On/Off status of the selected bits (coils) (see the Output Coils table shown in *Table O.14*). The SEL-351 coil addresses start at 0. The coil status is packed one coil per bit of the data field. The Least Significant Bit (LSB) of the first data byte contains the starting coil address in the query. The other coils follow towards the high order end of this byte and from low order to high order in subsequent bytes.

Table O.4 01h Read Discrete Output Coil Status Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (01h)
2 bytes	Address of the first bit
2 bytes	Number of bits to read
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (01h)
1 byte	Bytes of data (*n*)
n bytes	Data
2 bytes	CRC-16

To build the response, the SEL-351 calculates the number of bytes required to contain the number of bits requested. If the number of bits requested is not evenly divisible by eight, the device adds one more byte to maintain the balance of bits, padded by zeros to make an even byte. *Table O.14* includes the coil number and lists all possible coils (identified as Outputs and Remote bits) available in the device.

The relay responses to errors in the query are shown in *Table O.5*.

Table O.5 Responses to 01h Read Discrete Output Coil Query Errors

Error	Error Code Returned	Communication Counter Increments
Invalid bit to read	Illegal Data Address (02h)	Invalid Address
Invalid number of bits to read	Illegal Data Value (03h)	Illegal Register
Format error	Illegal Data Value (03h)	Bad Packet Format

02 Read Input Status Command

Use function code 02h to read the On/Off status of the selected bits (inputs), as shown in *Table O.7*. Input addresses start at 0. The input status is packed one input per bit of the data field. The LSB of the first data byte contains the starting input address in the query. The other inputs follow towards the high order end of this byte, and from low order to high order in subsequent bytes.

Table O.6 02h Read Input Status Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (02h)
2 bytes	Address of the first bit
2 bytes	Number of bits to read
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (02h)
1 byte	Bytes of data (*n*)
n bytes	Data
2 bytes	CRC-16

To build the response, the device calculates the number of bytes required to contain the number of bits requested. If the number of bits requested is not evenly divisible by eight, the device adds one more byte to maintain the balance of bits, padded by zeros to make an even byte.

In each row, the input numbers are assigned from the right-most input to the left-most input (i.e., input address 0 is 81 and input address 7 is EN). Input addresses start at 0000. *Table O.7* includes the input address in decimal and hexadecimal and lists all possible inputs (Relay Word bits) available in the device.

The Address numbers are assigned from the right-most Address to the left-most Address in the Relay row as shown in the SEL-351 example below.

Address 7 = EN
Address 6 = TRIP
Address 5 = INST
Address 4 = COMM
Address 3 = SOTF
Address 2 = 50
Address 1 = 51
Address 0 = 81

Address 15 = A
Address 14 = B
Address 13 = C
Address 12 = G
Address 11 = N
Address 10 = RS
Address 9 = CY
Address 8 = LO

Table O.7 02h SEL-351 Inputs[a] (Sheet 1 of 4)

Discrete Input Address in Decimal	Discrete Input Address in Hex	Function Code Supported	Discrete Address Description
0–7	0–7	2	Relay Element Status Row 0
8–15	8–F	2	Relay Element Status Row 1
16–23	10–17	2	Relay Element Status Row 2
24–31	18–1F	2	Relay Element Status Row 3

Table O.7 02h SEL-351 Inputs[a] (Sheet 2 of 4)

Discrete Input Address in Decimal	Discrete Input Address in Hex	Function Code Supported	Discrete Address Description
32–39	20–27	2	Relay Element Status Row 4
40–47	28–2F	2	Relay Element Status Row 5
48–55	30–37	2	Relay Element Status Row 6
56–63	38–3F	2	Relay Element Status Row 7
64–71	40–47	2	Relay Element Status Row 8
72–79	48–4F	2	Relay Element Status Row 9
80–87	50–57	2	Relay Element Status Row 10
88–95	58–5F	2	Relay Element Status Row 11
96–103	60–67	2	Relay Element Status Row 12
104–111	68–6F	2	Relay Element Status Row 13
112–119	70–77	2	Relay Element Status Row 14
120–127	78–7F	2	Relay Element Status Row 15
128–135	80–87	2	Relay Element Status Row 16
136–143	88–8F	2	Relay Element Status Row 17
144–151	90–97	2	Relay Element Status Row 18
152–159	98–9F	2	Relay Element Status Row 19
160–167	A0–A7	2	Relay Element Status Row 20
168–175	A8–AF	2	Relay Element Status Row 21
176–183	B0–B7	2	Relay Element Status Row 22
184–191	B8–BF	2	Relay Element Status Row 23
192–199	C0–C7	2	Relay Element Status Row 24
200–207	C8–CF	2	Relay Element Status Row 25
208–215	D0–D7	2	Relay Element Status Row 26
216–223	D8–DF	2	Relay Element Status Row 27
224–231	E0–E7	2	Relay Element Status Row 28
232–239	E8–EF	2	Relay Element Status Row 29
240–247	F0–F7	2	Relay Element Status Row 30
248–255	F8–FF	2	Relay Element Status Row 31
256–263	100–107	2	Relay Element Status Row 32
264–271	108–10F	2	Relay Element Status Row 33
272–279	110–117	2	Relay Element Status Row 34
280–287	118–11F	2	Relay Element Status Row 35
288–295	120–127	2	Relay Element Status Row 36
296–303	128–12F	2	Relay Element Status Row 37
304–311	130–137	2	Relay Element Status Row 38
312–319	138–13F	2	Relay Element Status Row 39
320–327	140–147	2	Relay Element Status Row 40
328–335	148–14F	2	Relay Element Status Row 41
336–343	150–157	2	Relay Element Status Row 42
344–351	158–15F	2	Relay Element Status Row 43

Table O.7 02h SEL-351 Inputs[a] (Sheet 3 of 4)

Discrete Input Address in Decimal	Discrete Input Address in Hex	Function Code Supported	Discrete Address Description
352–359	160–167	2	Relay Element Status Row 44
360–367	168–16F	2	Relay Element Status Row 45
368–375	170–177	2	Relay Element Status Row 46
376–383	178–17F	2	Relay Element Status Row 47
384–391	180–187	2	Relay Element Status Row 48
392–399	188–18F	2	Relay Element Status Row 49
400–407	190–197	2	Relay Element Status Row 50
408–415	198–19F	2	Relay Element Status Row 51
416–423	1A0–1A7	2	Relay Element Status Row 52
424–431	1A8–1AF	2	Relay Element Status Row 53
432–439	1B0–1B7	2	Relay Element Status Row 54
440–447	1B8–1BF	2	Relay Element Status Row 55
448–455	1C0–1C7	2	Relay Element Status Row 56
456–463	1C8–1CF	2	Relay Element Status Row 57
464–471	1D0–1D7	2	Relay Element Status Row 58
472–479	1D8–1DF	2	Relay Element Status Row 59
480–487	1E0–1E7	2	Relay Element Status Row 60
488–495	1E8–1EF	2	Relay Element Status Row 61
496–503	1F0–1F7	2	Relay Element Status Row 62
504–511	1F8–1FF	2	Relay Element Status Row 63
512–519	200–207	2	Relay Element Status Row 64
520–527	208–20F	2	Relay Element Status Row 65
528–535	210–217	2	Relay Element Status Row 66
536–543	218–21F	2	Relay Element Status Row 67
544–551	220–227	2	Relay Element Status Row 68
552–559	228–22F	2	Relay Element Status Row 69
560-567	230–237	2	Relay Element Status Row 70
568–575	238–23F	2	Relay Element Status Row 71
576–583	240–247	2	Relay Element Status Row 72
584–591	248–24F	2	Relay Element Status Row 73
592–599	250–257	2	Relay Element Status Row 74
600–607	258–25F	2	Relay Element Status Row 75
608–615	260–267	2	Relay Element Status Row 76
616–623	268–26F	2	Relay Element Status Row 77
624–631	270–277	2	Relay Element Status Row 78
632–639	278–27F	2	Relay Element Status Row 79
640–647	280–287	2	Relay Element Status Row 80
648–655	288–28F	2	Relay Element Status Row 81
656–663	290–297	2	Relay Element Status Row 82
664–671	298–29F	2	Relay Element Status Row 83

Table O.7 02h SEL-351 Inputs[a] (Sheet 4 of 4)

Discrete Input Address in Decimal	Discrete Input Address in Hex	Function Code Supported	Discrete Address Description
672–679	2A0–2A7	2	Relay Element Status Row 84
680–687	2A8–2AF	2	Relay Element Status Row 85
688–695	2B0–2B7	2	Relay Element Status Row 86
696–703	2B8–2BF	2	Relay Element Status Row 87
704–711	2C0–2C7	2	Relay Element Status Row 88
712–719	2C8–2CF	2	Relay Element Status Row 89
720–727	2D0–2D7	2	Relay Element Status Row 90
728–735	2D8–2DF	2	Relay Element Status Row 91
736–743	2E0–2E7	2	Relay Element Status Row 92
744–751	2E8–2EF	2	Relay Element Status Row 93
752–759	2F0–2F7	2	Relay Element Status Row 94
760–767	2F8–2FF	2	Relay Element Status Row 95
768–775	300–307	2	Relay Element Status Row 96
776–783	308–30F	2	Relay Element Status Row 97
784–791	310–317	2	Relay Element Status Row 98
792–799	318–31F	2	Relay Element Status Row 99
800–807	320–327	2	Relay Element Status Row 100
808–815	328–32F	2	Relay Element Status Row 101
816–823	330–337	2	Relay Element Status Row 102

[a] See *Appendix D: Relay Word Bits* for relay element row numbers and definitions.

The relay responses to errors in the query are shown in *Table O.8*.

Table O.8 Responses to 02h Read Input Query Errors

Error	Error Code Returned	Communication Counter Increments
Invalid bit to read	Illegal Data Address (02h)	Invalid Address
Invalid number of bits to read	Illegal Data Value (03h)	Illegal Register
Format error	Illegal Data Value (03h)	Bad Packet Format

03h Read Holding Register Command

Use function code 03h to read directly from the Modbus Register Map shown in *Table O.23*. Use the **SET M** command (see *Configurable Register Mapping* on page O.17) to configure the map using the register label names shown in *Table O.22*. You can read a maximum of 125 registers at once with this function code. Most masters use 4X references with this function code.

Table O.9 03h Read Holding Register Command (Sheet 1 of 2)

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (03h)

Table O.9 03h Read Holding Register Command (Sheet 2 of 2)

Bytes	Field
2 bytes	Starting Register Address
2 bytes	Number of Registers to Read
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (03h)
1 byte	Bytes of data (*n*)
n bytes	Data (2–250)
2 bytes	CRC-16

The relay responses to errors in the query are shown in *Table O.10*.

Table O.10 Responses to 03h Read Holding Register Query Errors

Error	Error Code Returned	Communication Counter Increments
Illegal register to read	Illegal Data Address (02h)	Invalid Address
Illegal number of registers to read	Illegal Data Value (03h)	Illegal Register
Format error	Illegal Data Value (03h)	Bad Packet Format

04h Read Input Register Command

Use function code 04h to read directly from the Modbus Register Map shown in *Table O.23*. Use the **SET M** command (see *Configurable Register Mapping* on page O.17) to configure the map using the register label names shown in *Table O.22*. You can read a maximum of 125 registers at once with this function code. Most masters use 3X references with this function code.

Table O.11 04h Read Input Register Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (04h)
2 bytes	Starting Register Address
2 bytes	Number of Registers to Read
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (04h)
1 byte	Bytes of data (*n*)
n bytes	Data (2–250)
2 bytes	CRC-16

The relay responses to errors in the query are shown in *Table O.12*.

Table O.12 Responses to 04h Read Input Register Query Errors

Error	Error Code Returned	Communication Counter Increments
Illegal register to read	Illegal Data Address (02h)	Invalid Address
Illegal number of registers to read	Illegal Data Value (03h)	Illegal Register
Format error	Illegal Data Value (03h)	Bad Packet Format

05h Force Single Coil Command

Use function code 05h to set or clear a coil. The command response is identical to the command request shown in *Table O.13*.

Table O.13 05h Force Single Coil Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (05h)
2 bytes	Coil Reference
1 byte	Operation Code (FF for bit set, 00 for bit clear)
1 byte	Placeholder (00)
2 bytes	CRC-16

Table O.14 lists the coil numbers supported by the SEL-351. The physical coils (coils 00–23) are self-resetting. Pulsing a Set remote bit (decimal address 64 through 79 and 128 through 143) causes the remote bit to be cleared at the end of the pulse.

Table O.14 01h, 05h SEL-351 Output Coils (Sheet 1 of 5)

Coil Address in Decimal	Coil Address in Hex	Function Code Supported	Coil Description	Coil Function	Duration
0	0	1, 5	OUT101[a]	Pulse	1 second
1	1	1, 5	OUT102[a]	Pulse	1 second
2	2	1, 5	OUT103[a]	Pulse	1 second
3	3	1, 5	OUT104[a]	Pulse	1 second
4	4	1, 5	OUT105[a]	Pulse	1 second
5	5	1, 5	OUT106[a]	Pulse	1 second
6	6	1, 5	OUT107[a]	Pulse	1 second
7	7	1, 5	ALRMOUT[b]	Pulse	1 second
8	8	1, 5	Reserved		
9	9	1, 5	Reserved		
10	A	1, 5	Reserved		
11	B	1, 5	Reserved		
12	C	1, 5	OUT201[a,c]	Pulse	1 second
13	D	1, 5	OUT202[a,c]	Pulse	1 second
14	E	1, 5	OUT203[a,c]	Pulse	1 second
15	F	1, 5	OUT204[a,c]	Pulse	1 second
16	10	1, 5	OUT205[a,c]	Pulse	1 second

Table O.14 01h, 05h SEL-351 Output Coils (Sheet 2 of 5)

Coil Address in Decimal	Coil Address in Hex	Function Code Supported	Coil Description	Coil Function	Duration
17	11	1, 5	OUT206[a,c]	Pulse	1 second
18	12	1, 5	OUT207[a,c]	Pulse	1 second
19	13	1, 5	OUT208[a,c]	Pulse	1 second
20	14	1, 5	OUT209[a,c]	Pulse	1 second
21	15	1, 5	OUT210[a,c]	Pulse	1 second
22	16	1, 5	OUT211[a,c]	Pulse	1 second
23	17	1, 5	OUT212[a,c]	Pulse	1 second
24	18	1, 5	Reserved		
25	19	1, 5	Reserved		
26	1A	1, 5	Reserved		
27	1B	1, 5	Reserved		
28	1C	1, 5	Reserved		
29	1D	1, 5	Reserved		
30	1E	1, 5	Reserved		
31	1F	1, 5	Reserved		
32	20	1, 5	Reserved		
33	21	1, 5	Reserved		
34	22	1, 5	Reserved		
35	23	1, 5	Reserved		
36	24	1, 5	Reserved		
37	25	1, 5	Reserved		
38	26	1, 5	Reserved		
39	27	1, 5	Reserved		
40	28	1, 5	Reserved		
41	29	1, 5	Reserved		
42	2A	1, 5	Reserved		
43	2B	1, 5	Reserved		
44	2C	1, 5	Reserved		
45	2D	1, 5	Reserved		
46	2E	1, 5	Reserved		
47	2F	1, 5	Reserved		
48	30	1, 5	RB1	Set/Clear	
49	31	1, 5	RB2	Set/Clear	
50	32	1, 5	RB3	Set/Clear	
51	33	1, 5	RB4	Set/Clear	
52	34	1, 5	RB5	Set/Clear	
53	35	1, 5	RB6	Set/Clear	
54	36	1, 5	RB7	Set/Clear	
55	37	1, 5	RB8	Set/Clear	
56	38	1, 5	RB9	Set/Clear	

Table O.14 01h, 05h SEL-351 Output Coils (Sheet 3 of 5)

Coil Address in Decimal	Coil Address in Hex	Function Code Supported	Coil Description	Coil Function	Duration
57	39	1, 5	RB10	Set/Clear	
58	3A	1, 5	RB11	Set/Clear	
59	3B	1, 5	RB12	Set/Clear	
60	3C	1,5	RB13	Set/Clear	
61	3D	1, 5	RB14	Set/Clear	
62	3E	1, 5	RB15	Set/Clear	
63	3F	1, 5	RB16	Set/Clear	
64	40	1, 5	RB1	Pulse[d]	1 SELOGIC Processing Interval
65	41	1, 5	RB2	Pulse[d]	1 SELOGIC Processing Interval
66	42	1, 5	RB3	Pulse[d]	1 SELOGIC Processing Interval
67	43	1, 5	RB4	Pulse[d]	1 SELOGIC Processing Interval
68	44	1, 5	RB5	Pulse[d]	1 SELOGIC Processing Interval
69	45	1, 5	RB6	Pulse[d]	1 SELOGIC Processing Interval
70	46	1, 5	RB7	Pulse[d]	1 SELOGIC Processing Interval
71	47	1, 5	RB8	Pulse[d]	1 SELOGIC Processing Interval
72	48	1, 5	RB9	Pulse[d]	1 SELOGIC Processing Interval
73	49	1, 5	RB10	Pulse[d]	1 SELOGIC Processing Interval
74	4A	1, 5	RB11	Pulse[d]	1 SELOGIC Processing Interval
75	4B	1, 5	RB12	Pulse[d]	1 SELOGIC Processing Interval
76	4C	1, 5	RB13	Pulse[d]	1 SELOGIC Processing Interval
77	4D	1, 5	RB14	Pulse[d]	1 SELOGIC Processing Interval
78	4E	1, 5	RB15	Pulse[d]	1 SELOGIC Processing Interval
79	4F	1, 5	RB16	Pulse[d]	1 SELOGIC Processing Interval
80	50	1, 5	Reserved		
81	51	1, 5	Reserved		
82	52	1, 5	Reserved		
83	53	1, 5	Reserved		
84	54	1, 5	Breaker Open	Pulse[e]	1 SELOGIC Processing Interval
85	55	1, 5	Breaker Close	Pulse[e]	1 SELOGIC Processing Interval
86	56	1, 5	Reserved		
87	57	1, 5	Reserved		
88	58	1, 5	Target Reset	Pulse	
89	59	1, 5	Reset Demands	Pulse	
90	5A	1, 5	Reset Peak Demand	Pulse	
91	5B	1, 5	Reset Energy Data	Pulse	
92	5C	1, 5	Reset Breaker Monitor	Pulse	
93	5D	1, 5	Reset Min/Max	Pulse	
94	5E	1, 5	Reset Event History	Pulse	

Table O.14 01h, 05h SEL-351 Output Coils (Sheet 4 of 5)

Coil Address in Decimal	Coil Address in Hex	Function Code Supported	Coil Description	Coil Function	Duration
95	5F	1, 5	Reset Hardware Alarm	Pulse	
96	60	1, 5	Reserved		
97	61	1, 5	Reserved		
98	62	1, 5	Reserved		
99	63	1, 5	Reserved		
100	64	1, 5	Reserved		
101	65	1, 5	Reserved		
102	66	1, 5	Reserved		
103	67	1, 5	Reserved		
104	68	1, 5	Reserved		
105	69	1, 5	Reserved		
106	6A	1, 5	Reserved		
107	6B	1, 5	Reserved		
108	6C	1, 5	Reserved		
109	6D	1, 5	Reserved		
110	6E	1, 5	Reserved		
111	6F	1, 5	Reserved		
112	70	1, 5	RB17	Set/Clear	
113	71	1, 5	RB18	Set/Clear	
114	72	1, 5	RB19	Set/Clear	
115	73	1, 5	RB20	Set/Clear	
116	74	1, 5	RB21	Set/Clear	
117	75	1, 5	RB22	Set/Clear	
118	76	1, 5	RB23	Set/Clear	
119	77	1, 5	RB24	Set/Clear	
120	78	1, 5	RB25	Set/Clear	
121	79	1, 5	RB26	Set/Clear	
122	7A	1, 5	RB27	Set/Clear	
123	7B	1, 5	RB28	Set/Clear	
124	7C	1, 5	RB29	Set/Clear	
125	7D	1, 5	RB30	Set/Clear	
126	7E	1, 5	RB31	Set/Clear	
127	7F	1, 5	RB32	Set/Clear	
128	80	1, 5	RB17	Pulse[d]	1 SELOGIC Processing Interval
129	81	1, 5	RB18	Pulse[d]	1 SELOGIC Processing Interval
130	82	1, 5	RB19	Pulse[d]	1 SELOGIC Processing Interval
131	83	1, 5	RB20	Pulse[d]	1 SELOGIC Processing Interval
132	84	1, 5	RB21	Pulse[d]	1 SELOGIC Processing Interval
133	85	1, 5	RB22	Pulse[d]	1 SELOGIC Processing Interval
134	86	1, 5	RB23	Pulse[d]	1 SELOGIC Processing Interval

Table O.14 01h, 05h SEL-351 Output Coils (Sheet 5 of 5)

Coil Address in Decimal	Coil Address in Hex	Function Code Supported	Coil Description	Coil Function	Duration
135	87	1, 5	RB24	Pulse[d]	1 SELOGIC Processing Interval
136	88	1, 5	RB25	Pulse[d]	1 SELOGIC Processing Interval)
137	89	1, 5	RB26	Pulse[d]	1 SELOGIC Processing Interval
138	8A	1, 5	RB27	Pulse[d]	1 SELOGIC Processing Interval
139	8B	1, 5	RB28	Pulse[d]	1 SELOGIC Processing Interval
140	8C	1, 5	RB29	Pulse[d]	1 SELOGIC Processing Interval
141	8D	1, 5	RB30	Pulse[d]	1 SELOGIC Processing Interval
142	8E	1, 5	RB31	Pulse[d]	1 SELOGIC Processing Interval
143	8F	1, 5	RB32	Pulse[d]	1 SELOGIC Processing Interval

[a] Coils are also controlled by the SELOGIC control equation of the same name.
[b] ALRMOUT coil is also controlled by SELOGIC control equation ALRMOUT.
[c] Supported in 3U relay with extra I/O board, otherwise Reserved.
[d] Pulsing a remote bit which is already set will cause the remote bit to be cleared at the end of the pulse.
[e] If the relay is disabled or the breaker control jumper is removed, the relay returns an error code 06 (Slave Device Busy).

Coil addresses start at 0000. If the device is disabled, a function code 05h to any coil will result in an Error Code 4 response. The device responses to other errors in the query are shown in *Table O.15*.

Table O.15 Responses to 05h Force Single Coil Query Errors

Error	Error Code Returned	Communication Counter Increments
Invalid bit (coil)	Illegal Data Address (02h)	Invalid Address
Invalid bit state requested	Illegal Data Value (03h)	Illegal Register
Format Error	Illegal Data Value (03h)	Bad Packet Format

06h Preset Single Register Command

The SEL-351 uses this function to allow a Modbus master to write directly to a database register. Refer to the Modbus Quantities Table in *Table O.22* for a list of registers that can be written by using this function code.

The command response is identical to the command request shown in *Table O.16*.

Table O.16 06h Preset Single Register Command

Bytes	Field
Queries from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (06h)
2 bytes	Register Address
2 bytes	Data
2 bytes	CRC-16

The relay responses to errors in the query are shown in *Table O.17*.

Table O.17 Responses to 06h Preset Single Register Query Errors

Error	Error Code Returned	Communication Counter Increments
Illegal register address	Illegal Data Address (02h)	Invalid Address Illegal Write
Illegal register value	Illegal Data Value (03h)	Illegal Write
Format error	Illegal Data Value (03h)	Bad Packet Format

08h Loopback Diagnostic Command

The SEL-351 uses this function to allow a Modbus master to perform a diagnostic test on the Modbus communications channel and relay. When the subfunction field is 0000h, the relay returns a replica of the received message.

Table O.18 08h Loopback Diagnostic Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (08h)
2 bytes	Subfunction (0000h)
2 bytes	Data Field
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (08h)
2 bytes	Subfunction (0000h)
2 bytes	Data Field (identical to data in Master request)
2 bytes	CRC-16

The relay responses to errors in the query are shown in *Table O.19*.

Table O.19 Responses to 08h Loopback Diagnostic Query Errors

Error	Error Code Returned	Communication Counter Increments
Illegal subfunction code	Illegal Data Value (03h)	Illegal Function Code/Op Code
Format error	Illegal Data Value (03h)	Bad Packet Format

10h Preset Multiple Registers Command

This function code works much like code 06h, except that it allows you to write multiple registers at once, to as many as 100 per operation.

Table O.20 10h Preset Multiple Registers Command (Sheet 1 of 2)

Bytes	Field
Queries from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (10h)

Table O.20 10h Preset Multiple Registers Command (Sheet 2 of 2)

Bytes	Field
2 bytes	Starting Address
2 bytes	Number of Registers to Write
1 byte	Number of Bytes of Data (*n*)
n bytes	Data
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (10h)
2 bytes	Starting Address
2 bytes	Number of Registers
2 bytes	CRC-16

The relay responses to errors in the query are shown below.

Table O.21 10h Preset Multiple Registers Query Error Messages

Error	Error Code Returned	Communication Counter Increments
Illegal register to set	Illegal Data Address (02h)	Invalid Address Illegal Write
Illegal number of registers to set	Illegal Data Value (03h)	Illegal Register Illegal Write
Incorrect number of bytes in query data region	Illegal Data Value (03h)	Bad Packet Format Illegal Write
Invalid register data value	Illegal Data Value (03h)	Illegal Write

Bit Operations Using Function Codes 06h and 10h

The SEL-351 includes registers for controlling some of the outputs. See LOG_CMD and RSTDAT in *Table O.22*. Use Modbus function codes 06h or 10h to write appropriate flags. Remember that when writing to the Logic command register with output contacts, it is not a bit operation. All the bits in that register need to be written together to reflect the state you want for each of the outputs.

Remote Bit labels RB1_8S, RB1_8C, RB1_8P, RB9_16S, etc., are also bit operations. Only those bit positions containing a 1 will operate when writing to registers containing the Remote Bit labels.

For Set and Clear operations, each single register write operation will be atomic. For Pulse operations, bits pulsed in a single register write are not guaranteed to be atomic.

In the case of function code 10h Multiple Register write, the order of operation is determined by the order the Remote Bits are received. When multiple registers are written to, the registers with the highest address take priority.

A function code 03h or 04h read of any of the bit operation registers (LOG_CMD, RSTDAT, or Remote Bit Operations) will return a value of 0.

Modbus Documentation

Configurable Register Mapping

The SEL-351 Modbus Register Map defines an area of 250 contiguous addresses whose contents are defined by user-settable labels. This feature allows you to take 250 discrete values from anywhere in the Modbus Quantities Table (*Table O.22*) and place them in contiguous registers that you can then read in a single command. Use the SEL ASCII command **SET M** (or the Modbus User Map settings in ACSELERATOR QuickSet SEL-5030 software) to define the user map addresses. A default map is provided with the relay. If the default Modbus map is not appropriate or more data are desired, edit the map as necessary for your application.

To use the user-defined data region, follow the steps listed below.

Step 1. Define the list of desired quantities (as many as 250). Arrange the quantities in any order that is convenient for you to use.

Step 2. Refer to *Table O.22* for a list of the Modbus labels for each quantity.

Step 3. Use the **SET M** command from the command line or QuickSet Modbus User Map to map user registers 001 to 250 (MOD_001 to MOD_250) using the labels in *Table O.22*.

Step 4. Use Modbus function code 03h or 04h to read the desired quantities from addresses 0 through 249 (decimal).

Note that the Modbus addresses begin with zero, which corresponds to Set M setting MOD_001.

NOTE: If your master uses 5 or 6 digit address references, add the appropriate number to the Modbus Address provided in *Table O.23* when configuring your master. For example, if your master uses 5-digit addressing, add 40001 for holding register operations. For Input register functions, add 30001.

If your master uses 6-digit addressing, add 400001 for holding register operations or 300001 for input register functions.

The actual address that appears in the address field of the message will be the Modbus Address shown in *Table O.23*. For example, MOD_001 is address 0000 (see *Table O.23* for Modbus register addresses). A master using 6-digit addresses to read a holding register may be configured for address 400001. However, the data address field of the message from the master will contain address 0000.

As each label is entered in a register via the **SET M** command, the relay will increment to the next valid register.

If a label is entered for a 32-bit quantity register (e.g., VA, VB, VC, KW3), the relay will automatically skip a register in the sequence because two registers are required for the 32-bit quantity. The register with the lower index is the most significant word and the register with the higher index is the least significant word in the 32-bit quantity. In the following example, MOD_015 was previously set to 3I2, which is a 16 bit value and consumes one register. By changing the register label to KW3, a 32 bit value, the next register shown available for setting is MOD_017.

```
=>>SET M MOD_015 <Enter>

Modbus Map, Section 1:
USER REG#015
MOD_015 = 3I2
     ? KW3

USER REG#017
MOD_017 = VA
     ?

USER REG#019
MOD_019 = VAFA
     ?
=>>
```

Similarly, in this example, MOD_017 was previously set to VA, which is a 32 bit value and consumes two registers. By changing the register label to IA, a 16 bit value, the next register shown available for setting is MOD_018. Because MOD_018 was previously not available, as it was the second register used for MOD_017 (VA), there is no label assigned to it and shows NA.

```
=>>SET M MOD_017 <Enter>

Modbus Map, Section 1:
USER REG#017
MOD_017 = VA
     ? IA

USER REG#018
MOD_018 = NA
     ? IAFA

USER REG#019
MOD_019 = VAFA
     ? IB

=>>
```

Modbus Quantities Table

The available labels for the user-defined Modbus data region are defined in *Table O.22*.

Table O.22 Modbus Quantities Table (Sheet 1 of 15)

Description	Valid Function Codes	SET_M Point Label/Enums[a]	Number of 16-Bit Registers	Min Value	Max Value	Scaling[b] (X1 unless specified)
Special Quantities						
Constant		0	1	0	0	
Constant		1	1	1	1	
No Operation		NOOP	1	0	0	
Not Assigned		NA	1	0	0	
Relay Firmware Revision	03, 04	FWREV	1	0	9999	
Relay Serial Number, Lowest 4 Digits	03, 04	SNUMBL	1	0	9999	
Relay Serial Number, Middle 4 Digits	03, 04	SNUMBM	1	0	9999	
Relay Serial Number, High 4 Digits	03, 04	SNUMBH	1	0	9999	
Reset Bits						
Reset Data	03, 04, 06, 10h	**RSTDAT**	1	0	65535	
Reset Targets		**Bit 0**				
Reserved		**Bit 1**				
Reserved		**Bit 2**				
Reset History Data		**Bit 3**				
Reset Comm Counters		**Bit 4**				
Reset Breaker Monitor		**Bit 5**				
Reset Energy Data		**Bit 6**				
Reset Max/Min Data		**Bit 7**				
Reset Demands		**Bit 8**				
Reset Peak Demand		**Bit 9**				
Reset Hardware Alarm		**Bit 10**				
Reserved		**Bits 11–15**				

Table O.22 Modbus Quantities Table (Sheet 2 of 15)

Description	Valid Function Codes	SET_M Point Label/Enums[a]	Number of 16-Bit Registers	Min Value	Max Value	Scaling[b] (X1 unless specified)
Date/Time Set						
Set Seconds	03, 04, 06, 10h	**TIME_S**	1	0	59	
Set Minutes	03, 04, 06, 10h	**TIME_M**	1	0	59	
Set Hour	03, 04, 06, 10h	**TIME_H**	1	0	23	
Set Day	03, 04, 06, 10h	**DATE_D**	1	1	31	
Set Month	03, 04, 06, 10h	**DATE_M**	1	1	12	
Set Year	03, 04, 06, 10h	**DATE_Y**	1	2000	2550	
Historical Data						
No. of Event Logs	03, 04	NUMEVE	1	0	See *Table 12.1*	
Event Selected	03, 04, 06, 10h	**EVESEL**	1	0	See *Table 12.1*	
Fault Time Second	03, 04	FTIME_S	1	0	59999	1000
Fault Time Minute	03, 04	FTIME_M	1	0	59	
Fault Time Hour	03, 04	FTIME_H	1	0	23	
Fault Time Day	03, 04	FDATE_D	1	1	31	
Fault Time Month	03, 04	FDATE_M	1	1	12	
Fault Time Year	03, 04	FDATE_Y	1	0	9999	
Event Type	03, 04	EVE_TYPE	1			
1 = A Phase Trip						
2 = B Phase Trip						
3 = AB Fault Trip						
4 = C Phase Trip						
5 = CA Fault Trip						
6 = BC Fault Trip						
7 = ABC Fault Trip						
9 = AG Fault Trip						
10 = BG Fault Trip						
11 = ABG Fault Trip						
12 = CG Fault Trip						
13 = CAG Fault Trip						
14 = BCG Fault Trip						
15 = ABCG						
16 = Trigger						
32 = Pulse						
64 = Trip						
128 = ER Trigger						
Fault Location	03, 04	FLOC[c]	1	–32768	32767	100
Maximum Phase Fault Current	03, 04	FI[d]	1	0	65535	
Max A Phase Current	03, 04	FIA[d]	1	0	65535	

Table O.22 Modbus Quantities Table (Sheet 3 of 15)

Description	Valid Function Codes	SET_M Point Label/Enums[a]	Number of 16-Bit Registers	Min Value	Max Value	Scaling[b] (X1 unless specified)
Max B Phase Current	03, 04	FIB[d]	1	0	65535	
Max C Phase Current	03, 04	FIC[d]	1	0	65535	
Max Ground Current	03, 04	FIG[d]	1	0	65535	
Max Neutral Current	03, 04	FIN[d]	1	0	65535	
Max Neg. Seq. Current	03, 04	FIQ[d]	1	0	65535	
Fault Frequency	03, 04	FFREQ	1	4000	7000	100
Fault Group	03, 04	FGRP	1	1	6	
Fault Shot Count	03, 04	FSHO	1	0	4	
Fault Impedance Magnitude in Ohms Secondary	03, 04	FZ	1	0	65535	100
Fault Impedance Angle in Degrees	03, 04	FZFA	1	–18000	18000	100
Control I/O Commands						
Logic Command[e]	03, 04, 06, 10h	**LOG_CMD**	1			
Breaker Close		**Bit 0**				
Breaker Open		**Bit 1**				
Remote Bit Operations						
Remote Bits 1–8 Set	03, 04, 06, 10h	**RB1_8S**	1	0	65535	
RB8		**Bit 0**				
RB7		**Bit 1**				
RB6		**Bit 2**				
RB5		**Bit 3**				
RB4		**Bit 4**				
RB3		**Bit 5**				
RB2		**Bit 6**				
RB1		**Bit 7**				
Reserved		**Bits 8–15**				
Remote Bits 9–16 Set	03, 04, 06, 10h	**RB9_16S**	1	0	65535	
RB16		**Bit 0**				
RB15		**Bit 1**				
RB14		**Bit 2**				
RB13		**Bit 3**				
RB12		**Bit 4**				
RB11		**Bit 5**				
RB10		**Bit 6**				
RB9		**Bit 7**				
Reserved		**Bits 8–15**				
Remote Bits 17–24 Set	03, 04, 06, 10h	**RB17_24S**	1	0	65535	
RB24		**Bit 0**				
RB23		**Bit 1**				

Table O.22 Modbus Quantities Table (Sheet 4 of 15)

Description	Valid Function Codes	SET_M Point Label/Enums[a]	Number of 16-Bit Registers	Min Value	Max Value	Scaling[b] (X1 unless specified)
RB22		**Bit 2**				
RB21		**Bit 3**				
RB20		**Bit 4**				
RB19		**Bit 5**				
RB18		**Bit 6**				
RB17		**Bit 7**				
Reserved		**Bits 8–15**				
Remote Bits 25–32 Set	03, 04, 06, 10h	**RB25_32S**	1	0	65535	
RB32		**Bit 0**				
RB31		**Bit 1**				
RB30		**Bit 2**				
RB29		**Bit 3**				
RB28		**Bit 4**				
RB27		**Bit 5**				
RB26		**Bit 6**				
RB25		**Bit 7**				
Reserved		**Bits 8–15**				
Remote Bits 1–8 Clear	03, 04, 06, 10h	**RB1_8C**	1	0	65535	
RB8		**Bit 0**				
RB7		**Bit 1**				
RB6		**Bit 2**				
RB5		**Bit 3**				
RB4		**Bit 4**				
RB3		**Bit 5**				
RB2		**Bit 6**				
RB1		**Bit 7**				
Reserved		**Bits 8–15**				
Remote Bits 9–16 Clear	03, 04, 06, 10h	**RB9_16C**	1	0	65535	
RB16		**Bit 0**				
RB15		**Bit 1**				
RB14		**Bit 2**				
RB13		**Bit 3**				
RB12		**Bit 4**				
RB11		**Bit 5**				
RB10		**Bit 6**				
RB9		**Bit 7**				
Reserved		**Bits 8–15**				
Remote Bits 17–24 Clear	03, 04, 06, 10h	**RB17_24C**	1	0	65535	
RB24		**Bit 0**				
RB23		**Bit 1**				

Table O.22 Modbus Quantities Table (Sheet 5 of 15)

Description	Valid Function Codes	SET_M Point Label/Enums[a]	Number of 16-Bit Registers	Min Value	Max Value	Scaling[b] (X1 unless specified)
RB22		**Bit 2**				
RB21		**Bit 3**				
RB20		**Bit 4**				
RB19		**Bit 5**				
RB18		**Bit 6**				
RB17		**Bit 7**				
Reserved		**Bits 8–15**				
Remote Bits 25–32 Clear	03, 04, 06, 10h	**RB25_32C**	1	0	65535	
RB32		**Bit 0**				
RB31		**Bit 1**				
RB30		**Bit 2**				
RB29		**Bit 3**				
RB28		**Bit 4**				
RB27		**Bit 5**				
RB26		**Bit 6**				
RB25		**Bit 7**				
Reserved		**Bits 8–15**				
Remote Bits 1–8 Pulse	03, 04, 06, 10h	**RB1_8P**	1	0	65535	
RB8		**Bit 0**				
RB7		**Bit 1**				
RB6		**Bit 2**				
RB5		**Bit 3**				
RB4		**Bit 4**				
RB3		**Bit 5**				
RB2		**Bit 6**				
RB1		**Bit 7**				
Reserved		**Bits 8–15**				
Remote Bits 9–16 Pulse	03, 04, 06, 10h	**RB9_16P**	1	0	65535	
RB16		**Bit 0**				
RB15		**Bit 1**				
RB14		**Bit 2**				
RB13		**Bit 3**				
RB12		**Bit 4**				
RB11		**Bit 5**				
RB10		**Bit 6**				
RB9		**Bit 7**				
Reserved		**Bits 8–15**				
Remote Bits 17–24 Pulse	03, 04, 06, 10h	**RB17_24P**	1	0	65535	
RB24		**Bit 0**				
RB23		**Bit 1**				

Table O.22 Modbus Quantities Table (Sheet 6 of 15)

Description	Valid Function Codes	SET_M Point Label/Enums[a]	Number of 16-Bit Registers	Min Value	Max Value	Scaling[b] (X1 unless specified)
RB22		**Bit 2**				
RB21		**Bit 3**				
RB20		**Bit 4**				
RB19		**Bit 5**				
RB18		**Bit 6**				
RB17		**Bit 7**				
Reserved		**Bits 8–15**				
Remote Bits 25–32 Pulse	03, 04, 06, 10h	**RB25_32P**	1	0	65535	
RB32		**Bit 0**				
RB31		**Bit 1**				
RB30		**Bit 2**				
RB29		**Bit 3**				
RB28		**Bit 4**				
RB27		**Bit 5**				
RB26		**Bit 6**				
RB25		**Bit 7**				
Reserved		**Bits 8–15**				
Current Data						
Phase A Current Mag.	03, 04	IA	1	0	65535	
Phase A Angle	03, 04	IAFA	1	–18000	18000	100
Phase B Current Mag.	03, 04	IB	1	0	65535	
Phase B Angle	03, 04	IBFA	1	–18000	18000	100
Phase C Current Mag.	03, 04	IC	1	0	65535	
Phase C Angle	03, 04	ICFA	1	–18000	18000	100
Neutral Current Mag.	03, 04	IN	1	0	65535	
Neutral Current Angle	03, 04	INFA	1	–18000	18000	100
Residual Ground Current Mag.	03, 04	IG	1	0	65535	
Residual Ground Current Angle	03, 04	IGFA	1	–18000	18000	100
3I0 Current Mag.	03, 04	3I0	1	0	65535	
3I0 Current Angle	03, 04	3I0FA	1	–18000	18000	100
Positive Seq. Current Mag.	03, 04	I1	1	0	65535	
Positive Seq. Current Angle	03, 04	I1FA	1	–18000	18000	100
Negative Seq. Current Mag.	03, 04	3I2	1	0	65535	
Negative Seq. Current Angle	03, 04	3I2FA	1	–18000	18000	100
Voltage Data						
Phase A Voltage Mag.	03, 04	VA[f]	2	0	4294967295	
Phase A Voltage Angle	03, 04	VAFA[f]	1	–18000	18000	100
Phase B Voltage Mag.	03, 04	VB[f]	2	0	4294967295	

Table O.22 Modbus Quantities Table (Sheet 7 of 15)

Description	Valid Function Codes	SET_M Point Label/Enums[a]	Number of 16-Bit Registers	Min Value	Max Value	Scaling[b] (X1 unless specified)
Phase B Voltage Angle	03, 04	VBFA[f]	1	–18000	18000	100
Phase C Voltage Mag.	03, 04	VC[f]	2	0	4294967295	
Phase C Voltage Angle	03, 04	VCFA[f]	1	–18000	18000	100
VS Voltage Mag.	03, 04	VS	2	0	4294967295	
VS Voltage Angle	03, 04	VSFA	1	–18000	18000	100
Phase AB Voltage Mag.	03, 04	VAB	2	0	4294967295	
Phase AB Voltage Angle	03, 04	VABFA	1	–18000	18000	100
Phase BC Voltage Mag.	03, 04	VBC	2	0	4294967295	
Phase BC Voltage Angle	03, 04	VBCFA	1	–18000	18000	100
Phase CA Voltage Mag.	03, 04	VCA	2	0	4294967295	
Phase CA Voltage Angle	03, 04	VCAFA	1	–18000	18000	100
Pos. Seq. Voltage Mag.	03, 04	V1[g]	2	0	4294967295	
Pos. Seq. Voltage Angle	03, 04	V1FA[d]	1	–18000	18000	100
Neg. Seq. Voltage Mag.	03, 04	V2[d]	2	0	4294967295	
Neg. Seq. Voltage Angle	03, 04	V2FA[d]	1	–18000	18000	100
3V0 Voltage Mag.	03, 04	3V0_MAG[d,h]	2	0	4294967295	
3V0 Voltage Angle	03, 04	3V0FA[d,e]	1	–18000	18000	100
Power Data						
Phase A Real Power	03, 04	KWA[e,i]	2	–2147483648	2147483647	
Phase B Real Power	03, 04	KWB[e,f]	2	–2147483648	2147483647	
Phase B Real Power	03, 04	KWC[e,f]	2	–2147483648	2147483647	
Three-Phase Real Power	03, 04	KW3[f]	2	–2147483648	2147483647	
Phase A Reactive Power	03, 04	KVARA[e,f]	2	–2147483648	2147483647	
Phase B Reactive Power	03, 04	KVARB[e,f]	2	–2147483648	2147483647	
Phase C Reactive Power	03, 04	KVARC[e,f]	2	–2147483648	2147483647	
Three-Phase Reactive Power	03, 04	KVAR3[f]	2	–2147483648	2147483647	
Phase A Power Factor	03, 04	PFA[e,f]	1	–100	100	100
Phase B Power Factor	03, 04	PFB[e,f]	1	–100	100	100
Phase C Power Factor	03, 04	PFC[e,f]	1	–100	100	100
Three-Phase Power Factor	03, 04	PF3[f]	1	–100	100	100
Phase A PF Leading 0 = Lag 1 = Lead	03, 04	LDPFA[e,f]	1	0	1	
Phase B PF Leading 0 = Lag 1 = Lead	03, 04	LDPFB[e,f]	1	0	1	

Table 0.22 Modbus Quantities Table (Sheet 8 of 15)

Description	Valid Function Codes	SET_M Point Label/Enums[a]	Number of 16-Bit Registers	Min Value	Max Value	Scaling[b] (X1 unless specified)
Phase C PF Leading 0 = Lag 1 = Lead	03, 04	LDPFC[e,f]	1	0	1	
Three-Phase PF Leading 0 = Lag 1 = Lead	03, 04	LDPF3[f]	1	0	1	
Energy Data						
Phase A Real Energy IN	03, 04	MWHAI[e,f]	2	–2147483648	2147483647	
Phase B Real Energy IN	03, 04	MWHBI[e,f]	2	–2147483648	2147483647	
Phase C Real Energy IN	03, 04	MWHCI[e,f]	2	–2147483648	2147483647	
Three-Phase Real Energy IN	03, 04	MWH3I[f]	2	–2147483648	2147483647	
Phase A Real Energy OUT	03, 04	MWHAO[e,f]	2	–2147483648	2147483647	
Phase B Real Energy OUT	03, 04	MWHBO[e,f]	2	–2147483648	2147483647	
Phase C Real Energy OUT	03, 04	MWHCO[e,f]	2	–2147483648	2147483647	
Three-Phase Real Energy OUT	03, 04	MWH3O[f]	2	–2147483648	2147483647	
Phase A Reactive Energy IN	03, 04	MVRHAI[e,f]	2	–2147483648	2147483647	
Phase B Reactive Energy IN	03, 04	MVRHBI[e,f]	2	–2147483648	2147483647	
Phase C Reactive Energy IN	03, 04	MVRHCI[e,f]	2	–2147483648	2147483647	
Three-Phase Reactive Energy IN	03, 04	MVRH3I[f]	2	–2147483648	2147483647	
Phase A Reactive Energy OUT	03, 04	MVRHAO[e,f]	2	–2147483648	2147483647	
Phase B Reactive Energy OUT	03, 04	MVRHBO[e,f]	2	–2147483648	2147483647	
Phase C Reactive Energy OUT	03, 04	MVRHCO[e,f]	2	–2147483648	2147483647	
Three-Phase Reactive Energy OUT	03, 04	MVRH3O[f]	2	–2147483648	2147483647	
Demand Data						
Phase A Demand Current	03, 04	IADEM	1	0	65535	
Phase B Demand Current	03, 04	IBDEM	1	0	65535	
Phase C Demand Current	03, 04	ICDEM	1	0	65535	
Neutral Demand Current	03, 04	INDEM	1	0	65535	
Residual Ground Demand Current	03, 04	IGDEM	1	0	65535	
Neg. Seq. Demand Current	03, 04	3I2DEM	1	0	65535	
Phase A Real Power Demand IN	03, 04	KWADI[e,f]	2	–2147483648	2147483647	
Phase B Real Power Demand IN	03, 04	KWBDI[e,f]	2	–2147483648	2147483647	
Phase C Real Power Demand IN	03, 04	KWCDI[e,f]	2	–2147483648	2147483647	

Table O.22 Modbus Quantities Table (Sheet 9 of 15)

Description	Valid Function Codes	SET_M Point Label/Enums[a]	Number of 16-Bit Registers	Min Value	Max Value	Scaling[b] (X1 unless specified)
Three-Phase Real Power Demand IN	03, 04	KW3DI[f]	2	–2147483648	2147483647	
Phase A Reactive Power Demand IN	03, 04	KVRADI[e,f]	2	–2147483648	2147483647	
Phase B Reactive Power Demand IN	03, 04	KVRBDI[e,f]	2	–2147483648	2147483647	
Phase C Reactive Power Demand IN	03, 04	KVRCDI[e,f]	2	–2147483648	2147483647	
Three-Phase Reactive Power Demand IN	03, 04	KVR3DI[f]	2	–2147483648	2147483647	
Phase A Real Power Demand OUT	03, 04	KWADO[e,f]	2	–2147483648	2147483647	
Phase B Real Power Demand OUT	03, 04	KWBDO[e,f]	2	–2147483648	2147483647	
Phase C Real Power Demand OUT	03, 04	KWCDO[e,f]	2	–2147483648	2147483647	
Three-Phase Real Power Demand OUT	03, 04	KW3DO[f]	2	–2147483648	2147483647	
Phase A Reactive Power Demand OUT	03, 04	KVRADO[e,f]	2	–2147483648	2147483647	
Phase B Reactive Power Demand OUT	03, 04	KVRBDO[e,f]	2	–2147483648	2147483647	
Phase C Reactive Power Demand OUT	03, 04	KVRCDO[e,f]	2	–2147483648	2147483647	
Three-Phase Reactive Power Demand OUT	03, 04	KVR3DO[f]	2	–2147483648	2147483647	
Phase A Peak Demand Current	03, 04	IAPK	1	0	65535	
Phase B Peak Demand Current	03, 04	IBPK	1	0	65535	
Phase C Peak Demand Current	03, 04	ICPK	1	0	65535	
Neutral Peak Demand Current	03, 04	INPK	1	0	65535	
Residual Ground Peak Demand Current	03, 04	IGPK	1	0	65535	
Negative-Sequence Peak Demand Current	03, 04	3I2PK	1	0	65535	
Phase A Real Power Peak Demand IN	03, 04	KWAPI[e,f]	2	–2147483648	2147483647	
Phase B Real Power Peak Demand IN	03, 04	KWBPI[e,f]	2	–2147483648	2147483647	
Phase C Real Power Peak Demand IN	03, 04	KWCPI[e,f]	2	–2147483648	2147483647	
Three-Phase Real Power Peak Demand IN	03, 04	KW3PI[f]	2	–2147483648	2147483647	
Phase A Reactive Power Peak Demand IN	03, 04	KVRAPI[e,f]	2	–2147483648	2147483647	

Table O.22 Modbus Quantities Table (Sheet 10 of 15)

Description	Valid Function Codes	SET_M Point Label/Enums[a]	Number of 16-Bit Registers	Min Value	Max Value	Scaling[b] (X1 unless specified)
Phase B Reactive Power Peak Demand IN	03, 04	KVRBPI[e,f]	2	–2147483648	2147483647	
Phase C Reactive Power Peak Demand IN	03, 04	KVRCPI[e,f]	2	–2147483648	2147483647	
Three-Phase Reactive Power Peak Demand IN	03, 04	KVR3PI[f]	2	–2147483648	2147483647	
Phase A Real Power Peak Demand OUT	03, 04	KWAPO[e,f]	2	–2147483648	2147483647	
Phase B Real Power Peak Demand OUT	03, 04	KWBPO[e,f]	2	–2147483648	2147483647	
Phase C Real Power Peak Demand OUT	03, 04	KWCPO[e,f]	2	–2147483648	2147483647	
Three-Phase Real Power Peak Demand OUT	03, 04	KW3PO[f]	2	–2147483648	2147483647	
Phase A Reactive Power Peak Demand OUT	03, 04	KVRAPO[e,f]	2	–2147483648	2147483647	
Phase B Reactive Power Peak Demand OUT	03, 04	KVRBPO[e,f]	2	–2147483648	2147483647	
Phase C Reactive Power Peak Demand OUT	03, 04	KVRCPO[e,f]	2	–2147483648	2147483647	
Three-Phase Reactive Power Peak Demand OUT	03, 04	KVR3PO[f]	2	–2147483648	2147483647	
Harmonic Metering Data						
Phase A Current THD	03, 04	IAHT	1	0	995	
Phase B Current THD	03, 04	IBHT	1	0	995	
Phase C Current THD	03, 04	ICHT	1	0	995	
Neutral Current THD	03, 04	INHT	1	0	995	
Phase A Voltage THD	03, 04	VAHT[j]	1	0	995	
Phase B Voltage THD	03, 04	VBHT[g]	1	0	995	
Phase C Voltage THD	03, 04	VCHT[g]	1	0	995	
VS Voltage THD	03, 04	VSHT	1	0	995	
Phase A RMS Current	03, 04	IAHR	1	0	65535	
Phase B RMS Current	03, 04	IBHR	1	0	65535	
Phase C RMS Current	03, 04	ICHR	1	0	65535	
Neutral RMS Current	03, 04	INHR	1	0	65535	
Phase A RMS Voltage	03, 04	VAHR[g]	2	0	4294967295	
Phase B RMS Voltage	03, 04	VBHR[g]	2	0	4294967295	
Phase C RMS Voltage	03, 04	VCHR[g]	2	0	4294967295	
VS RMS Voltage	03, 04	VSHR	2	0	4294967295	
Phase A Fundamental Current (from harmonics calculation)	03, 04	IAH01	1	0	65535	
Phase B Fundamental Current (from harmonics calculation)	03, 04	IBH01	1	0	65535	

Table O.22 Modbus Quantities Table (Sheet 11 of 15)

Description	Valid Function Codes	SET_M Point Label/Enums[a]	Number of 16-Bit Registers	Min Value	Max Value	Scaling[b] (X1 unless specified)
Phase C Fundamental Current (from harmonics calculation)	03, 04	ICH01	1	0	65535	
Neutral Fundamental Current (from harmonics calculation)	03, 04	INH01	1	0	65535	
Phase A Fundamental Voltage (from harmonics calculation)	03, 04	VAH01[g]	2	0	4294967295	
Phase B Fundamental Voltage (from harmonics calculation)	03, 04	VBH01[g]	2	0	4294967295	
Phase C Fundamental Voltage (from harmonics calculation)	03, 04	VCH01[g]	2	0	4294967295	
VS Fundamental Voltage (from harmonics calculation)	03, 04	VSH01	2	0	4294967295	
Other Data						
System Frequency	03, 04	FREQ	1	4000	7000	100
Station DC Battery Voltage	03, 04	VDC	1	–5000	5000	10
Relay Internal Temperature	03, 04	TEMP	1	–400	1250	10
Breaker Monitor						
Internal Trip Counter	03, 04	INTTR	1	0	65535	
External Trip Counter	03, 04	EXTTR	1	0	65535	
Average Electrical Trip Operating Time, A-Phase	03, 04	EOTTRAAV	1	0	65535	10
Average Electrical Trip Operating Time, B-Phase	03, 04	EOTTRBAV	1	0	65535	10
Average Electrical Trip Operating Time, C-Phase	03, 04	EOTTRCAV	1	0	65535	10
Average Electrical Close Operating Time, A-Phase	03, 04	EOTCLAAV	1	0	65535	10
Average Electrical Close Operating Time, B-Phase	03, 04	EOTCLBAV	1	0	65535	10
Average Electrical Close Operating Time, C-Phase	03, 04	EOTCLCAV	1	0	65535	10
Average Mechanical Trip Operating Time	03, 04	MOTTRAV	1	0	65535	10
Average Mechanical Close Operating Time	03, 04	MOTCLAV	1	0	65535	10
Electrical Operating Time Alarm Counter	03, 04	ESOALCNT	1	0	65535	
Mechanical Operating Time Alarm Counter	03, 04	MSOALCNT	1	0	65535	
Breaker Wear A Phase	03, 04	WEARA	1	0	65535	
Breaker Wear B Phase	03, 04	WEARB	1	0	65535	

Table O.22 Modbus Quantities Table (Sheet 12 of 15)

Description	Valid Function Codes	SET_M Point Label/Enums[a]	Number of 16-Bit Registers	Min Value	Max Value	Scaling[b] (X1 unless specified)
Breaker Wear C Phase	03, 04	WEARC	1	0	65535	
Max Breaker Wear	03, 04	MAXWEAR	1	0	65535	
Modbus Communication Counters						
Num Messages Received	03, 04	MSGRCD	1	0	65535	
Num Msgs to Other devices (Other ID)	03, 04	MSGOID	1	0	65535	
Illegal Address	03, 04	ILLADDR	1	0	65535	
Bad CRC	03, 04	BADCRC	1	0	65535	
Uart Error	03, 04	UARTER	1	0	65535	
Illegal Function	03, 04	ILLFUNC	1	0	65535	
Illegal Register	03, 04	ILLREG	1	0	65535	
Illegal Data	03, 04	ILLDATA	1	0	65535	
Bad Packet Format	03, 04	BADPF	1	0	65535	
Bad Packet Length	03, 04	BADPL	1	0	65535	
Active Group						
Active Settings Group	03, 04, 06, 10h	**ACTGRP**[k]	1	1	6	
Relay Elements (Target Rows) (See *Appendix D: Relay Word Bits* for relay element row numbers and definitions)						
ROW 0	03, 04	ROW_0	1	0	255	
ROW 1	03, 04	ROW_1	1	0	255	
ROW 2	03, 04	ROW_2	1	0	255	
ROW 3	03, 04	ROW_3	1	0	255	
ROW 4	03, 04	ROW_4	1	0	255	
ROW 5	03, 04	ROW_5	1	0	255	
ROW 6	03, 04	ROW_6	1	0	255	
ROW 7	03, 04	ROW_7	1	0	255	
ROW 8	03, 04	ROW_8	1	0	255	
ROW 9	03, 04	ROW_9	1	0	255	
ROW 10	03, 04	ROW_10	1	0	255	
ROW 11	03, 04	ROW_11	1	0	255	
ROW 12	03, 04	ROW_12	1	0	255	
ROW 13	03, 04	ROW_13	1	0	255	
ROW 14	03, 04	ROW_14	1	0	255	
ROW 15	03, 04	ROW_15	1	0	255	
ROW 16	03, 04	ROW_16	1	0	255	
ROW 17	03, 04	ROW_17	1	0	255	
ROW 18	03, 04	ROW_18	1	0	255	
ROW 19	03, 04	ROW_19	1	0	255	
ROW 20	03, 04	ROW_20	1	0	255	
ROW 21	03, 04	ROW_21	1	0	255	
ROW 22	03, 04	ROW_22	1	0	255	

Table O.22 Modbus Quantities Table (Sheet 13 of 15)

Description	Valid Function Codes	SET_M Point Label/Enums[a]	Number of 16-Bit Registers	Min Value	Max Value	Scaling[b] (X1 unless specified)
ROW 23	03, 04	ROW_23	1	0	255	
ROW 24	03, 04	ROW_24	1	0	255	
ROW 25	03, 04	ROW_25	1	0	255	
ROW 26	03, 04	ROW_26	1	0	255	
ROW 27	03, 04	ROW_27	1	0	255	
ROW 28	03, 04	ROW_28	1	0	255	
ROW 29	03, 04	ROW_29	1	0	255	
ROW 30	03, 04	ROW_30	1	0	255	
ROW 31	03, 04	ROW_31	1	0	255	
ROW 32	03, 04	ROW_32	1	0	255	
ROW 33	03, 04	ROW_33	1	0	255	
ROW 34	03, 04	ROW_34	1	0	255	
ROW 35	03, 04	ROW_35	1	0	255	
ROW 36	03, 04	ROW_36	1	0	255	
ROW 37	03, 04	ROW_37	1	0	255	
ROW 38	03, 04	ROW_38	1	0	255	
ROW 39	03, 04	ROW_39	1	0	255	
ROW 40	03, 04	ROW_40	1	0	255	
ROW 41	03, 04	ROW_41	1	0	255	
ROW 42	03, 04	ROW_42	1	0	255	
ROW 43	03, 04	ROW_43	1	0	255	
ROW 44	03, 04	ROW_44	1	0	255	
ROW 45	03, 04	ROW_45	1	0	255	
ROW 46	03, 04	ROW_46	1	0	255	
ROW 47	03, 04	ROW_47	1	0	255	
ROW 48	03, 04	ROW_48	1	0	255	
ROW 49	03, 04	ROW_49	1	0	255	
ROW 50	03, 04	ROW_50	1	0	255	
ROW 51	03, 04	ROW_51	1	0	255	
ROW 52	03, 04	ROW_52	1	0	255	
ROW 53	03, 04	ROW_53	1	0	255	
ROW 54	03, 04	ROW_54	1	0	255	
ROW 55	03, 04	ROW_55	1	0	255	
ROW 56	03, 04	ROW_56	1	0	255	
ROW 57	03, 04	ROW_57	1	0	255	
ROW 58	03, 04	ROW_58	1	0	255	
ROW 59	03, 04	ROW_59	1	0	255	
ROW 60	03, 04	ROW_60	1	0	255	
ROW 61	03, 04	ROW_61	1	0	255	

Table O.22 Modbus Quantities Table (Sheet 14 of 15)

Description	Valid Function Codes	SET_M Point Label/Enums[a]	Number of 16-Bit Registers	Min Value	Max Value	Scaling[b] (X1 unless specified)
ROW 62	03, 04	ROW_62	1	0	255	
ROW 63	03, 04	ROW_63	1	0	255	
ROW 64	03, 04	ROW_64	1	0	255	
ROW 65	03, 04	ROW_65	1	0	255	
ROW 66	03, 04	ROW_66	1	0	255	
ROW 67	03, 04	ROW_67	1	0	255	
ROW 68	03, 04	ROW_68	1	0	255	
ROW 69	03, 04	ROW_69	1	0	255	
ROW 70	03, 04	ROW_70	1	0	255	
ROW 71	03, 04	ROW_71	1	0	255	
ROW 72	03, 04	ROW_72	1	0	255	
ROW 73	03, 04	ROW_73	1	0	255	
ROW 74	03, 04	ROW_74	1	0	255	
ROW 75	03, 04	ROW_75	1	0	255	
ROW 76	03, 04	ROW_76	1	0	255	
ROW 77	03, 04	ROW_77	1	0	255	
ROW 78	03, 04	ROW_78	1	0	255	
ROW 79	03, 04	ROW_79	1	0	255	
ROW 80	03, 04	ROW_80	1	0	255	
ROW 81	03, 04	ROW_81	1	0	255	
ROW 82	03, 04	ROW_82	1	0	255	
ROW 83	03, 04	ROW_83	1	0	255	
ROW 84	03, 04	ROW_84	1	0	255	
ROW 85	03, 04	ROW_85	1	0	255	
ROW 86	03, 04	ROW_86	1	0	255	
ROW 87	03, 04	ROW_87	1	0	255	
ROW 88	03, 04	ROW_88	1	0	255	
ROW 89	03, 04	ROW_89	1	0	255	
ROW 90	03, 04	ROW_90	1	0	255	
ROW 91	03, 04	ROW_91	1	0	255	
ROW 92	03, 04	ROW_92	1	0	255	
ROW 93	03, 04	ROW_93	1	0	255	
ROW 94	03, 04	ROW_94	1	0	255	
ROW 95	03, 04	ROW_95	1	0	255	
ROW 96	03, 04	ROW_96	1	0	255	
ROW 97	03, 04	ROW_97	1	0	255	
ROW 98	03, 04	ROW_98	1	0	255	
ROW 99	03, 04	ROW_99	1	0	255	
ROW 100	03, 04	ROW_100	1	0	255	

Table O.22 Modbus Quantities Table (Sheet 15 of 15)

Description	Valid Function Codes	SET_M Point Label/Enums[a]	Number of 16-Bit Registers	Min Value	Max Value	Scaling[b] (X1 unless specified)
ROW 101	03, 04	ROW_101	1	0	255	
ROW 102	03, 04	ROW_102	1	0	255	

[a] Point names appearing in bold can be written with function code 06h or 10h.
[b] Scaling occurs prior to Min/Max Value check.
[c] If the fault location is undefined, Modbus will report the value as 32767.
[d] Current is controlled by Global Setting FLTDISP. When FLTDISP = MAX, registers are populated with currents from the maximum fault row. When FLTDISP = FL, registers are populated with fault locator currents. See *Standard Event Report Summary* on page 12.6.
[e] Breaker Close and Breaker Open are mutually exclusive and the relay asserts neither bit and returns the Exception Response if an attempt is made to write both bits.
[f] When PTCONN = DELTA, the relay returns phase-to-phase values for voltage labels VA, VB, VC, VAFA, VBFA, VCFA (i.e., VA returns VAB, VB returns VBC, and VC returns VCA).
[g] Voltage symmetrical component metering values forced to 0.00 when Global setting PTCONN = SINGLE.
[h] Zero-sequence voltage, and per-phase power, power factor, demand power, peak demand power, and energy values are not available when PTCONN = DELTA. The Modbus map may contain these labels, and the relay will return values of 0.00, except for power factors which will be reported as 1.00.
[i] Power factors forced to 1.00 lagging, metering power, energy, and related demand values forced to 0.00 when Global settings PTCONN = SINGLE and PHANTV = OFF.
[j] When Global setting PTCONN = DELTA, harmonic labels for VA returns VAB, VB returns 0.00, and VC returns VBC.
[k] The active settings group can be modified by writing the desired settings group number to ACTGRP. If any of the SELOGIC Group Switch equations SS1–SS6 are asserted, the write is accepted but the active group will not change.

Default Modbus Map and Modbus Addresses

The default user map entries and correlation to Modbus address fields are defined in *Table O.23*. Use the **SET M** and **SHO M** commands to modify or view these map settings, or QuickSet to manage the Modbus mapping.

Table O.23 Default Modbus Map (Sheet 1 of 2)

Modbus Address	User Map Register	Mapped Register Label[a]	Notes
000	MOD_001	IA	
001	MOD_002	IAFA	
002	MOD_003	IB	
003	MOD_004	IBFA	
004	MOD_005	IC	
005	MOD_006	ICFA	
006	MOD_007	IG	
007	MOD_008	IGFA	
008	MOD_009	IN	
009	MOD_010	INFA	
010	MOD_011	**VA**	VA contains VAB for PTCONN = DELTA
012	MOD_013	VAFA	VAFA contains VABFA angle for PTCONN = DELTA
013	MOD_014	**VB**	VB contains VBC for PTCONN = DELTA
015	MOD_016	VBFA	VBFA contains VBCFA angle for PTCONN = DELTA
016	MOD_017	**VC**	VC contains VCA for PTCONN = DELTA
018	MOD_019	VCFA	VCFA contains VCAFA angle for PTCONN = DELTA

Table O.23 Default Modbus Map (Sheet 2 of 2)

Modbus Address	User Map Register	Mapped Register Label[a]	Notes
019	MOD_020	**VS**	
021	MOD_022	VSFA	
022	MOD_023	**KW3**	
024	MOD_025	**KVAR3**	
026	MOD_027	PF3	
027	MOD_028	LDPF3	
028	MOD_029	FREQ	
029	MOD_030	VDC	
030	MOD_031	**MWH3I**	
032	MOD_033	**MWH3O**	
034	MOD_035	**MVRH3I**	
036	MOD_037	**MVRH3O**	
038	MOD_039	ACTGRP	
039	MOD_040	ROW_0	Front panel indicator LEDs
040	MOD_041	ROW_1	Front panel indicator LEDs
041	MOD_042	ROW_35	Contains 79RS, 79CY, 79LO
042	MOD_043	ROW_37	Contains 52A
043–249	MOD_044–MOD_250	Not Assigned	
250–1000		Reserved	
1001–1016		RID	Value of setting RID, two characters per register[b]
1017–1032		TID	Value of setting TID, two characters per register[b]

[a] Register labels appearing in bold are 32-bit quantities and consume two registers.

[b] Modbus Addresses 1001–1032 contain string data. Strings are packed 2 characters per register, with the most significant bit containing the character closest to the beginning of the string.

Reading Event Data Using Modbus

The SEL-351 provides a feature that allows relay event history data to be retrieved via Modbus. The Event History registers are listed in *Table O.22* under the Historical Data description heading. To read the history data, set the Modbus Map to contain the EVESEL label, along with the other Fault History related labels. The following example shows some of the available history data labels in the Modbus Map:

```
=>>SHO M <Enter>

MOD_001 = NUMEVE
MOD_002 = EVESEL
MOD_003 = FTIME_S
MOD_004 = FTIME_M
MOD_005 = FTIME_H
MOD_006 = FDATE_D
MOD_007 = FDATE_M
MOD_008 = FDATE_Y
MOD_009 = FLOC
MOD_010 = FI
MOD_011 = FIA
MOD_012 = FIB
MOD_013 = FIC
MOD_014 = FIG
MOD_015 = FIN
MOD_016 = FFREQ
MOD_017 = FGRP
MOD_018 = FSHO
MOD_019 = EVE_TYPE
```

Use Modbus function code 03 or 04 to read the Modbus registers. The NUMEVE label will contain the number of events listed in the event history, **HIS** command, and response. To read relay event history data using Modbus, use function code 06 to write the event number to the Modbus register containing the EVESEL label. The SEL-351 will populate the other event related registers with the data related to the event number specified in the EVESEL label address. Issue a Modbus function code 03 or 04 command to read the registers containing the history data.

For example, use the following relay response to the **HIS** command:

```
=>>HIS <Enter>
FEEDER 1                           Date: 06/05/01    Time: 13:32:54.127
STATION A

# DATE     TIME         EVENT    LOCAT    CURR   FREQ  GRP SHOT   TARGETS
1 06/05/13 04:14:19.950 ABC T    64.93    2144   60.00  1    1    ZONE 1
2 12/06/13 08:31:50.978 ABG T    94.95    9983   60.00  1    1    INST SOTF 50 51
   81
3 02/13/14 12:25:44.449 PULSE    26.92    1830   60.00  2    1    TRIP SOTF
4 06/22/14 07:18:19.088 AG T      9.65    2279   60.00  3    1    TIME 51
```

Retrieve the history data in this example for event number 4, using the map shown above, by setting register address 0001 to the value of 4 using a function code 06 command. (Note: The Modbus Map is indexed beginning with 1, which corresponds to register address 0 in Modbus). If a value is written to the EVESEL register for an event that does not currently exist in the history data, the SEL-351 will respond with an exception code 03.

Following the function code 06 command, issue a function code 03 or 04 command to read registers 0–18. The data returned in registers 2–18 would contain the event time, event date, fault location, maximum fault current, fault current per phase, ground fault current, neutral fault current, the frequency, settings group, number of shots, and event type associated with event number 4.

The **HIS E** command returns the same history data, but uses a unique event number in the range 10000 to 65535. The relay will also return the history data if the unique event number is written to the EVESEL register as long as that event is currently in the history data.

```
=>>HIS E <Enter>
FEEDER 1                          Date: 06/05/01    Time: 13:36:29.192
STATION A

#     DATE     TIME          EVENT  LOCAT  CURR  FREQ   GRP SHOT  TARGETS
10007 06/05/13 04:14:19.950  ABC T  64.93  2144  60.00   1   1    ZONE 1
10006 12/06/13 08:31:50.978  ABG T  94.95  9983  60.00   1   1    INST SOTF 50 51
   81
10005 02/13/14 12:25:44.449  PULSE  26.92  1830  60.00   2   1    TRIP SOTF
10004 06/22/14 07:18:19.088  AG T    9.65  2279  60.00   3   1    TIME 51
```

When the history data are cleared in the relay, either from the **HIS C** command or from a remote control point, the NUMEVE register will contain the value of 0, indicating there are no events that can be read using Modbus. The Modbus fault data registers may contain data from a past event, until a new valid event number is written to the EVESEL register.

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Modbus Settings Sheets

Modbus Map Settings (SET M Command)

Modbus User Map

See *Table O.22* for list of valid labels.

NOTE: 32-bit values, such as VA, VB, and VC consume two registers. When assigning registers, skip the registers following a 32-bit value to avoid errors in settings.

User Map Register Label Name	**MOD_001 :=** ________________
User Map Register Label Name	**MOD_002 :=** ________________
User Map Register Label Name	**MOD_003 :=** ________________
User Map Register Label Name	**MOD_004 :=** ________________
User Map Register Label Name	**MOD_005 :=** ________________
User Map Register Label Name	**MOD_006 :=** ________________
User Map Register Label Name	**MOD_007 :=** ________________
User Map Register Label Name	**MOD_008 :=** ________________
User Map Register Label Name	**MOD_009 :=** ________________
User Map Register Label Name	**MOD_010 :=** ________________
User Map Register Label Name	**MOD_011 :=** ________________
User Map Register Label Name	**MOD_012 :=** ________________
User Map Register Label Name	**MOD_013 :=** ________________
User Map Register Label Name	**MOD_014 :=** ________________
User Map Register Label Name	**MOD_015 :=** ________________
User Map Register Label Name	**MOD_016 :=** ________________
User Map Register Label Name	**MOD_017 :=** ________________
User Map Register Label Name	**MOD_018 :=** ________________
User Map Register Label Name	**MOD_019 :=** ________________
User Map Register Label Name	**MOD_020 :=** ________________
User Map Register Label Name	**MOD_021 :=** ________________
User Map Register Label Name	**MOD_022 :=** ________________
User Map Register Label Name	**MOD_023 :=** ________________
User Map Register Label Name	**MOD_024 :=** ________________
User Map Register Label Name	**MOD_025 :=** ________________
User Map Register Label Name	**MOD_026 :=** ________________
User Map Register Label Name	**MOD_027 :=** ________________
User Map Register Label Name	**MOD_028 :=** ________________
User Map Register Label Name	**MOD_029 :=** ________________

User Map Register Label Name	**MOD_030 :=** ________________
User Map Register Label Name	**MOD_031 :=** ________________
User Map Register Label Name	**MOD_032 :=** ________________
User Map Register Label Name	**MOD_033 :=** ________________
User Map Register Label Name	**MOD_034 :=** ________________
User Map Register Label Name	**MOD_035 :=** ________________
User Map Register Label Name	**MOD_036 :=** ________________
User Map Register Label Name	**MOD_037 :=** ________________
User Map Register Label Name	**MOD_038 :=** ________________
User Map Register Label Name	**MOD_039 :=** ________________
User Map Register Label Name	**MOD_040 :=** ________________
User Map Register Label Name	**MOD_041 :=** ________________
User Map Register Label Name	**MOD_042 :=** ________________
User Map Register Label Name	**MOD_043 :=** ________________
User Map Register Label Name	**MOD_044 :=** ________________
User Map Register Label Name	**MOD_045 :=** ________________
User Map Register Label Name	**MOD_046 :=** ________________
User Map Register Label Name	**MOD_047 :=** ________________
User Map Register Label Name	**MOD_048 :=** ________________
User Map Register Label Name	**MOD_049 :=** ________________
User Map Register Label Name	**MOD_050 :=** ________________
User Map Register Label Name	**MOD_051 :=** ________________
User Map Register Label Name	**MOD_052 :=** ________________
User Map Register Label Name	**MOD_053 :=** ________________
User Map Register Label Name	**MOD_054 :=** ________________
User Map Register Label Name	**MOD_055 :=** ________________
User Map Register Label Name	**MOD_056 :=** ________________
User Map Register Label Name	**MOD_057 :=** ________________
User Map Register Label Name	**MOD_058 :=** ________________
User Map Register Label Name	**MOD_059 :=** ________________
User Map Register Label Name	**MOD_060 :=** ________________
User Map Register Label Name	**MOD_061 :=** ________________
User Map Register Label Name	**MOD_062 :=** ________________
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APPENDIX P

IEC 61850

Features

NOTE: The SEL-351 supports one CID file, which should be transferred only if a change in the relay configuration is required.

The SEL-351 Relay supports the following features using Ethernet and IEC 61850:

- **SCADA**—Connect as many as seven simultaneous IEC 61850 MMS client sessions. The SEL-351 also supports as many as seven buffered and seven unbuffered report control blocks. See the CON Logical Device Table for Logical Node mapping that enables SCADA control via a Manufacturing Messaging Specification (MMS) browser. Controls support the direct control, select before operate control (SBO), and SBO with enhanced security control models.
- **Peer-to-Peer Real-Time Status and Control**—Use GOOSE with as many as 24 incoming (receive) and 8 outgoing (transmit) messages. Virtual bits (VB001–VB128) can be mapped from incoming GOOSE messages.
- **Configuration**—Use FTP client software, an MMS file transfer utility, or ACSELERATOR Architect SEL-5032 Software to transfer the Substation Configuration Language (SCL) Configured IED Description (CID) file to the relay.
- **Commissioning and Troubleshooting**—Use the SEL Real Time Automation Controller (RTAC) as an MMS client to poll data sets in the relay or use IEC 61850 MMS client software to browse the relay logical nodes and verify functionality.
- **IEC 61850 Standard**—IEC 61850 Standard, Edition 1 is supported unless noted otherwise.

This section presents the information you need to use the IEC 61850 features of the SEL-351:

Introduction to IEC 61850

In the early 1990s, the Electric Power Research Institute (EPRI) and the Institute of Electrical and Electronics Engineers, Inc. (IEEE) began to define a Utility Communications Architecture (UCA). They initially focused on inter-control center and substation-to-control center communications and produced the Inter-

Control Center Communications Protocol (ICCP) specification. This specification, later adopted by the IEC as 60870-6 TASE.2, became the standard protocol for real-time exchange of data between databases.

In 1994, EPRI and IEEE began work on UCA 2.0 for Field Devices (simply referred to as UCA2). In 1997, they combined efforts with Technical Committee 57 of the IEC to create a common international standard. Their joint efforts created the current IEC 61850 standard.

The IEC 61850 standard, a superset of UCA2, contains most of the UCA2 specification, plus additional functionality. The standard describes client/server and peer-to-peer communications, substation design and configuration, testing, and project standards.

The IEC 61850 standard consists of the parts listed in *Table P.1*.

Table P.1 IEC 61850 Document Set

IEC 61850 Sections	Definitions
IEC 61850-1	Introduction and overview
IEC 61850-2	Glossary
IEC 61850-3	General requirements
IEC 61850-4	System and project management
IEC 61850-5	Communication requirements
IEC 61850-6	Configuration description language for substation IEDs
IEC 61850-7-1	Basic communication structure for substations and feeder equipment—Principles and models
IEC 61850-7-2	Basic communication structure for substations and feeder equipment—Abstract communication service interface (ACSI)
IEC 61850-7-3	Basic communication structure for substations and feeder equipment—Common data classes
IEC 61850-7-4	Basic communication structure for substations and feeder equipment—Compatible logical node (LN) classes and data classes
IEC 61850-8-1	SCSM—Mapping to Manufacturing Messaging Specification (MMS) (ISO/IEC 9506-1 and ISO/IEC 9506-2 over ISO/IEC 8802-3)
IEC 61850-9-1	SCSM—Sampled values over serial multidrop point-to-point link
IEC 61850-9-2	SCSM—Sampled values over ISO/IEC 8802-3
IEC 61850-10	Conformance testing

The IEC 61850 document set, available directly from the IEC at http://www.iec.ch, contains information necessary for successful implementation of this protocol. SEL strongly recommends that anyone involved with the design, installation, configuration, or maintenance of IEC 61850 systems be familiar with the appropriate sections of this standard.

IEC 61850 Operation

Ethernet Networking

IEC 61850 and Ethernet networking model options are available when ordering a new SEL-351 and may also be available as field upgrades to relays equipped with dual copper and dual or single fiber-optic Ethernet. In addition to IEC 61850, the relay provides support protocols and data exchange, including FTP and Telnet. Access the SEL-351 Port 5 settings to configure all of the Ethernet settings, including IEC 61850 enable settings.

The SEL-351 supports IEC 61850 services, including transport of Logical Node objects, over TCP/IP. The relay can coordinate a maximum of seven concurrent IEC 61850 sessions.

Object Models

The IEC 61850 standard relies heavily on the Abstract Communication Service Interface (ACSI) models to define a set of services and the responses to those services. In terms of network behavior, abstract modeling enables all IEDs to act identically. These abstract models are used to create objects (data items) and services that exist independently of any underlying protocols. These objects are in conformance with the common data class (CDC) specification IEC 61850-7-3, which describes the type and structure of each element within a logical node. CDCs for status, measurements, controllable analogs and statuses, and settings all have unique CDC attributes. Each CDC attribute belongs to a set of functional constraints that groups the attributes into specific categories such as status (ST), description (DC), and substituted value (SV). Functional constraints, CDCs, and CDC attributes are used as building blocks for defining Logical Nodes.

UCA2 used GOMSFE (Generic Object Models for Substation and Feeder Equipment) to present data from station IEDs as a series of objects called models or bricks. The IEC working group has incorporated GOMSFE concepts into the standard, with some modifications to terminology; one change was the renaming of bricks to logical nodes. Each logical node represents a group of data (controls, status, measurements, etc.) associated with a particular function. For example, the MMXU logical node (polyphase measurement unit) contains measurement data and other points associated with three-phase metering including voltages and currents. Each IED may contain many functions such as protection, metering, and control. Multiple logical nodes represent the functions in multifunction devices.

Logical nodes can be organized into logical devices that are similar to directories on a computer disk. As represented in the IEC 61850 network, each physical device can contain many logical devices and each logical device can contain many logical nodes. Many relays, meters, and other IEC 61850 devices contain one primary logical device where all models are organized.

IEC 61850 devices are capable of self-description. You do not need to refer to the specifications for the logical nodes, measurements, and other components to request data from another IEC 61850 device. IEC 61850 clients can request and display a list and description of the data available in an IEC 61850 server device. This process is similar to the autoconfiguration process used within SEL communications processors (SEL-2032 and SEL-2030). Simply run an MMS browser to query devices on an IEC 61850 network and discover what data are available. Self-description also permits extensions to both standard and custom data models. Instead of having to look up data in a profile stored in its database, an IEC 61850 client can simply query an IEC 61850 device and receive a description of all logical devices, logical nodes, and available data.

Unlike other Supervisory Control and Data Acquisition (SCADA) protocols that present data as a list of addresses or indices, IEC 61850 presents data with descriptors in a composite notation made up of components. *Table P.2* shows how the A-Phase current expressed as METMMXU1AphsA$cVal is broken down into its component parts. The Data Attribute is characterized (filtered) by a functional constraint (FC) property. The supported FCs are listed in *Table P.3*. The FC for the given example above is MX.

Table P.2 Example IEC 61850 Descriptor Components

Component		Description
METMMXU1	Logical Node	Polyphase measurement unit
A	Data Object	Phase-to-ground amperes
phsA	Sub-Data Object	Phase A
cVal	Data Attribute	Complex value

Table P.3 Functional Constraints

FC	Description
ST	Status information
MX	Measurements (analog values)
CO	Control
CF	Configuration
DC	Description
EX	Extended definition

Data Mapping

Device data are mapped to IEC 61850 Logical Nodes (LN) according to rules defined by SEL. Refer to IEC 61850-5:2003(E) and IEC 61850-7-4:2003(E) for the mandatory content and usage of these LNs. The SEL-351 logical nodes are grouped under Logical Devices for organization based on function. See *Table P.4* for descriptions of the Logical Devices in an SEL-351. See *Logical Nodes* on page P.29 for a description of the LNs that make up these Logical Devices.

Table P.4 SEL-351 Logical Devices

Logical Device	Description
ANN	Annunciator elements—alarms, status values
CFG	Configuration elements—data sets and report control blocks
CON	Control elements—remote bits
MET	Metering or Measurement elements—currents, voltages, power, etc.
PRO	Protection elements—protection functions and breaker control

MMS

Manufacturing Messaging Specification (MMS) provides services for the application-layer transfer of real-time data within a substation LAN. MMS was developed as a network independent data exchange protocol for industrial networks in the 1980s and standardized as ISO 9506.

In theory, you can map IEC 61850 to any protocol. However, it can become unwieldy and quite complicated to map objects and services to a protocol that only provides access to simple data points via registers or index numbers. MMS supports complex named objects and flexible services that enable mapping to IEC 61850 in a straightforward manner. This was why the UCA users group used MMS for UCA from the start, and why the IEC chose to keep it for IEC 61850.

Event files and Reports are also available through MMS. See *File Transfer Protocol (FTP) and MMS File Transfer* on page 10.22, *Retrieving COMTRADE Event Files* on page 12.15, and *Retrieving Event Reports Via Ethernet File Transfer* on page 12.19.

If MMS authentication is enabled, the device authenticates each MMS association by requiring the client to provide the password authentication parameter with a value that is equal to the 2AC password of the SEL-351.

- ➤ If the correct password authentication parameter is not received, the device returns a not authenticated error code.
- ➤ If the correct password authentication parameter value is received, the device gives a successful association response.

Once an authenticated association is established, the device allows access to all supported MMS services for that association.

GOOSE

The Generic Object Oriented Substation Event (GOOSE) object within IEC 61850 is for high-speed control messaging. IEC 61850 GOOSE automatically broadcasts messages containing status, controls, and measured values onto the network for use by other devices. IEC 61850 GOOSE sends the message several times, increasing the likelihood that other devices receive the messages. GOOSE message publication is a persistent function. Once GOOSE is enabled, the IED will continuously publish GOOSE messages until they are disabled regardless of the contents. The publication process description indicates when and why the publication rate changes.

IEC 61850 GOOSE objects can quickly and conveniently transfer status, controls, and measured values between peers on an IEC 61850 network. Configure SEL devices to respond to GOOSE messages from other network devices with Architect. Also, configure outgoing GOOSE messages for SEL devices in Architect. See the Architect instruction manual or online help for more information.

Each IEC 61850 GOOSE sender includes a text identification string (GOOSE Control Block Reference), APP ID field, and an Ethernet multicast group address, in each outgoing message. Some devices that receive GOOSE messages use the text identification and multicast group to identify and filter incoming GOOSE messages. The SEL-351 uses only the APP ID and multicast group to identify and filter incoming GOOSE messages.

Virtual bits (VB001–VB128) are control inputs that you can map to GOOSE receive messages using the Architect software. If you intend to use any SEL-351 virtual bits for controls, you must create SELOGIC control equations to define these operations.

File Services

The Ethernet file system allows reading or writing data as files. The file system supports FTP and MMS file transfer. The file system provides:

- A means for the device to transfer data as files.
- A hierarchical file structure for the device data.

The SEL-351 supports MMS file transfer with or without authentication.

The service is intended to support the following:

- CID file download and upload
- Retrieval of events, reports, and relay diagnostics

MMS file services are enabled or disabled via Port 5 settings. See *Virtual File Interface* on page 10.26 for details on the files available for MMS file services.

SCL Files

Substation Configuration Language (SCL) is an XML-based configuration language used to support the exchange of database configuration data between different tools, which may come from different manufacturers. There are four types of SCL files:

- Intelligent Electronic Device (IED) Capability Description file (.ICD)
- System Specification Description (.SSD) file
- Substation Configuration Description file (.SCD)
- Configured IED Description file (.CID)

The ICD file describes the capabilities of an IED, including information on LN and GOOSE support. The SSD file describes the single-line diagram of the substation and the required LNs. The SCD file contains information on all IEDs, communications configuration data, and a substation description. The CID file, of which there may be several, describes a single instantiated IED within the project, and includes address information.

Datasets

Datasets are configured using Architect and contain data attributes which represent real data values within the SEL-351 device. See *Logical Nodes* for the logical node tables that list the available data attributes for each logical node and the Relay Word bit mapping for these data attributes. The list of data sets in *Figure P.1* are the defaults for an SEL-351 device. Datasets BRDSet01 through BRDSet07 and URDSet01 through URDSet07 are preconfigured with common FCDAs to be used for reporting. These data sets can be configured to represent the desired data to be monitored. Dataset GPDSet01 is a preconfigured example data set used for the example GOOSE publication GPub01.

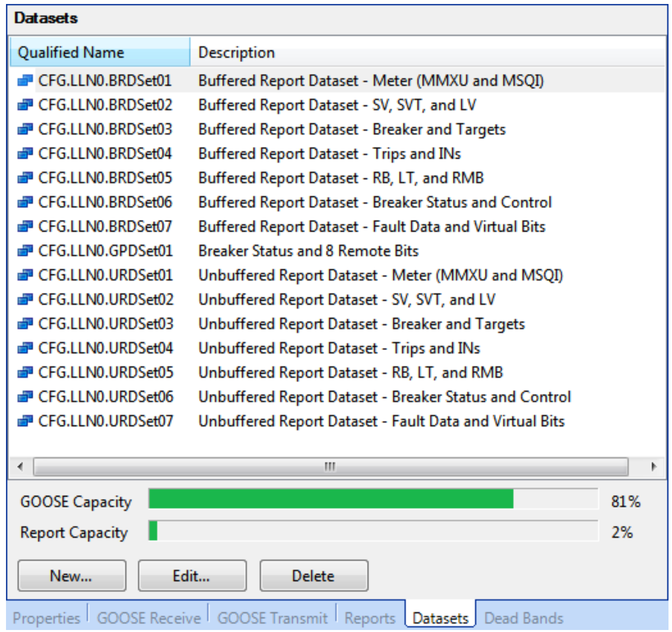


Figure P.1 SEL-351 Datasets

Within Architect, IEC 61850 data sets have the following purposes:

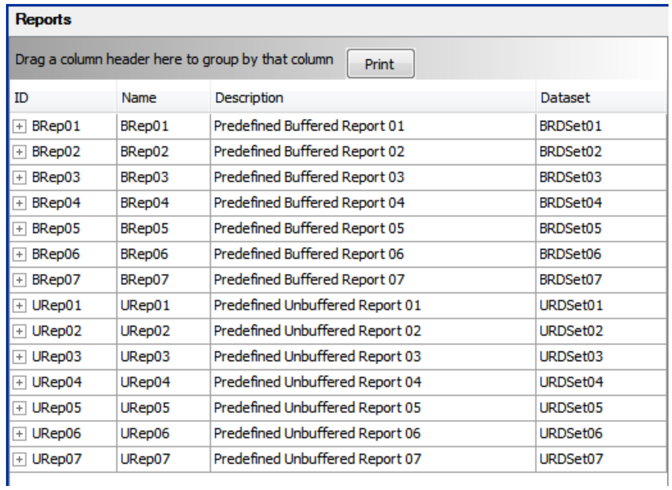
- GOOSE: You can use predefined or edited data sets, or create new data sets for outgoing GOOSE transmission.
- Reports: Fourteen predefined data sets (BRDSet01 through BRDSet07 and URDSet01 through URDSet07) correspond to the default seven buffered and seven unbuffered reports. Note that you cannot change the number (14) or type of reports (buffered or unbuffered) within Architect. However, you can alter the data attributes that a data set contains and so define what data an IEC 61850 client receives with a report.
- MMS: You can use predefined or edited data sets, or create new data sets to be monitored by MMS clients.

NOTE: Do not edit the data set names used in reports (data sets 1–12). Changing or deleting any of those data set names will cause a failure in generating the corresponding report.

Reports

The SEL-351 implements the IEC 61850 reporting service as part of its server functionality. The reporting service includes the functionality necessary to configure, manage, and send IEC 61850 buffered and unbuffered reports as unsolicited reports, periodic integrity reports, or as the result of a general interrogation. See the IEC 61850 standard, Part 7-1, Section 6.4.3.3, Part 7-2, Section 14, and Part 8-1, Section 17 for more details on the IEC 61850 reporting service.

A total of 14 predefined reports (seven buffered and seven unbuffered) are supported. The predefined reports and the data sets assigned to each report are shown in *Figure P.2* and are available by default via IEC 61850. The number of reports (14), the data set assigned to each report, and the type of reports (buffered or unbuffered) cannot be changed. However, by using Architect, you can reallocate data within each report data set to present different data attributes for each report beyond the predefined data sets.



Reports

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ID	Name	Description	Dataset
BRep01	BRep01	Predefined Buffered Report 01	BRDSet01
BRep02	BRep02	Predefined Buffered Report 02	BRDSet02
BRep03	BRep03	Predefined Buffered Report 03	BRDSet03
BRep04	BRep04	Predefined Buffered Report 04	BRDSet04
BRep05	BRep05	Predefined Buffered Report 05	BRDSet05
BRep06	BRep06	Predefined Buffered Report 06	BRDSet06
BRep07	BRep07	Predefined Buffered Report 07	BRDSet07
URep01	URep01	Predefined Unbuffered Report 01	URDSet01
URep02	URep02	Predefined Unbuffered Report 02	URDSet02
URep03	URep03	Predefined Unbuffered Report 03	URDSet03
URep04	URep04	Predefined Unbuffered Report 04	URDSet04
URep05	URep05	Predefined Unbuffered Report 05	URDSet05
URep06	URep06	Predefined Unbuffered Report 06	URDSet06
URep07	URep07	Predefined Unbuffered Report 07	URDSet07

Figure P.2 SEL-351 Predefined Reports

For each buffered report control block (BRCB), there can be just one client association, i.e., only one client can be associated to a BRCB at any given time. The client association occurs when the client enables the RptEna attribute of the BRCB. Once enabled, the associated client has exclusive access to the BRCB until the connection is closed or the client disables the RptEna attribute. Once enabled, all unassociated clients have read-only access to the BRCB and the associated client will be the only client that receives buffered report data. The BRCB parameters are shown in *Table P.5*.

Table P.5 Buffered Report Control Block Client Access (Sheet 1 of 2)

RCB Attribute	User Changeable (Report Disabled)	User Changeable (Report Enabled)	Default Values
RptId	YES		BRep01–BRep07
RptEna	YES	YES	FALSE
DatSet	YES		BRDSet01–BRDSet07
ConfRev			1
OptFlds	YES		0111100100
reserved			
sequence-number			TRUE
report-time-stamp			TRUE
reason-for-inclusion			TRUE
data-set-name			TRUE
data-reference			FALSE
buffer-overflow			FALSE
entryID			TRUE
conf-revision			FALSE
segmentation			
BufTm	YES		500
SqNum			0
TrgOps	YES		011011

Table P.5 Buffered Report Control Block Client Access (Sheet 2 of 2)

RCB Attribute	User Changeable (Report Disabled)	User Changeable (Report Enabled)	Default Values
reserved			
dchg			TRUE
qchg			TRUE
dupd[a]			
integrity			TRUE
gi			TRUE
IntgPd	YES		0
GI	YES[b,c]	YES[b]	FALSE
PurgeBuf	YES		FALSE
EntryId	YES		00 00 00 00 00 00 00 00
TimeofEntry			

[a] TrgOps data update (dupd) is not supported.

[b] Exhibits a pulse behavior. Write a one to issue the command. Once command is accepted will return to zero. Always read as zero.

[c] When disabled, a GI will be processed and the report buffered if a buffer has been previously established. A buffer is established when the report is enabled for the first time.

Once a BRCB has been enabled, a report buffer is established. The buffer is sized to contain 10 complete reports with a size hard coded in the SEL-351 ICD file. However, in cases where the report data set is smaller than the allowed maximum size, or when the encoded report does not include the entire data set, as many as 200 reports may appear in the buffer. Reports are maintained in the buffer regardless of having been sent. This allows the client to retrieve reports that have already been sent by writing an EntryID prior to the current EntryID.

When a client sets the RptEna attribute of a BRCB to true, all new reports contained in the report buffer, starting from the buffer entry following the EntryID attribute specified in the BRCB until the most current buffered report are sent. At this time, new reports will be sent as required by normal report processing. This behavior allows the client to write the last received EntryID to the BRCB before enabling the report in an attempt to retrieve all report entries that were lost during a lapse in the client association.

When insertion of a new report into a report buffer would cause the buffer size to be exceeded, the oldest entries in the buffer are discarded until the buffer size has been reduced sufficiently to allow the new report to be added to the buffer. If the reports removed from the buffer have not yet been sent to the client, a buffer overflow indication is set in the next report queued for transmission to indicate that reports have been lost. The buffer overflow indication is reported in the BufOvfl field of the report if the buffer overflow OptFld has been enabled in the BRCB.

The contents of a report buffer are deleted when a PurgeBuf is commanded by a client. As noted in the requirements for the BRCB, the PurgeBuf can only be commanded when the report is disabled. The buffer overflow indication is cleared when the client commands a PurgeBuf. Additionally, the buffered reports will be purged if any of the BRCB attributes RptID, DatSet, BufTm, TrgOps, or IntgPd are modified by the client while the report is disabled.

For each unbuffered control block (URCB), there can be up to six client associations. The client association occurs when the client enables the RptEna attribute of the URCB. Once enabled, each client has independent access to its instance of the URCB and all associated clients receive unbuffered report data. The URCB parameters are shown in *Table P.6*.

The URCB Resv attribute is writable, however, the SEL-351 does not support reservations. Writing any field of the URCB causes the client to obtain their own instance of the URCB—in essence, acquiring a reservation.

Table P.6 Unbuffered Report Control Block Client Access

RCB Attribute	User Changeable (Report Disabled)	User Changeable (Report Enabled)	Default Values
RptId	YES		URep01–URep07
RptEna	YES	YES	FALSE
Resv	YES		FALSE
DatSet	YES		URDSet01–URDSet07
ConfRev			1
OptFlds	YES		0111100000
reserved			
sequence-number			TRUE
report-time-stamp			TRUE
reason-for-inclusion			TRUE
data-set-name			TRUE
data-reference			FALSE
buffer-overflow			FALSE
entryID			TRUE
conf-revision			FALSE
segmentation			
BufTm	YES		250
SqNum			0
TrgOps	YES		011011
reserved			
dchg			TRUE
qchg			TRUE
dupd[a]			
integrity			TRUE
gi			TRUE
IntgPd	YES		0
GI		YES[b]	FALSE

[a] TrgOps data update (dupd) is not supported.
[b] Exhibits a pulse behavior. Write a one to issue the command. Once command is accepted will return to zero. Always read as zero.

NOTE: The TrgOp data update is not supported by the SEL-351 device.

The IEC 61850 standard defines the trigger options (TrgOp) of data change, quality change, and data update. These TrgOps allow reports to be filtered to report only changes associated with the selected TrgOps. Additionally, each of these

TrgOps is only associated with or valid for certain data attributes. The valid TrgOps for any given data attribute is described in the Common Data Class (CDC) Descriptions contained within the IEC standard, Part 7-3.

When a client has enabled the RptEna attribute of a BRCB or an URCB, and any of the data change or quality change TrgOps are enabled within the same BRCB or URCB, the SEL-351 sends an unsolicited report to that client upon detecting a change on an FCDA with a reason corresponding to one of the enabled TrgOps. The unsolicited report contains only those FCDAs that have been detected to have changed for a reason corresponding to one of the enabled TrgOps.

When a client has enabled the RptEna attribute of a BRCB or an URCB, and that same client writes a non-zero value to the GI attribute of the BRCB or URCB, a report is sent to that client containing the current data for all FCDAs within the report data set.

When a client has enabled the RptEna attribute and the IntgPd TrgOp of a BRCB or an URCB, and the IntgPd attribute of the BRCB or URCB is set to a non-zero value, a report is sent to that client containing the current data for all FCDAs within the report data set upon detecting an expiration of the IntgPd.

FCDA updates are serviced every 500 ms. The client can set the report control block (BRCB or URCB) IntgPd to any value greater than 500 ms with a resolution of 1 ms. However, the integrity report is only sent when the period has been detected as having expired. The new IntgPd will begin at the time that the current report is serviced.

BufTm timers are part of the report control block (BRCB and URCB). Each client that enables an unbuffered report can have a BufTm value independent of other clients which enable the same unbuffered report. This does not apply to buffered reports because only one client can enable a buffered report.

Setting BufTm less than 500 ms does not result in data changes from multiple scans being buffered into a single report. For a BRCB with a non-zero BufTm attribute, a BufTm timer is started upon receiving notification of the change of a member of a data set, and all changes received during BufTm are combined into a single report to be buffered and sent at the expiration of BufTm. If a second internal notification of the same member of a data set has occurred prior to the expiration of BufTm, a report is immediately buffered and sent.

Reports are formatted as specified in the IEC 61850 standard, Part 7-2, Table 24. The report EntryID attribute is incremented each time a report is built.

Supplemental Software

Examine the data structure and values of the supported IEC 61850 LNs with an MMS browser such as AX-S4 61850 Explorer and AX-S4 61850 from Sisco, Inc.

The settings needed to browse an SEL-351 with an MMS browser are shown below.

OSI-PSEL (Presentation Selector)	00000001
OSI-SSEL (Session Selector)	0001
OSI-TSEL (Transport Selector)	0001

Time Stamps and Quality

In addition to the various data values, the two attributes quality (q) and time stamp (t) are available at any time. The time stamp is determined when data or quality change is detected and is UTC reported as the Second of Century since January 1, 1970, plus fractional seconds.

The timestamp is applied to all data and quality attributes (Boolean, Bstrings, Analogs, etc.) in the same fashion when a data or quality change is detected.

Functionally Constrained Data Attributes (FCDA) mapped to points assigned to the SER report have SER-accuracy timestamps for data change events. To ensure that you will get SER-quality timestamps for changes to certain points, you must include those points in the SER report. All other FCDAs are scanned for data changes on a 1/2-second interval and have 1/2-second time stamp accuracy. See ***SET*** *(Change Settings)* on page 10.68 for information on programming the SER report.

The SEL-351 uses GOOSE quality attributes to indicate the quality of the data in its transmitted GOOSE messages. Under normal conditions, all attributes are zero, indicating good quality data. Internal status indicators provide the information necessary for the device to set these attributes. If the device becomes disabled, as shown via status indications (e.g., an internal self-test failure), the SEL-351 will stop transmitting GOOSE messages.

GOOSE Processing and Performance

SEL devices support GOOSE processing as defined by IEC 61850-7-1:2003(E), IEC 61850-7-2:2003(E), and IEC 61850-8-1:2004(E).

Four times per power system cycle, the relay reads inputs, processes protection algorithms, and controls outputs. Each of these quarter-cycle periods is called a processing interval. GOOSE messages are considered inputs and outputs, and are processed with the same priority as contact inputs, contact outputs, and protection algorithms. The relay processes incoming GOOSE messages near the beginning of every processing interval just after it reads the contact inputs, and processes outgoing GOOSE messages near the end of every processing interval after it controls the contact outputs. See *Table F.5* for more information about processing order in the SEL-351.

GOOSE Construction Tips

- Quality bit strings published from SEL relays are not generally useful in determining the quality of associated data because the SEL IEDs suspend publication of GOOSE messages if any quality attribute fails. Therefore receipt of the message indicates that all quality attributes are normal. Do not include quality bit strings in published GOOSE messages unless required by some other type of IED.
- Make GOOSE publications as small as possible. Include in the GOOSE publication only the information required by subscribing relays.

➤ Give higher VLAN priority tags to more important GOOSE. This allows the network to preferentially forward those GOOSE to the subscribers, and also gives a subscribing SEL-351 an indication that the more important GOOSE should be decoded before lower priority GOOSE.

➤ The relay supports no more than 128 unique Boolean elements mapped between all GOOSE publications.

GOOSE Construction Example

The data set shown in *Figure P.3* is used in a GOOSE publication from an SEL-421. It contains information that is not necessary to a subscribing SEL-351. For example, the data set contains the Mod, Beh, and Health fields (ANN.CCOUTGGIO21.Mod.*, ANN.CCOUTGGIO21.Beh.*, and ANN.CCOUTGGIO21.Health.*) from the CCOUT logical node. In this case, the information in those fields are of no use to a subscribing SEL-351. Also, each of the two CCOUT contained in the data set are accompanied by their corresponding quality bit strings and time stamps (ANN.CCOUTGGIO21.Ind01.q, ANN.CCOUTGGIO21.Ind01.t, ...). If the quality field is included in a GOOSE to which the SEL-351 subscribes, then the SEL-351 must spend additional processing time decoding that quality bit string and applying it to the associated data.

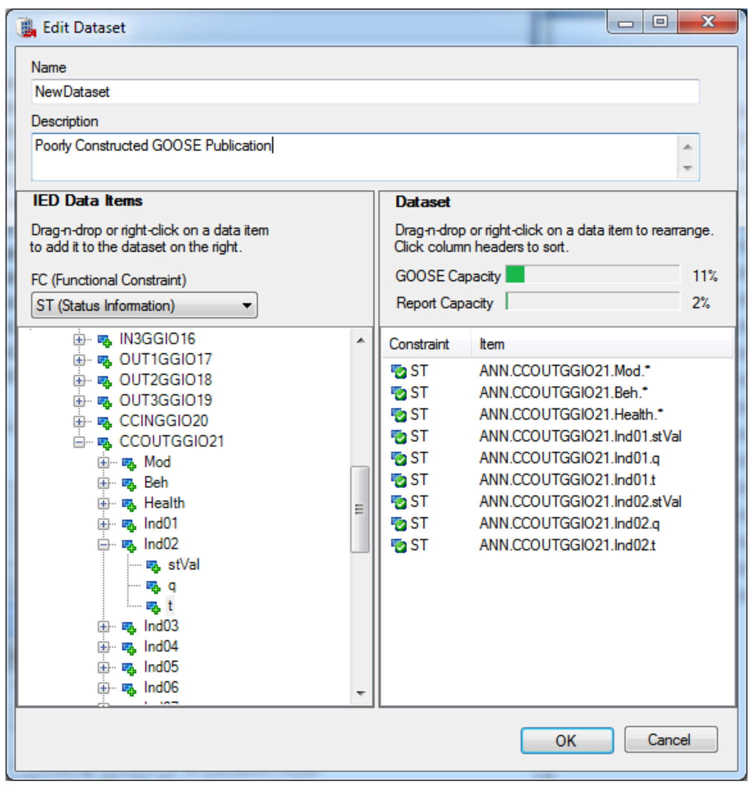

Figure P.3 Example of a Poorly Constructed GOOSE Dataset

Figure P.4 shows an example of a GOOSE publication from an SEL-351 with better construction. This data set contains only the information required by the subscribing relay(s) to decode the CCOUT status from the publishing SEL-351 (.CCOUTGGIO21.Ind01.stVal and CCOUTGGIO21.Ind02.stVal) and does not include quality bit strings or time stamps.

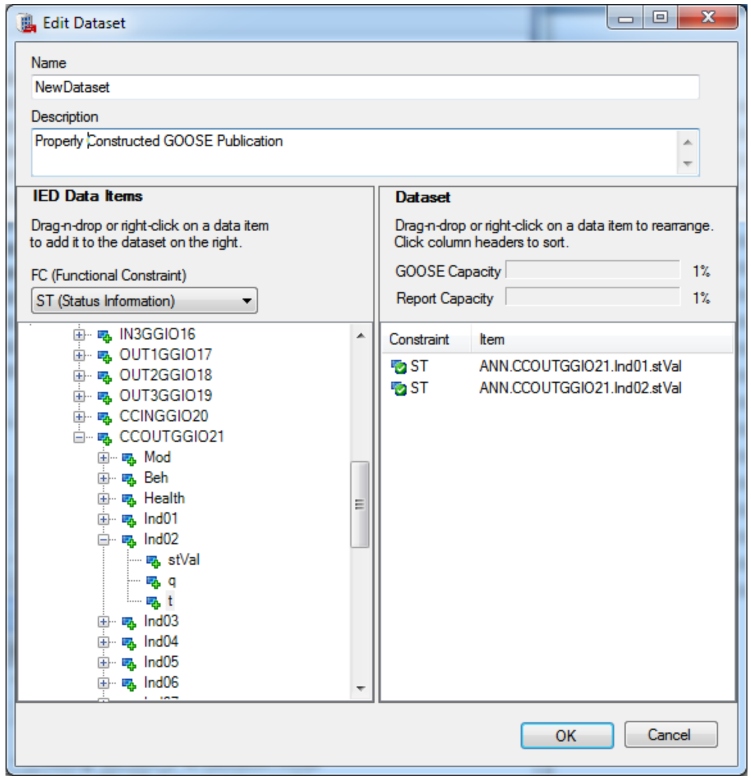

Figure P.4 Example of a Properly Constructed GOOSE Dataset

GOOSE Receive and Transmit Capacity

Each processing interval, the relay processes received and transmitted GOOSE messages. The relay assigns each received and transmitted message a point value at configuration time (when the relay receives and parses the CID file). The point values for various messages are calculated as described in *GOOSE Subscription (Receive) Processing* on page P.15 and *GOOSE Publication (Transmit) Processing* on page P.19. The number of points that can be received and transmitted during each processing interval varies depending upon Group settings E81R and E50BF and Port 5 settings EDNP and EMODBUS. *Table P.7* shows the number of GOOSE receive and transmit points per processing interval with various settings combinations.

Table P.7 GOOSE Receive and Transmit Point Capacity

Group Settings		Port 5 Settings		Number of Points Per Processing Interval	
E81R	**E50BF**	**EDNP**	**EMODBUS**	**GOOSE Receive**	**GOOSE Transmit**
N	N	0	2	128	104
N	N	1	1	128	104
N	N	2	0	128	104
Any other combination of E81R, E50BF, EDNP, and EMODBUS				80	40

GOOSE Subscription (Receive) Processing

The relay supports as many as 24 GOOSE subscriptions. GOOSE messages which arrive at the relay are subjected to the following processing steps when Port setting EGSE is set to Y.

Filter

Each message is inspected for proper multicast MAC address and GOOSE App ID. If those parameters match values expected by the relay for one of the as many as 24 GOOSE subscriptions, then the message is passed on to the next level of processing. Otherwise the message is discarded. Each message on the LAN must have a unique combination of multicast MAC address and GOOSE App ID.

Buffer

The relay retains the most recent arrival for as many as 24 subscriptions. If a subsequent GOOSE arrives for a subscription that already has a message buffered, then the earlier arrival is discarded.

Decode

The decoding process consists of several stages. Each decoding stage has an associated processing cost, and the relay limits the total cost of all received GOOSE decoding to reserve enough time to process protection algorithms, programmable logic, outputs, outgoing GOOSE messages, etc. *Table P.7* shows how the total cost is limited based on various combinations of settings. If the total point value of the messages in the receive buffers at the beginning of the processing interval exceeds the capacity given in *Table P.7*, then some messages will be decoded on subsequent processing intervals. The sections below describe how the relay scores each message as it is decoded.

Header Decoding

Each message contains a header which indicates the status of the message. The relay ignores the remainder of the message if any of four indicators in the message header are true:

- Configuration Mismatch. The configuration number of the incoming GOOSE changes.
- Needs Commissioning. This Boolean parameter of the incoming GOOSE message is true.
- Test Mode. This Boolean parameter of the incoming GOOSE message is true.
- State Number. This parameter is the same as the last time the message was decoded. State Number increments when the contents of the message change, so if the State Number is unchanged, there is no reason to decode the rest of the message.

Whether the header indicates the message should be subjected to further decoding or ignored, decoding the header always costs eight points.

Message Body Decoding

The cost of decoding the message body depends on the structure of the message. *Table P.8* shows the cost of each type of data in the message body, and also shows the cost of decoding the message header.

Table P.8 Point Cost of Decoding GOOSE Messages

Data Type	Description	Point Value	Comments
	Message header	8	Each message counts for at least eight points, regardless of the content of the message.
Message Quality Bit	A Boolean value created in the receiving relay indicating the status of the received message	0	This bit can always be mapped to local virtual bits for zero cost.
Boolean	A Boolean value mapped to a virtual bit	1	Boolean values not mapped to local virtual bits count as zero points.
Quality Bit String	A quality field associated with a data item, where the data item contains data mapped to a virtual bit	1	Quality fields not associated with a data item containing data that are mapped to a virtual bit count as zero points.
Time	Data item time stamp	0	Some data items are accompanied by a time stamp. The time stamp is never used or decoded by the SEL-351. It counts as zero points.
Bit String (other than Quality)	Several bits packed together in the same data item, where at least one of the bits is mapped to a virtual bit	1 for the bit string, plus 1 per bit in the bit string mapped to a virtual bit	Bit strings are often used for breaker position. A bit string that contains no bits mapped to a virtual bit counts as zero points.
Floating Point	Either single or double precision floating-point values	0	Floating-point values always count as zero points.
Other types of data	Any data type other than those shown above		The relay will correctly process any valid GOOSE message to which it subscribes. However, some data types are costly for the relay to process even if the data are not used by the receiving relay. Contact the SEL factory if you must configure the SEL-351 to subscribe to GOOSE messages with data types other than those listed above.

Message Point Value Calculation Example

Assume the relay subscribes to a message with 10 Boolean values, five of which are mapped to local virtual bits. Each of the 10 Boolean values is accompanied by a quality indicator. The message also contains one breaker position (a two-bit string) with accompanying quality indicator and time stamp. The two bits of breaker position are mapped to two virtual bits in the SEL-351. The message also contains one single precision floating-point number and one double precision floating-point number. In addition, the message quality bit is mapped to a local virtual bit.

The data set for such a message is shown in *Figure P.5*. As described above not all items from the data set are mapped to local resources within the receive SEL-351. Similar to the example GOOSE shown in *Figure P.3*, the GOOSE message show in *Figure P.5* is poorly constructed and is shown only as an example of a GOOSE message containing several types of data.

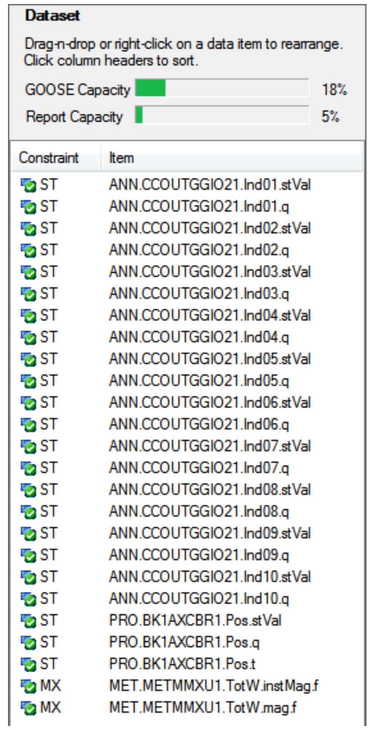

Figure P.5 Example Receive GOOSE Dataset

The score for this message is as follows:

- 8 points for the message
- 0 points for the message quality bit
- 5 points for 5 mapped Booleans
- 5 points for 5 quality fields associated with data items that have data mapped to local virtual bits
- 3 points total for the breaker position indication (one for the bit string and one each for the two bits in the string)
- 1 point for the quality bit string associated with the breaker position bit string
- 0 points for the breaker position bit string time stamp
- 0 points for the single precision floating-point data
- 0 points for the double precision floating-point number

22 total points in this message

Examples of GOOSE Subscription (Receive) Processing

If E81R = N, E50BF = N, the total number of Ethernet DNP and Modbus sessions is less than three, and the total score for all messages received in a single processing interval is 128 or fewer points, then the relay is guaranteed to process and apply all received data during that processing interval. For example, assume the relay subscribes to messages as shown in *Table P.9*.

NOTE: The relay processes either 80 or 128 GOOSE receive points per quarter-cycle interval. See *Table P.7* for point capacity with various settings combinations. For this example, the settings are such that 128 points are processed per interval.

Table P.9 Scores for Subscribed Messages Use in Example

Subscription Number	Message Score
1	16
2	20
3	10
4	16
5	16
6	10
7	12
8	28
Total	128

The total score for all of the subscribed messages is 128 points. Even if every message in *Table P.9* arrives every processing interval, and even if the header information from every message indicates that the message must be decoded, the relay is guaranteed to process every message, update the local virtual bits, and use those updated values in programmable logic during that processing interval.

Next, assume that the relay subscribes to messages as shown in *Table P.10*.

Table P.10 Scores for Subscribed Messages Used in Example

Subscription Number	Message Score
1	16
2	20
3	10
4	16
5	16
6	10
7	12
8	28
9	16
10	20
11	10
12	16
13	10
14	10
15	12
Total	222

The total score for all of the subscribed message is 222 points. Notice that if all of the message points are the result of message headers and mapped Boolean values, then these 15 messages represent 102 Boolean values mapped to local virtual bits. Assume every message arrives during the same processing interval, but messages 1 through 12 are repeats of messages processed earlier (i.e., those messages do not have changed state numbers). Those 12 repeated messages count as 8 points each, or 96 points total. Assume messages 13, 14, and 15 each contain changed data, so the state number has incremented since the last time the message was processed. The combined score for messages 13, 14, and 15 is 32 points. So the total score for all messages is 128 points. In this case, the relay will process all messages in a single processing interval.

Finally, assume that the relay subscribes to messages as shown in *Table P.11*.

Table P.11 Scores for Subscribed Messages Used in Example

Subscription Number	Message Score
1	16
2	20
3	10
4	16
5	16
6	10
7	12
8	28
9	16
10	20
11	10
12	16
13	10
14	10
15	12
16	16
17	20
18	10
19	16
20	16
21	10
22	12
23	28
24	16
Total	366

The total combined score for all of the subscribed messages is 366 points. As long as messages totaling 128 or fewer points arrive each processing interval, the relay will process all received messages every processing interval. If messages totaling more than 128 points arrive in any processing interval, then the relay will process messages totaling 128 or fewer points, and will continue processing during the next quarter-cycle processing interval.

GOOSE Publication (Transmit) Processing

The relay supports as many as eight GOOSE publications. Each publication can contain data from any logical node in the relay. The relay supports no more than 128 unique Boolean elements mapped between all GOOSE publications.

The relay transmits a message from each publication soon after initialization (e.g., after power up). Near the end of each processing interval, the relay transmits one message from as many publications as possible in which the state numbers have incremented. The relay then transmits one message from as many publications as possible in which the transmit interval timers have expired. Transmission of GOOSE messages does not occur if the relay is disabled, port setting EGSE is set to NO, or after a permanent self-test failure.

State Number

The relay maintains a count of the number of times the contents of a publication have changed. The count is called the state number. If the state number increments, then the relay transmits a message from that publication, as discussed below.

Transmit Interval

If the data contained in the messages do not change (i.e., if the state number does not increase), then the relay retransmits the message based on the configured MinTime and MaxTime settings from the CID file. The first transmission occurs immediately upon the trigger occurring. The second occurs approximately MinTime later. The third occurs approximately MinTime after the second. The fourth occurs twice MinTime after the third. All subsequent transmissions occur at the MaxTime interval. For example, if MinTime is 4 ms and MaxTime is 100 ms, the intervals between transmissions will be 4 ms, 4 ms, 8 ms, and then 100 ms. If MaxTime is not greater than twice MinTime, the third and all subsequent transmissions will occur at the MaxTime interval. The MinTime and MaxTime intervals can be configured for each GOOSE transmit message using Architect. The time-to-live reported in the first two messages is three times MinTime. The time-to-live in all subsequent messages is two times MaxTime.

The total number of message transmissions possible during each processing interval because of either state number changes or transmit interval timeout depends on the structure of the messages to be transmitted. The relay assigns each message a point value at configuration time (when the relay receives and parses the CID file). Each processing interval the relay processes and transmits messages with total point values as great as the capacity given in *Table P.7*. If messages totaling more than the transmit point capacity of *Table P.7* are available to be transmitted either because their transmit intervals have timed out or because their state numbers have incremented, then some of the messages will be transmitted on subsequent processing intervals. *Table P.12* shows the point value for different parts of the GOOSE message.

Table P.12 Score for Data Types Contained in Published Messages (Sheet 1 of 2)

Data Type	Description	Point Value	Comments
	Message	8	Each message counts at least 8 points every time it is transmitted, regardless of the content of the message. A message that is not transmitted counts as zero points.
Quality Bit String	A quality field associated with a data item	0	Transmit quality is always zero points.

Table P.12 Score for Data Types Contained in Published Messages (Sheet 2 of 2)

Data Type	Description	Point Value	Comments
Boolean, Time, Bit Strings (Other than Quality), Integer, Floating Point, Enumerations		1	Each of these data types cost one point to process and transmit.
Other Types of Data	Types of data other than those mentioned above		The relay will correctly process and transmit any valid GOOSE message. However, some data types are costly for the relay to process. Contact the SEL factory if you must configure the SEL-351 to publish GOOSE messages with data types other than those listed above.

Message Point Value Calculation Example

Assume the relay publishes a message with 10 Boolean values. Each of the 10 Boolean values is accompanied by a Quality indicator and a time stamp. The message contains two floating-point numbers, each with an associated time stamp.

The data set for such a message is shown in *Figure P.6*. Similar to the example GOOSE shown in *Figure P.3*, the GOOSE message show in *Figure P.6* is poorly constructed and is shown only as an example of a GOOSE message containing several types of data.

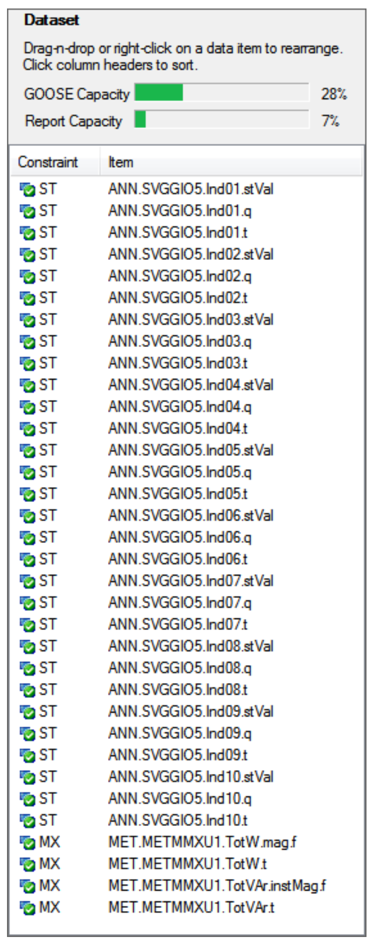

Figure P.6 Example Transmit GOOSE Dataset

The score for this message is as follows:

- ➤ 8 points for the message
- ➤ 10 points for 10 Boolean values
- ➤ 0 points for 10 quality bit strings associated with the Boolean values
- ➤ 10 points for 10 time stamps associated with the Boolean values
- ➤ 2 points for the two floating-point values
- ➤ 2 points for the time stamps associated with the floating-point values

32 total points in this message

Message Transmission Example

Assume the relay publishes eight GOOSE messages as shown in *Table P.13*.

Table P.13 Scores for Published Messages Used In Example

Publication Number	Message Score
1	16
2	20
3	10
4	16
5	16
6	10
7	8
8	8
Total	104

NOTE: The relay processes either 40 or 104 GOOSE transmit points per quarter-cycle interval. See *Table P.7* for point capacity with various settings combinations. For this example, the settings are such that 104 points are processed per interval.

The total score for all publications in this example is 104 points. If E81R = N, E50BF = N, and the total number of Ethernet DNP and Modbus sessions is less than three, the relay can process and transmit all messages every processing interval if required.

Next assume the relay publishes messages as shown in *Table P.14*.

Table P.14 Scores for Published Messages Used In Example

Publication Number	Message Score
1	32
2	40
3	20
4	32
5	32
6	20
7	24
8	56
Total	256

The total score for all publications in this example is 256 points. If messages totaling more than 104 points are due to be transmitted in any single processing interval, then the relay will transmit messages until the next message transmitted would cause the total score for that processing interval to exceed 104 points. The relay will then continue transmitting during the next quarter-cycle processing interval.

IEC 61850 Configuration

Settings

Table P.15 lists IEC 61850 settings. These settings are only available if your device includes the optional IEC 61850 protocol.

Table P.15 IEC 61850 Settings

Label	Description	Range	Default
E61850	IEC 61850 interface enable	Y, N	N
EGSE[a]	IEC 61850 GSE message enable	Y[b], N	N
EMMSFS[a]	MMS file services enable	Y[b], N	N[c]

[a] Settings EGSE and EMMSFS are hidden when E61850 is set to N.
[b] Requires E61850 set to Y.
[c] For firmware versions prior to R516, if E61850 = Y during firmware upgrade to R516 or higher, EMMSFS will be set to Y.

NOTE: Virtual bits retain state until overwritten, a new CID file is loaded, or the device is restarted. To reset the virtual bits by restarting the device, issue a **STA C** command or cycle power on the device.

Devices ordered with the optional IEC 61850 protocol are delivered with a default CID file loaded on the device. The file is named “SET_61850.CID.” To make the device communicate with other devices over IEC 61850, the device must be configured. Configure all other IEC 61850 settings, including subscriptions to incoming GOOSE messages, with Architect.

When IEC 61850 is enabled (E61850 = Y), the device parses the CID file to determine the device's IEC 61850 configuration. When EGSE = Y, the device begins transmitting GOOSE messages and receiving GOOSE subscriptions configured in the CID file. Issuing the ASCII **GOO** command will provide GOOSE status information. See ***GOO*** on page 10.48 for a detailed description of the **GOO** command.

NOTE: Firmware versions lower than R516 will display `PARSE FAILURE` in the iedName, type, and configVersion fields of the **ID** command if the CID file is invalid. No GOOSE messages will be transmitted and MMS will be unavailable if `PARSE FAILURE` is displayed in these fields.

If the device does not have a valid IEC 61850 configuration, it will not send or receive any IEC 61850 communications. Issuing the ASCII **ID** command provides information on the status of the CID file. If there is a problem with the CID file, the iedName, type, and configVersion fields of the ID command response will display `PARSE FAILURE`, as shown below.

```
=>>ID <Enter>

"FID=SEL-351-5-R512-V0-Z104104-D20120830","0908"
"BFID=SLBT-3CF1-R200-V0-Z100100-D20120321","097A"
"CID=7CF9","0276"
"DEVID=STATION A","049C"
"DEVCODE=30","030A"
"PARTNO=035152C4D54XX2","05B7"
"SERIALNO=0000000000","04EA"
"CONFIG=11112201","03EC"
"SPECIAL=11000","03A0"
"iedName=PARSE FAILURE","0703"
"type=PARSE FAILURE","0612"
"configVersion=PARSE FAILURE","09AC"

=>>
```

NOTE: MMS File Services can be used to load a new CID file if EMMSFS = Y.

You will need to load a valid CID file into the device using FTP, Architect, or MMS File Services. When loading a new CID file, Architect returns an error message if the file is not accepted. If using FTP or MMS File Services to load a new CID file, follow the write operation with a read of the ERR.TXT file from the device to verify successful transmission and configuration of the new CID file. If the file transfer fails or the device detects an invalid CID file, the ERR.TXT file will contain an error message. If the ERR.TXT file is blank (length is zero), then the new CID file was accepted by the device. If a failure occurs, the CID file that you previously loaded in the device will be retained. The new CID file will replace the current CID file only if the transfer and configuration of the new CID file is successful.

Once a valid CID file is loaded into the device, the **ID** command response should look like that shown below with the iedName, type, and configVersion fields revealing the proper configured information. The iedName displays the configured IED name, which can be modified using Architect. The type and configVersion fields cannot be modified and represent the relay type and the ICD file version used for the configured CID file.

```
=>>ID <Enter>

"FID=SEL-351-5-R512-V0-Z104104-D20120830","0908"
"BFID=SLBT-3CF1-R200-V0-Z100100-D20120321","097A"
"CID=7CF9","0276"
"DEVID=STATION A","049C"
"DEVCODE=30","030A"
"PARTNO=035152C4D54XX2","05B7"
"SERIALNO=0000000000","04EA"
"CONFIG=11112201","03EC"
"SPECIAL=11000","03A0"
"iedName=SEL_351_1","05CC"
"type=SEL_351","044B"
"configVersion=ICD-351-R201-V0-Z001001-D20120615","0D0F"

=>>
```

Architect

The Architect software enables users to design and commission IEC 61850 substations containing SEL IEDs.

Users can use Architect to:

- Organize and configure all SEL IEDs in a substation project.
- Configure incoming and outgoing GOOSE messages.
- Edit and create GOOSE data sets.
- Read non-SEL IED Capability Description (ICD) and Configured IED Description (CID) files and determine the available IEC 61850 messaging options.
- Use or edit preconfigured data sets for reports.
- Enable/disable MMS authentication.
- Configure MMS inactivity timeout.
- Load IEC 61850 CID files into SEL IEDs.
- Generate ICD and CID files that will provide SEL IED descriptions to other manufacturers' tools so they can use SEL GOOSE messages and reporting features.
- Edit deadband settings for measured values.

Architect provides a Graphical User Interface (GUI) for users to select, edit, and create IEC 61850 GOOSE messages important for substation protection, coordination, and control schemes. Typically, the user first places icons representing IEDs in a substation container, then edits the outgoing GOOSE messages or creates new ones for each IED. The user can also select incoming GOOSE messages for each IED to receive from any other IEDs in the domain.

Some measured values are reported to IEC 61850 only when the value changes beyond a defined deadband value. Architect allows a deadband to be changed during the CID file configuration. Check and set the deadband values for your particular application when configuring the CID file for a device.

Architect has the capability to read other manufacturers' ICD and CID files, enabling the user to map the data seamlessly into SEL IED logic. See the Architect online help for more information.

SEL ICD File Versions

Architect version R.1.1.69.0 and later supports multiple ICD file versions for each type of IED in a project. Because relays with different firmware versions may require different CID file versions, users can manage the CID files of all IEDs within a single project.

Please ensure that you work with the appropriate version of Architect relative to your current configuration, existing project files, and ultimate goals. If you want the best available IEC 61850 functionality for your SEL relay, obtain the latest version of Architect and select the appropriate ICD version(s) for your needs.

Architect generates CID files from ICD files so the ICD file version Architect uses also determines the CID file version generated. Details about the different SEL-351 ICD files can be found in *Table A.3*.

Logical Node Extensions

The following Logical Nodes and Data Classes were created in this device as extensions to the IEC 61850 standard, in accordance with IEC 61850 guidelines.

Table P.16 New Logical Node Extensions

Logical Node	IEC 61850	Description or Comments
Demand Metering Statistics	MDST	Demand and peak demand values for current and energy.
Control Breaker Supervision	SCBR	Circuit breaker supervision abrasion and operation values.

Table P.17 Demand Metering Logical Node Class Definition

IEC 61850 Logical Node Class: MDST					
Attribute Name	**Attribute Type**	**Data Source**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName			The name is composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2.		
Data					
Common Logical Node Information					
			LN inherits all mandatory data from Common Logical Node Class		M
Measured Values					
DmdA.nseq	MV	3I2DEM	Demand, negative sequence current		O
PkDmdA.nseq	MV	3I2PK	Peak demand, negative sequence current		O
DmdA.phsA	MV	IADEM	Demand, phase A current		O
PkDmdA.phsA	MV	IAPK	Peak demand, phase A current		O
DmdA.phsB	MV	IBDEM	Demand, phase B current		O
PkDmdA.phsB	MV	IBPK	Peak demand, phase B current		O
DmdA.phsC	MV	ICDEM	Demand, phase C current		O
PkDmdA.phsC	MV	ICPK	Peak demand, phase C current		O
DmdA.res	MV	IGDEM	Demand, residual current		O
PkDmdA.res	MV	IGPK	Peak demand, residual current		O
DmdA.neut	MV	INDEM	Demand, neutral current		O
PkDmdA.neut	MV	INPK	Peak demand, neutral current		O
SupVArh	MV	MVRH3I	Energy, reactive (MVARh), supply direction toward busbar		O
DmdVArh	MV	MVRH3O	Energy, reactive (MVARh), supply direction away from busbar		O
SupWh	MV	MWH3I	Energy, real (MWh), supply direction toward busbar		O
DmdWh	MV	MWH3O	Energy, real (MWh), supply direction away from busbar		O

[a] Transient data objects—the status of data objects with this designation is momentary and must be logged or reported to provide evidence of their momentary state.
[b] M: Mandatory; O: Optional; C: Conditional; E: Extension.

Table P.18 Circuit Breaker Supervision (Per-Phase) Logical Node Class Definition (Sheet 1 of 2)

IEC 61850 Logical Node Class: SCBR				
Attribute Name	**Attribute Type**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name is composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2.		
Data				
Common Logical Node Information				
		LN inherits all mandatory data from Common Logical Node Class		M
Status Information				
ColOpn	SPS	Open command of trip coil		M
OpTmAlm1	SPS	Switch operating time exceeded—electrical close time	T	O
OpTmAlm2	SPS	Switch operating time exceeded—electrical open time	T	O
OpCnt	INS	Switch operating time exceeded counter		E

Table P.18 Circuit Breaker Supervision (Per-Phase) Logical Node Class Definition (Sheet 2 of 2)

IEC 61850 Logical Node Class: SCBR				
Attribute Name	**Attribute Type**	**Explanation**	**T[a]**	**M/O/C/E[b]**
Measured Values				
OpTmCls	MV	Operation time close		O
OpTmOpn	MV	Operation time open		O
AbrPrt	MV	Calculated or measured wear (e.g. of main contact), expressed in % where 0 % corresponds to new condition		E
MaxAbrPrt	MV	Maximum breaker wear (greatest wear of WEARA, WEARB, or WEARC), expressed in %		E

[a] Transient data objects—the status of data objects with this designation is momentary and must be logged or reported to provide evidence of their momentary state.
[b] M: Mandatory; O: Optional; C: Conditional; E: Extension.

Table P.19 Circuit Breaker Supervision Logical Node Class Definition

IEC 61850 Logical Node Class: SCBR				
Attribute Name	**Attribute Type**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name is composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2.		
Data				
Common Logical Node Information				
		LN inherits all mandatory data from Common Logical Node Class		M
Status Information				
ColOpn	SPS	Open command of trip coil		M
OpTmAlm1	SPS	Switch operating time exceeded—mechanical close time	T	O
OpTmAlm2	SPS	Switch operating time exceeded—mechanical open time	T	O
OpCnt	INS	Switch operating time exceeded counter		E
Measured Values				
OpTmCls	MV	Operation time close		O
OpTmOpn	MV	Operation time open		O

[a] Transient data objects—the status of data objects with this designation is momentary and must be logged or reported to provide evidence of their momentary state.
[b] M: Mandatory; O: Optional; C: Conditional; E: Extension.

Table P.20 Compatible Logical Nodes With Extensions

Logical Node	**IEC 61850**	**Description or Comments**
Measurement	MMXU	This LN is used for power system measurement data.
Under Voltage	PTUV	This LN is used for loss-of-potential status.
Fault Locator	RFLO	This LN is used for fault locator measurement data.
Circuit Breaker	XCBR	This LN is used for circuit breaker status and measurement data.

Table P.21 Measurement Logical Node Class Definition

IEC 61850 Logical Node Class: MMXU				
Attribute Name	**Attribute Type**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name is composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2.		
Data				
Common Logical Node Information				
		LN inherits all mandatory data from Common Logical Node Class		M
Measured Values				
TotW	MV	Total active power		O
TotVAr	MV	Total reactive power		O
TotPF	MV	Average power factor		O
Hz	MV	Frequency		O
PPV	DEL	Phase-to-phase voltages		O
PhV	WYE	Phase-to-ground voltages		O
A	WYE	Phase currents		O
W	WYE	Phase active power		O
Var	WYE	Phase reactive power		O
PF	WYE	Phase power factor		O
VSyn	CMV	Synchronous voltage		E

[a] Transient data objects—the status of data objects with this designation is momentary and must be logged or reported to provide evidence of their momentary state.

[b] M: Mandatory; O: Optional; C: Conditional; E: Extension.

Table P.22 Undervoltage Logical Node Class Definition

IEC 61850 Logical Node Class: PTUV				
Attribute Name	**Attribute Type**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name is composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2.		
Data				
Common Logical Node Information				
		LN inherits all mandatory data from Common Logical Node Class		M
Status Information				
Str	ACD	Start (pickup)	T	M
Op	ACT	Operate	T	M
LOP3	SPS	LOP—latched		E
LOP2	SPS	Drop in voltage without change in current LOP logic asserted	T	E
LOPBLK	SPS	SELOGIC variable LOPBLK asserted	T	E
LOPRST	SPS	LOP reset condition based on healthy voltages	T	E

[a] Transient data objects—the status of data objects with this designation is momentary and must be logged or reported to provide evidence of their momentary state.

[b] M: Mandatory; O: Optional; C: Conditional; E: Extension.

Table P.23 Fault Locator Logical Node Class Definition

IEC 61850 Logical Node Class: RFLO				
Attribute Name	**Attribute Type**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name is composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2.		
Data				
Common Logical Node Information				
		LN inherits all mandatory data from Common Logical Node Class		M
Measured Values				
FltZ	CMV	Fault impedance		M
FltDiskm	MV	Fault distance		O
A	WYE	Fault currents		E

[a] Transient data objects—the status of data objects with this designation is momentary and must be logged or reported to provide evidence of their momentary state.
[b] M: Mandatory; O: Optional; C: Conditional; E: Extension.

Table P.24 Circuit Breaker Logical Node Class Definition

IEC 61850 Logical Node Class: XCBR				
Attribute Name	**Attribute Type**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name is composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2.		
Data Objects				
Common Logical Node Information				
		LN inherits all mandatory data from Common Logical Node Class		M
Status Information				
Loc	SPS	Local control behavior		M
OpCnt	INS	Operation counter		M
OpCntEx	INS	Operation counter—external		E
CBOpCap	INS	Circuit breaker operating capability		M
Controls				
Pos	DPC	Switch position		M
BlkOpn	SPC	Block opening		M
BlkCls	SPC	Block closing		M

[a] Transient data objects—the status of data objects with this designation is momentary and must be logged or reported to provide evidence of their momentary state.
[b] M: Mandatory; O: Optional; C: Conditional; E: Extension.

Logical Nodes

Table P.25 through *Table P.29* show the logical nodes (LNs) supported in the SEL-351 and the Relay Word bits or Measured Values mapped to those LNs.

Table P.25 shows the LNs associated with protection elements, defined as Logical Device PRO. See *Appendix D: Relay Word Bits* and *Appendix E: Analog Quantities* for descriptions.

Table P.25 Logical Device: PRO (Protection) (Sheet 1 of 11)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = CO			
BCCSWI1	Pos.Oper.ctlVal	CC:OC[a]	Circuit breaker close/open command
Functional Constraint = MX[b]			
FLTRFLO1	A.phsMax.instMag.f	FI[c]	Fault current, maximum phase current in primary amperes
FLTRFLO1	A.phsA.instMag.f	FIA[c]	A-Phase fault current in primary amperes
FLTRFLO1	A.phsB.instMag.f	FIB[c]	B-Phase fault current in primary amperes
FLTRFLO1	A.phsC.instMag.f	FIC[c]	C-Phase fault current in primary amperes
FLTRFLO1	A.res.instMag.f	FIG[c]	Ground fault current in primary amperes
FLTRFLO1	A.neut.instMag.f	FIN[c]	Neutral fault current in primary amperes
FLTRFLO1	A.nseq.instMag.f	FIQ[c]	Negative-sequence fault current in primary amperes
FLTRFLO1	FltDiskm.instMag.f	FLOC[d,e]	Fault location
FLTRFLO1	FltZ.instCVal.mag.f	FZ[d]	Fault impedance magnitude in ohms, secondary
FLTRFLO1	FltZ.instCVal.ang.f	FZFA[d]	Fault impedance angle in degrees
BSASCBR1	AbrPrt.instMag.f	WEARA	Breaker wear %, A-Phase
BSASCBR1	MaxAbrPrt.instMag.f	MAXWEAR	Greatest wear of WEARA, WEARB, or WEARC
BSASCBR1	OpTmCls.instMag.f	EOTCLAAV	Average electrical close operating time, A-Phase
BSASCBR1	OpTmOpn.instMag.f	EOTTRAAV	Average electrical trip operating time, A-Phase
BSBSCBR2	AbrPrt.instMag.f	WEARB	Breaker wear %, B-Phase
BSBSCBR2	MaxAbrPrt.instMag.f	MAXWEAR	Greatest wear of WEARA, WEARB, or WEARC
BSBSCBR2	OpTmCls.instMag.f	EOTCLBAV	Average electrical close operating time, B-Phase
BSBSCBR2	OpTmOpn.instMag.f	EOTTRBAV	Average electrical trip operating time, B-Phase
BSCSCBR3	AbrPrt.instMag.f	WEARC	Breaker wear %, C-Phase
BSCSCBR3	MaxAbrPrt.instMag.f	MAXWEAR	Greatest wear of WEARA, WEARB, or WEARC
BSCSCBR3	OpTmCls.instMag.f	EOTCLCAV	Average electrical close operating time, C-Phase
BSCSCBR3	OpTmOpn.instMag.f	EOTTRCAV	Average electrical trip operating time, C-Phase
BSMSCBR1	OpTmCls.instMag.f	MOTCLAV	Average mechanical close operating time
BSMSCBR1	OpTmOpn.instMag.f	MOTTRAV	Average mechanical trip operating time
Functional Constraint = ST			
A51PTOC1	Op.general	51AT	A-Phase time-overcurrent element 51AT timed-out
A51PTOC1	Str.general	51A	A-Phase current above pickup setting 51AP for time-overcurrent element 51AT
A51PTOC1	Str.dirGeneral	unknown	Direction unknown due to settings
ABPIOC1	Op.general	50AB1	Instantaneous AB phase-to-phase overcurrent, Level 1
ABPIOC2	Op.general	50AB2	Instantaneous AB phase-to-phase overcurrent, Level 2
ABPIOC3	Op.general	50AB3	Instantaneous AB phase-to-phase overcurrent, Level 3
ABPIOC4	Op.general	50AB4	Instantaneous AB phase-to-phase overcurrent, Level 4
ABPTOV1	Str.general	59AB	AB phase-to-phase overvoltage Level 1
ABPTOV1	Str.dirGeneral	unknown	Direction undefined
ABPTOV2	Str.general	59AB2	AB phase-to-phase overvoltage Level 2
ABPTOV2	Str.dirGeneral	unknown	Direction undefined
ABPTUV1	Op.general	27AB	AB phase-to-phase undervoltage, Level 1

Table P.25 Logical Device: PRO (Protection) (Sheet 2 of 11)

Logical Node	Attribute	Data Source	Comment
ABPTUV1	Str.general	27AB	AB phase-to-phase undervoltage, Level 1
ABPTUV1	Str.dirGeneral	unknown	Direction undefined
ABPTUV2	Op.general	27AB2	AB phase-to-phase undervoltage, Level 2
ABPTUV2	Str.general	27AB2	AB phase-to-phase undervoltage, Level 2
ABPTUV2	Str.dirGeneral	unknown	Direction undefined
APIOC1	Op.general	50A1	Instantaneous A-Phase overcurrent, Level 1
APIOC2	Op.general	50A2	Instantaneous A-Phase overcurrent, Level 2
APIOC3	Op.general	50A3	Instantaneous A-Phase overcurrent, Level 3
APIOC4	Op.general	50A4	Instantaneous A-Phase overcurrent, Level 4
APIOC5	Op.general	50A	Instantaneous A-Phase combined overcurrent, Levels 1–4
APTOV1	Str.general	59A1	A-Phase overvoltage Level 1
APTOV1	Str.dirGeneral	unknown	Direction undefined
APTOV2	Str.general	59A2	A-Phase overvoltage Level 2
APTOV2	Str.dirGeneral	unknown	Direction undefined
APTUV1	Op.general	27A1	A-Phase undervoltage, Level 1
APTUV1	Str.general	27A1	A-Phase undervoltage, Level 1
APTUV1	Str.dirGeneral	unknown	Direction undefined
APTUV2	Op.general	27A2	A-Phase undervoltage, Level 2
APTUV2	Str.general	27A2	A-Phase undervoltage, Level 2
APTUV2	Str.dirGeneral	unknown	Direction undefined
B51PTOC1	Op.general	51BT	B-Phase time-overcurrent element 51BT timed-out
B51PTOC1	Str.general	51B	B-Phase current above pickup setting 51BP for time-overcurrent element 51BT
B51PTOC1	Str.dirGeneral	unknown	Direction unknown due to settings
BCCSWI1	OpCls.general	CC	Circuit breaker close control
BCCSWI1	OpOpn.general	OC	Circuit breaker open control
BCCSWI1	Pos.stVal	52A?1:2[f]	Breaker position (52A = false, breaker opened; 52A = true, breaker closed)
BCPIOC1	Op.general	50BC1	Instantaneous BC phase-to-phase overcurrent, Level 1
BCPIOC2	Op.general	50BC2	Instantaneous BC phase-to-phase overcurrent, Level 2
BCPIOC3	Op.general	50BC3	Instantaneous BC phase-to-phase overcurrent, Level 3
BCPIOC4	Op.general	50BC4	Instantaneous BC phase-to-phase overcurrent, Level 4
BCPTOV1	Str.general	59BC	BC phase-to-phase overvoltage Level 1
BCPTOV1	Str.dirGeneral	unknown	Direction undefined
BCPTOV2	Str.general	59BC2	BC phase-to-phase overvoltage Level 2
BCPTOV2	Str.dirGeneral	unknown	Direction undefined
BCPTUV1	Op.general	27BC	BC phase-to-phase undervoltage, Level 1
BCPTUV1	Str.general	27BC	BC phase-to-phase undervoltage, Level 1
BCPTUV1	Str.dirGeneral	unknown	Direction undefined
BCPTUV2	Op.general	27BC2	BC phase-to-phase undervoltage, Level 2
BCPTUV2	Str.general	27BC2	BC phase-to-phase undervoltage, Level 2
BCPTUV2	Str.dirGeneral	unknown	Direction undefined

Table P.25 Logical Device: PRO (Protection) (Sheet 3 of 11)

Logical Node	Attribute	Data Source	Comment
BPIOC1	Op.general	50B1	Instantaneous B-Phase overcurrent, Level 1
BPIOC2	Op.general	50B2	Instantaneous B-Phase overcurrent, Level 2
BPIOC3	Op.general	50B3	Instantaneous B-Phase overcurrent, Level 3
BPIOC4	Op.general	50B4	Instantaneous B-Phase overcurrent, Level 4
BPIOC5	Op.general	50B	Instantaneous B-Phase combined overcurrent, Levels 1–4
BPTOV1	Str.general	59B1	B-Phase overvoltage Level 1
BPTOV1	Str.dirGeneral	unknown	Direction undefined
BPTOV2	Str.general	59B2	B-Phase overvoltage Level 2
BPTOV2	Str.dirGeneral	unknown	Direction undefined
BPTUV1	Op.general	27B1	B-Phase undervoltage, Level 1
BPTUV1	Str.general	27B1	B-Phase undervoltage, Level 1
BPTUV1	Str.dirGeneral	unknown	Direction undefined
BPTUV2	Op.general	27B2	B-Phase undervoltage, Level 2
BPTUV2	Str.general	27B2	B-Phase undervoltage, Level 2
BPTUV2	Str.dirGeneral	unknown	Direction undefined
BRBRF1	OpEx.general	BFTRIP	Circuit breaker failure trip
BRBRF1	OpIn.general	RT	Retrip
BRBRF1	Str.general	BFT	Circuit breaker failure
BRBRF1	Str.dirGeneral	unknown	Direction undefined
BSASCBR1	ColOpn.stVal	OC	Circuit breaker open control
BSASCBR1	OpCnt.stVal	ESOALCNT	Electrical operation alarm counter
BSASCBR1	OpTmAlm1.stVal	ESCLA	Electrical close operating time alarm, A-Phase
BSASCBR1	OpTmAlm2.stVal	ESTRA	Electrical trip operating time alarm, A-Phase
BSBSCBR2	ColOpn.stVal	OC	Circuit breaker open control
BSBSCBR2	OpCnt.stVal	ESOALCNT	Electrical operation alarm counter
BSBSCBR2	OpTmAlm1.stVal	ESCLB	Electrical close operating time alarm, B-Phase
BSBSCBR2	OpTmAlm2.stVal	ESTRB	Electrical trip operating time alarm, B-Phase
BSCSCBR3	ColOpn.stVal	OC	Circuit breaker open control
BSCSCBR3	OpCnt.stVal	ESOALCNT	Electrical operation alarm counter
BSCSCBR3	OpTmAlm1.stVal	ESCLC	Electrical close operating time alarm, C-Phase
BSCSCBR3	OpTmAlm2.stVal	ESTRC	Electrical trip operating time alarm, C-Phase
BSMSCBR1	ColOpn.stVal	OC	Circuit breaker open control
BSMSCBR1	OpCnt.stVal	MSOALCNT	Mechanical operation alarm counter
BSMSCBR1	OpTmAlm1.stVal	MSCL	Mechanical close operating time alarm
BSMSCBR1	OpTmAlm2.stVal	MSTR	Mechanical trip operating time alarm
BSXCBR1	BlkCls.stVal	0	Breaker close blocking not configured by default
BSXCBR1	BlkOpn.stVal	0	Breaker open blocking not configured by default
BSXCBR1	CBOpCap.stVal	None	Breaker physical operation capabilities not known to relay
BSXCBR1	Loc.stVal	0	Breaker local control status not configured by default
BSXCBR1	OpCnt.stVal	INTTR	Internal trip counter
BSXCBR1	OpCntEx.stVal	EXTTR	External trip counter

Table P.25 Logical Device: PRO (Protection) (Sheet 4 of 11)

Logical Node	Attribute	Data Source	Comment
BSXCBR1	Pos.stVal	52A?1:2[f]	Breaker position (52A = false, breaker opened; 52A = true, breaker closed)
C51PTOC1	Op.general	51CT	C-Phase time-overcurrent element 51CT timed-out
C51PTOC1	Str.general	51C	C-Phase current above pickup setting 51CP for time-overcurrent element 51CT
C51PTOC1	Str.dirGeneral	unknown	Direction unknown due to settings
CAPIOC1	Op.general	50CA1	Instantaneous CA phase-to-phase overcurrent, Level 1
CAPIOC2	Op.general	50CA2	Instantaneous CA phase-to-phase overcurrent, Level 2
CAPIOC3	Op.general	50CA3	Instantaneous CA phase-to-phase overcurrent, Level 3
CAPIOC4	Op.general	50CA4	Instantaneous CA phase-to-phase overcurrent, Level 4
CAPTOV1	Str.general	59CA	CA phase-to-phase overvoltage Level 1
CAPTOV1	Str.dirGeneral	unknown	Direction undefined
CAPTOV2	Str.general	59CA2	CA phase-to-phase overvoltage Level 2
CAPTOV2	Str.dirGeneral	unknown	Direction undefined
CAPTUV1	Op.general	27CA	CA phase-to-phase undervoltage, Level 1
CAPTUV1	Str.general	27CA	CA phase-to-phase undervoltage, Level 1
CAPTUV1	Str.dirGeneral	unknown	Direction undefined
CAPTUV2	Op.general	27CA2	CA phase-to-phase undervoltage, Level 2
CAPTUV2	Str.general	27CA2	CA phase-to-phase undervoltage, Level 2
CAPTUV2	Str.dirGeneral	unknown	Direction undefined
CPIOC1	Op.general	50C1	Instantaneous C-Phase overcurrent, Level 1
CPIOC2	Op.general	50C2	Instantaneous C-Phase overcurrent, Level 2
CPIOC3	Op.general	50C3	Instantaneous C-Phase overcurrent, Level 3
CPIOC4	Op.general	50C4	Instantaneous C-Phase overcurrent, Level 4
CPIOC5	Op.general	50C	Instantaneous C-Phase combined overcurrent, Levels 1–4
CPTOV1	Str.general	59C1	C-Phase overvoltage Level 1
CPTOV1	Str.dirGeneral	unknown	Direction undefined
CPTOV2	Str.general	59C2	C-Phase overvoltage Level 2
CPTOV2	Str.dirGeneral	unknown	Direction undefined
CPTUV1	Op.general	27C1	C-Phase undervoltage, Level 1
CPTUV1	Str.general	27C1	C-Phase undervoltage, Level 1
CPTUV1	Str.dirGeneral	unknown	Direction undefined
CPTUV2	Op.general	27C2	C-Phase undervoltage, Level 2
CPTUV2	Str.general	27C2	C-Phase undervoltage, Level 2
CPTUV2	Str.dirGeneral	unknown	Direction undefined
DCUBPSCH1	Echo.general	EKEY	Echo permissive trip received
DCUBPSCH1	Op.general	PTRX	Permissive trip signal (input into trip logic)
DCUBPSCH1	ProRx.stVal	PTRX	Permissive trip signal (input into trip logic)
DCUBPSCH1	ProTx.stVal	KEY	Key permissive trip
DCUBPSCH1	RvABlk.general	Z3RB	Current reversal guard
DCUBPSCH1	Str.general	KEY	Key permissive trip

Table P.25 Logical Device: PRO (Protection) (Sheet 5 of 11)

Logical Node	Attribute	Data Source	Comment
DCUBPSCH1	Str.dirGeneral	KEY?0:1	Key permissive, direction (KEY = false, direction unknown; KEY = true, direction forward)
DCUBPSCH1	WeiOp.general	ECTT	Echo conversion to trip
DPTOF1	BlkV.stVal	27B81A	Frequency blocking, Level 1
DPTOF1	Op.general	81D1T[g]	Frequency operate, Level 1
DPTOF1	Str.general	81D1[g]	Frequency pickup, Level 1
DPTOF1	Str.dirGeneral	unknown	Direction undefined
DPTOF2	BlkV.stVal	27B81A	Frequency blocking, Level 2
DPTOF2	Op.general	81D2T[g]	Frequency operate, Level 2
DPTOF2	Str.general	81D2[g]	Frequency pickup, Level 2
DPTOF2	Str.dirGeneral	unknown	Direction undefined
DPTOF3	BlkV.stVal	27B81A	Frequency blocking, Level 3
DPTOF3	Op.general	81D3T[g]	Frequency operate, Level 3
DPTOF3	Str.general	81D3[g]	Frequency pickup, Level 3
DPTOF3	Str.dirGeneral	unknown	Direction undefined
DPTOF4	BlkV.stVal	27B81A	Frequency blocking, Level 4
DPTOF4	Op.general	81D4T[g]	Frequency operate, Level 4
DPTOF4	Str.general	81D4[g]	Frequency pickup, Level 4
DPTOF4	Str.dirGeneral	unknown	Direction undefined
DPTOF5	BlkV.stVal	27B81A	Frequency blocking, Level 5
DPTOF5	Op.general	81D5T[g]	Frequency operate, Level 5
DPTOF5	Str.general	81D5[g]	Frequency pickup, Level 5
DPTOF5	Str.dirGeneral	unknown	Direction undefined
DPTOF6	BlkV.stVal	27B81A	Frequency blocking, Level 6
DPTOF6	Op.general	81D6T[g]	Frequency operate, Level 6
DPTOF6	Str.general	81D6[g]	Frequency pickup, Level 6
DPTOF6	Str.dirGeneral	unknown	Direction undefined
DPTUF1	BlkV.stVal	27B81A	Frequency blocking, Level 1
DPTUF1	Op.general	81D1T[g]	Frequency operate, Level 1
DPTUF1	Str.general	81D1[g]	Frequency pickup, Level 1
DPTUF1	Str.dirGeneral	unknown	Direction undefined
DPTUF2	BlkV.stVal	27B81A	Frequency blocking, Level 2
DPTUF2	Op.general	81D2T[g]	Frequency operate, Level 2
DPTUF2	Str.general	81D2[g]	Frequency pickup, Level 2
DPTUF2	Str.dirGeneral	unknown	Direction undefined
DPTUF3	BlkV.stVal	27B81A	Frequency blocking, Level 3
DPTUF3	Op.general	81D3T[g]	Frequency operate, Level 3
DPTUF3	Str.general	81D3[g]	Frequency pickup, Level 3
DPTUF3	Str.dirGeneral	unknown	Direction undefined
DPTUF4	BlkV.stVal	27B81A	Frequency blocking, Level 4
DPTUF4	Op.general	81D4T[g]	Frequency operate, Level 4

Table P.25 Logical Device: PRO (Protection) (Sheet 6 of 11)

Logical Node	Attribute	Data Source	Comment
DPTUF4	Str.general	81D4[g]	Frequency pickup, Level 4
DPTUF4	Str.dirGeneral	unknown	Direction undefined
DPTUF5	BlkV.stVal	27B81A	Frequency blocking, Level 5
DPTUF5	Op.general	81D5T[g]	Frequency operate, Level 5
DPTUF5	Str.general	81D5[g]	Frequency pickup, Level 5
DPTUF5	Str.dirGeneral	unknown	Direction undefined
DPTUF6	BlkV.stVal	27B81A	Frequency blocking, Level 6
DPTUF6	Op.general	81D6T[g]	Frequency operate, Level 6
DPTUF6	Str.general	81D6[g]	Frequency pickup, Level 6
DPTUF6	Str.dirGeneral	unknown	Direction undefined
FLTRDRE1	RcdMade.stVal	FLREP	Event report present
FLTRDRE1	FltNum.stVal	FLRNUM	Unique event ID number
G51PTOC1	Op.general	51GT	Residual time-overcurrent operate
G51PTOC1	Str.general	51G	Residual time-overcurrent pickup
G51PTOC1	Str.dirGeneral	unknown	Direction unknown due to settings
G51PTOC2	Op.general	51G2T	Residual time-overcurrent operate, Level 2
G51PTOC2	Str.general	51G2	Residual time-overcurrent pickup, Level 2
G51PTOC2	Str.dirGeneral	unknown	Direction unknown due to settings
G67PTOC1	Op.general	67G1T	Definite time, torque-controlled 50G1
G67PTOC1	Str.general	67G1	Torque-controlled 50G1
G67PTOC1	Str.dirGeneral	unknown	Direction unknown due to settings
G67PTOC2	Op.general	67G2T	Definite time, torque-controlled 50G2
G67PTOC2	Str.general	67G2	Torque-controlled 50G2
G67PTOC2	Str.dirGeneral	unknown	Direction unknown due to settings
G67PTOC3	Op.general	67G3T	Definite time, torque-controlled 50G3
G67PTOC3	Str.general	67G3	Torque-controlled 50G3
G67PTOC3	Str.dirGeneral	unknown	Direction unknown due to settings
G67PTOC4	Op.general	67G4T	Definite time, torque-controlled 50G4
G67PTOC4	Str.general	67G4	Torque-controlled 50G4
G67PTOC4	Str.dirGeneral	unknown	Direction unknown due to settings
GFPIOC1	Op.general	50GF	Residual forward direction decision supervision
GFRDIR1	Dir.general	32GF	Forward directional control routed to residual ground overcurrent elements
GFRDIR1	Dir.dirGeneral	32GF?0:1	Forward directional control routed to residual ground overcurrent elements, direction (32GF = false, direction unknown; 32GF = true, direction forward)
GPIOC1	Op.general	50G1	Instantaneous residual overcurrent, Level 1
GPIOC2	Op.general	50G2	Instantaneous residual overcurrent, Level 2
GPIOC3	Op.general	50G3	Instantaneous residual overcurrent, Level 3
GPIOC4	Op.general	50G4	Instantaneous residual overcurrent, Level 4
GPIOC5	Op.general	50G5	Instantaneous residual overcurrent, Level 5
GPIOC6	Op.general	50G6	Instantaneous residual overcurrent, Level 6

Table P.25 Logical Device: PRO (Protection) (Sheet 7 of 11)

Logical Node	Attribute	Data Source	Comment
GRPIOC1	Op.general	50GR	Residual reverse direction decision supervision
GRRDIR1	Dir.general	32GR	Reverse directional control routed to residual ground overcurrent elements
GRRDIR1	Dir.dirGeneral	32GR?0:2	Reverse directional control routed to residual ground overcurrent elements, direction (32GR = false, direction unknown; 32GR = true, direction reverse)
INTPTUV1	Op.general	INT3P	Three-phase voltage interruption from single-phase interruption
INTPTUV1	Op.phsA	INTA	A-Phase voltage interruption
INTPTUV1	Op.phsB	INTB	B-Phase voltage interruption
INTPTUV1	Op.phsC	INTC	C-Phase voltage interruption
INTPTUV1	Str.general	INT3P	Three-phase voltage interruption from single-phase interruption
INTPTUV1	Str.dirGeneral	unknown	Direction undefined
INTPTUV2	Op.general	INT3P	Three-phase voltage interruption from single-phase interruption
INTPTUV2	Op.phsA	INTAB	AB phase-to-phase voltage interruption
INTPTUV2	Op.phsB	INTBC	BC phase-to-phase voltage interruption
INTPTUV2	Op.phsC	INTCA	CA phase-to-phase voltage interruption
INTPTUV2	Str.general	INT3P	Three-phase voltage interruption from single-phase interruption
INTPTUV2	Str.dirGeneral	unknown	Direction undefined
LOPPTUV1	LOP2.stVal	LOP2	Drop in voltage without change in current LOP logic asserted
LOPPTUV1	LOP3.stVal	LOP3	LOP latched
LOPPTUV1	LOPBLK.stVal	LOPBLK	SELOGIC variable LOPBLK asserted
LOPPTUV1	LOPRST.stVal	LOPRST	LOP reset condition based on detection of healthy voltages
LOPPTUV1	Op.general	LOP	Loss of potential
LOPPTUV1	Str.general	LOP	Loss of potential
LOPPTUV1	Str.dirGeneral	unknown	Direction undefined
N51PTOC1	Op.general	51NT	Neutral time-overcurrent operate
N51PTOC1	Str.general	51N	Neutral time-overcurrent pickup
N51PTOC1	Str.dirGeneral	unknown	Direction unknown due to settings
N67PTOC1	Op.general	67N1T	Definite time, torque-controlled 50N1
N67PTOC1	Str.general	67N1	Torque-controlled 50N1
N67PTOC1	Str.dirGeneral	unknown	Direction unknown due to settings
N67PTOC2	Op.general	67N2T	Definite time, torque-controlled 50N2
N67PTOC2	Str.general	67N2	Torque-controlled 50N2
N67PTOC2	Str.dirGeneral	unknown	Direction unknown due to settings
N67PTOC3	Op.general	67N3T	Definite time, torque-controlled 50N3
N67PTOC3	Str.general	67N3	Torque-controlled 50N3
N67PTOC3	Str.dirGeneral	unknown	Direction unknown due to settings
N67PTOC4	Op.general	67N4T	Definite time, torque-controlled 50N4
N67PTOC4	Str.general	67N4	Torque-controlled 50N4
N67PTOC4	Str.dirGeneral	unknown	Direction unknown due to settings
NFRDIR1	Dir.general	32NF	Forward directional control routed to neutral-ground overcurrent elements

Table P.25 Logical Device: PRO (Protection) (Sheet 8 of 11)

Logical Node	Attribute	Data Source	Comment
NFRDIR1	Dir.dirGeneral	32NF?0:1	Forward directional control routed to neutral-ground overcurrent elements, direction (32NF = false, direction unknown; 32NF = true, direction forward)
NPIOC1	Op.general	50N1	Instantaneous neutral overcurrent, Level 1
NPIOC2	Op.general	50N2	Instantaneous neutral overcurrent, Level 2
NPIOC3	Op.general	50N3	Instantaneous neutral overcurrent, Level 3
NPIOC4	Op.general	50N4	Instantaneous neutral overcurrent, Level 4
NPIOC5	Op.general	50N5	Instantaneous neutral overcurrent, Level 5
NPIOC6	Op.general	50N6	Instantaneous neutral overcurrent, Level 6
NPTOV1	Str.general	59N1	Residual overvoltage, Level 1
NPTOV1	Str.dirGeneral	unknown	Direction undefined
NPTOV2	Str.general	59N2	Residual overvoltage, Level 2
NPTOV2	Str.dirGeneral	unknown	Direction undefined
NRRDIR1	Dir.general	32NR	Reverse directional control routed to neutral-ground overcurrent elements
NRRDIR1	Dir.dirGeneral	32NR?0:2	Reverse directional control routed to neutral-ground overcurrent elements, direction (32NR = false, direction unknown; 32NR = true, direction reverse)
P51PTOC1	Op.general	51PT	Phase time-overcurrent operate
P51PTOC1	Str.general	51P	Phase time-overcurrent pickup
P51PTOC1	Str.dirGeneral	unknown	Direction unknown due to settings
P67PTOC1	Op.general	67P1T	Definite time, torque-controlled 50P1
P67PTOC1	Str.general	67P1	Torque-controlled 50P1
P67PTOC1	Str.dirGeneral	unknown	Direction unknown due to settings
P67PTOC2	Op.general	67P2T	Definite time, torque-controlled 50P2
P67PTOC2	Str.general	67P2	Torque-controlled 50P2
P67PTOC2	Str.dirGeneral	unknown	Direction unknown due to settings
P67PTOC3	Op.general	67P3T	Definite time, torque-controlled 50P3
P67PTOC3	Str.general	67P3	Torque-controlled 50P3
P67PTOC3	Str.dirGeneral	unknown	Direction unknown due to settings
P67PTOC4	Op.general	67P4T	Definite time, torque-controlled 50P4
P67PTOC4	Str.general	67P4	Torque-controlled 50P4
P67PTOC4	Str.dirGeneral	unknown	Direction unknown due to settings
PFRDIR1	Dir.general	32PF	Forward directional control routed to phase overcurrent elements
PFRDIR1	Dir.dirGeneral	32PF?0:1	Forward directional control routed to phase overcurrent elements, direction (32PF = false, direction unknown; 32PF = true, direction forward)
PH3PTOV1	Str.general	3P59	Three-phase overvoltage
PH3PTOV1	Str.dirGeneral	unknown	Direction undefined
PH3PTUV1	Op.general	3P27	Three-phase undervoltage
PH3PTUV1	Str.general	3P27	Three-phase undervoltage
PH3PTUV1	Str.dirGeneral	unknown	Direction undefined
POTTPSCH1	Echo.general	EKEY	Echo permissive trip received

Table P.25 Logical Device: PRO (Protection) (Sheet 9 of 11)

Logical Node	Attribute	Data Source	Comment
POTTPSCH1	Op.general	PTRX	Permissive trip signal (input into trip logic)
POTTPSCH1	ProRx.stVal	PTRX	Permissive trip signal (input into trip logic)
POTTPSCH1	ProTx.stVal	KEY	Key permissive trip
POTTPSCH1	RvABlk.general	Z3RB	Current reversal guard
POTTPSCH1	Str.general	KEY	Key permissive trip
POTTPSCH1	Str.dirGeneral	KEY?0:1	Key permissive, direction (KEY = false, direction unknown; KEY = true, direction forward)
POTTPSCH1	WeiOp.general	ECTT	Echo conversion to trip
PPIOC1	Op.general	50P1	Instantaneous phase overcurrent, Level 1
PPIOC2	Op.general	50P2	Instantaneous phase overcurrent, Level 2
PPIOC3	Op.general	50P3	Instantaneous phase overcurrent, Level 3
PPIOC4	Op.general	50P4	Instantaneous phase overcurrent, Level 4
PPIOC5	Op.general	50P5	Instantaneous phase overcurrent, Level 5
PPIOC6	Op.general	50P6	Instantaneous phase overcurrent, Level 6
PRRDIR1	Dir.general	32PR	Reverse directional control routed to phase overcurrent elements
PRRDIR1	Dir.dirGeneral	32PR?0:2	Reverse directional control routed to phase overcurrent elements, direction (32PR = false, direction unknown; 32PR = true, direction reverse)
Q51PTOC1	Op.general	51QT	Negative-sequence time-overcurrent operate
Q51PTOC1	Str.general	51Q	Negative-sequence time-overcurrent pickup
Q51PTOC1	Str.dirGeneral	unknown	Direction unknown due to settings
Q67PTOC1	Op.general	67Q1T	Definite time, torque-controlled 50Q1
Q67PTOC1	Str.general	67Q1	Torque-controlled 50Q1
Q67PTOC1	Str.dirGeneral	unknown	Direction unknown due to settings
Q67PTOC2	Op.general	67Q2T	Definite time, torque-controlled 50Q2
Q67PTOC2	Str.general	67Q2	Torque-controlled 50Q2
Q67PTOC2	Str.dirGeneral	unknown	Direction unknown due to settings
Q67PTOC3	Op.general	67Q3T	Definite time, torque-controlled 50Q3
Q67PTOC3	Str.general	67Q3	Torque-controlled 50Q3
Q67PTOC3	Str.dirGeneral	unknown	Direction unknown due to settings
Q67PTOC4	Op.general	67Q4T	Definite time, torque-controlled 50Q4
Q67PTOC4	Str.general	67Q4	Torque-controlled 50Q4
Q67PTOC4	Str.dirGeneral	unknown	Direction unknown due to settings
QFPIOC1	Op.general	50QF	Negative-sequence forward direction decision supervision
QFRDIR1	Dir.general	32QF	Forward directional control routed to negative-sequence overcurrent elements
QFRDIR1	Dir.dirGeneral	32QF?0:1	Forward directional control routed to negative-sequence overcurrent elements, direction (32QF = false, direction unknown; 32QF = true, direction forward)
QPIOC1	Op.general	50Q1	Instantaneous negative-sequence overcurrent, Level 1
QPIOC2	Op.general	50Q2	Instantaneous negative-sequence overcurrent, Level 2
QPIOC3	Op.general	50Q3	Instantaneous negative-sequence overcurrent, Level 3
QPIOC4	Op.general	50Q4	Instantaneous negative-sequence overcurrent, Level 4

Table P.25 Logical Device: PRO (Protection) (Sheet 10 of 11)

Logical Node	Attribute	Data Source	Comment
QPIOC5	Op.general	50Q5	Instantaneous negative-sequence overcurrent, Level 5
QPIOC6	Op.general	50Q6	Instantaneous negative-sequence overcurrent, Level 6
QPTOV1	Str.general	59Q	Negative-sequence overvoltage, Level 1
QPTOV1	Str.dirGeneral	unknown	Direction undefined
QPTOV2	Str.general	59Q2	Negative-sequence overvoltage, Level 2
QPTOV2	Str.dirGeneral	unknown	Direction undefined
QRPIOC1	Op.general	50QR	Negative-sequence reverse direction decision supervision
QRRDIR1	Dir.general	32QR	Reverse directional control routed to negative-sequence overcurrent elements
QRRDIR1	Dir.dirGeneral	32QR?0:2	Reverse directional control routed to negative-sequence overcurrent elements, direction (32QR = false, direction unknown; 32QR = true, direction reverse)
R1PFRC1	Op.general	81R1T	Rate-of-change-of-frequency element 81R1T timed out
R1PFRC1	Str.general	81R1T	Rate-of-change-of-frequency element 81R1T timed out
R1PFRC1	Str.dirGeneral	unknown	Direction undefined
R2PFRC2	Op.general	81R2T	Rate-of-change-of-frequency element 81R2T timed out
R2PFRC2	Str.general	81R2T	Rate-of-change-of-frequency element 81R2T timed out
R2PFRC2	Str.dirGeneral	unknown	Direction undefined
R3PFRC3	Op.general	81R3T	Rate-of-change-of-frequency element 81R3T timed out
R3PFRC3	Str.general	81R3T	Rate-of-change-of-frequency element 81R3T timed out
R3PFRC3	Str.dirGeneral	unknown	Direction undefined
R4PFRC4	Op.general	81R4T	Rate-of-change-of-frequency element 81R4T timed out
R4PFRC4	Str.general	81R4T	Rate-of-change-of-frequency element 81R4T timed out
R4PFRC4	Str.dirGeneral	unknown	Direction undefined
RPFRC5	Op.general	81RT	Rate-of-change of frequency any element timed out
RPFRC5	Str.general	81RT	Rate-of-change of frequency any element timed out
RPFRC5	Str.dirGeneral	unknown	Direction undefined
SAGPTUV1	Op.general	SAG3P[h]	Three-phase voltage sag from phase-to-phase sag elements
SAGPTUV1	Op.phsA	SAGA[h]	A-Phase voltage sag
SAGPTUV1	Op.phsB	SAGB[h]	B-Phase voltage sag
SAGPTUV1	Op.phsC	SAGC[h]	C-Phase voltage sag
SAGPTUV1	Str.general	SAG3P[h]	Three-phase voltage sag from phase-to-phase sag elements
SAGPTUV1	Str.dirGeneral	unknown	Direction undefined
SAGPTUV2	Op.general	SAG3P[h]	Three-phase voltage sag from phase-to-phase sag elements
SAGPTUV2	Op.phsA	SAGAB[h]	AB phase-to-phase voltage sag
SAGPTUV2	Op.phsB	SAGBC[h]	BC phase-to-phase voltage sag
SAGPTUV2	Op.phsC	SAGCA[h]	CA phase-to-phase voltage sag
SAGPTUV2	Str.general	SAG3P[h]	Three-phase voltage sag from phase-to-phase sag elements
SAGPTUV2	Str.dirGeneral	unknown	Direction undefined
SPTOV1	Str.general	59S1	VS overvoltage, Level 1
SPTOV1	Str.dirGeneral	unknown	Direction undefined
SPTOV2	Str.general	59S2	VS overvoltage, Level 2

Table P.25 Logical Device: PRO (Protection) (Sheet 11 of 11)

Logical Node	Attribute	Data Source	Comment
SPTOV2	Str.dirGeneral	unknown	Direction undefined
SPTUV1	Op.general	27S	VS undervoltage
SPTUV1	Str.general	27S	VS undervoltage
SPTUV1	Str.dirGeneral	unknown	Direction undefined
SWLPTOV1	Op.general	SW3P	Three-phase voltage swell from phase-to-phase swell elements
SWLPTOV1	Op.phsA	SWA	A-Phase voltage swell
SWLPTOV1	Op.phsB	SWB	B-Phase voltage swell
SWLPTOV1	Op.phsC	SWC	C-Phase voltage swell
SWLPTOV1	Str.general	SW3P	Three-phase voltage swell from phase-to-phase swell elements
SWLPTOV1	Str.dirGeneral	unknown	Direction undefined
SWLPTOV2	Op.general	SW3P	Three-phase voltage swell from phase-to-phase swell elements
SWLPTOV2	Op.phsA	SWAB	AB phase-to-phase voltage swell
SWLPTOV2	Op.phsB	SWBC	BC phase-to-phase voltage swell
SWLPTOV2	Op.phsC	SWCA	CA phase-to-phase voltage swell
SWLPTOV2	Str.general	SW3P	Three-phase voltage swell from phase-to-phase swell elements
SWLPTOV2	Str.dirGeneral	unknown	Direction undefined
TRIPPTRC1	Tr.general	TRIP	Trip indication
VPTOV1	Str.general	59V1	Positive-sequence overvoltage
VPTOV1	Str.dirGeneral	unknown	Direction undefined

[a] Writing a 0 to BCCSWI1.CO.Pos.Oper.ctlVal will cause OC to assert and writing any other value will cause CC to assert.
[b] MX values contain instantaneous attributes (instMag and instCVal) which are updated whenever the source updates and attributes that are only updated when the source goes outside the points deadband (mag and cVal). Only the instantaneous values are shown in the table.
[c] Current is controlled by Global Setting FLTDISP. When FLTDISP = MAX, registers are populated with currents from the maximum fault row. When FLTDISP = FL, registers are populated with fault locator currents. See *Standard Event Report Summary* on page 12.6.
[d] When fault location is undefined, the relay will report –999.9 for FLOC and FZ, 0 for FZFA. FZ and FZFA are calculated by the fault locator and represent the portion of the line impedance between the relay and the fault.
[e] Fault location is a unitless quantity and depends upon the units used for entering group setting LL. IEC 61850 assumes the location is in km.
[f] If breaker is closed, value = 10 (2). If breaker is opened, value = 01 (1).
[g] There is only one set of frequency settings. Over/underfrequency determined by 81DxP setting. See *Create Over- and Underfrequency Elements* on page 3.58.
[h] Response controlled by Global setting PTCONN. See *Voltage Sag, Swell, and Interruption Elements* on page 3.66.

Table P.26 shows the LNs associated with measuring elements, defined as Logical Device MET. See *Appendix D: Relay Word Bits* and *Appendix E: Analog Quantities* for descriptions.

Table P.26 Logical Device: MET (Metering) (Sheet 1 of 3)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = MX[a]			
DCZBAT1	Vol.instMag.f	VDC	DC supply voltage
METMDST1	DmdA.nseq.instMag.f	3I2DEM	Demand, negative-sequence current
METMDST1	DmdA.phsA.instMag.f	IADEM	Demand, A-Phase current
METMDST1	DmdA.phsB.instMag.f	IBDEM	Demand, B-Phase current
METMDST1	DmdA.phsC.instMag.f	ICDEM	Demand, C-Phase current
METMDST1	DmdA.res.instMag.f	IGDEM	Demand, residual current
METMDST1	DmdA.neut.instMag.f	INDEM	Demand, neutral current

Table P.26 Logical Device: MET (Metering) (Sheet 2 of 3)

Logical Node	Attribute	Data Source	Comment
METMDST1	DmdVArh.instMag.f	MVRH3O	Energy, reactive (MVARh), supply direction away from busbar
METMDST1	DmdWh.instMag.f	MWH3O	Energy, real (MWh), supply direction away from busbar
METMDST1	PkDmdA.nseq.instMag.f	3I2PK	Peak demand, negative-sequence current
METMDST1	PkDmdA.phsA.instMag.f	IAPK	Peak demand, A-Phase current
METMDST1	PkDmdA.phsB.instMag.f	IBPK	Peak demand, B-Phase current
METMDST1	PkDmdA.phsC.instMag.f	ICPK	Peak demand, C-Phase current
METMDST1	PkDmdA.res.instMag.f	IGPK	Peak demand, residual current
METMDST1	PkDmdA.neut.instMag.f	INPK	Peak demand, neutral current
METMDST1	SupVArh.instMag.f	MVRH3I	Energy, reactive (MVARh), supply direction toward busbar
METMDST1	SupWh.instMag.f	MWH3I	Energy, real (MWh), supply direction toward busbar
METMMXU1	A.phsA.instCVal.mag.f	IA	A-Phase current magnitude
METMMXU1	A.phsA.instCVal.ang.f	IAFA	A-Phase current angle
METMMXU1	A.phsB.instCVal.mag.f	IB	B-Phase current magnitude
METMMXU1	A.phsB.instCVal.ang.f	IBFA	B-Phase current angle
METMMXU1	A.phsC.instCVal.mag.f	IC	C-Phase current magnitude
METMMXU1	A.phsC.instCVal.ang.f	ICFA	C-Phase current angle
METMMXU1	A.res.instCVal.mag.f	IG	Residual current magnitude
METMMXU1	A.res.instCVal.ang.f	IGFA	Residual current angle
METMMXU1	A.neut.instCVal.mag.f	IN	Neutral current magnitude
METMMXU1	A.neut.instCVal.ang.f	INFA	Neutral current angle
METMMXU1	Hz.instMag.f	FREQ	Measured frequency
METMMXU1	PF.phsA.instCVal.mag.f	PFA	A-Phase power factor
METMMXU1	PF.phsB.instCVal.mag.f	PFB	B-Phase power factor
METMMXU1	PF.phsC.instCVal.mag.f	PFC	C-Phase power factor
METMMXU1	PhV.phsA.instCVal.mag.f	VA	A-Phase voltage magnitude
METMMXU1	PhV.phsA.instCVal.ang.f	VAFA	A-Phase voltage angle
METMMXU1	PhV.phsB.instCVal.mag.f	VB	B-Phase voltage magnitude
METMMXU1	PhV.phsB.instCVal.ang.f	VBFA	B-Phase voltage angle
METMMXU1	PhV.phsC.instCVal.mag.f	VC	C-Phase voltage magnitude
METMMXU1	PhV.phsC.instCVal.ang.f	VCFA	C-Phase voltage angle
METMMXU1	PPV.phsAB.instCVal.mag.f	VAB	AB phase-to-phase voltage magnitude
METMMXU1	PPV.phsAB.instCVal.ang.f	VABFA	AB phase-to-phase voltage angle
METMMXU1	PPV.phsBC.instCVal.mag.f	VBC	BC phase-to-phase voltage magnitude
METMMXU1	PPV.phsBC.instCVal.ang.f	VBCFA	BC phase-to-phase voltage angle
METMMXU1	PPV.phsCA.instCVal.mag.f	VCA	CA phase-to-phase voltage magnitude
METMMXU1	PPV.phsCA.instCVal.ang.f	VCAFA	CA phase-to-phase voltage angle
METMMXU1	TotPF.instMag.f	PF3	Three-phase power factor
METMMXU1	TotVAr.instMag.f	KVAR3	Three-phase reactive power
METMMXU1	TotW.instMag.f	KW3	Three-phase real power
METMMXU1	VAr.phsA.instCVal.mag.f	KVARA	A-Phase reactive power
METMMXU1	VAr.phsB.instCVal.mag.f	KVARB	B-Phase reactive power

Table P.26 Logical Device: MET (Metering) (Sheet 3 of 3)

Logical Node	Attribute	Data Source	Comment
METMMXU1	VAr.phsC.instCVal.mag.f	KVARC	C-Phase reactive power
METMMXU1	VSyn.instCVal.mag.f	VS	VS input magnitude
METMMXU1	VSyn.instCVal.ang.f	VSFA	VS input angle
METMMXU1	W.phsA.instCVal.mag.f	KWA	A-Phase real power
METMMXU1	W.phsB.instCVal.mag.f	KWB	B-Phase real power
METMMXU1	W.phsC.instCVal.mag.f	KWC	C-Phase real power
METMSQI1	SeqA.c3.instCVal.mag.f	3I0	Zero-sequence current magnitude
METMSQI1	SeqA.c3.instCVal.ang.f	3I0FA	Zero-sequence current angle
METMSQI1	SeqA.c2.instCVal.mag.f	3I2	Negative-sequence current magnitude
METMSQI1	SeqA.c2.instCVal.ang.f	3I2FA	Negative-sequence current angle
METMSQI1	SeqA.c1.instCVal.mag.f	I1	Positive-sequence current magnitude
METMSQI1	SeqA.c1.instCVal.ang.f	I1FA	Positive-sequence current angle
METMSQI1	SeqA.seqT	0	Sequence type (0 = pos-neg-zero [I1-3I2-3I0])
METMSQI1	SeqV.c3.instCVal.mag.f	3V0_MAG	Zero-sequence voltage magnitude
METMSQI1	SeqV.c3.instCVal.ang.f	3V0FA	Zero-sequence voltage angle
METMSQI1	SeqV.c1.instCVal.mag.f	V1	Positive-sequence voltage magnitude
METMSQI1	SeqV.c1.instCVal.ang.f	V1FA	Positive-sequence voltage angle
METMSQI1	SeqV.c2.instCVal.mag.f	V2	Negative-sequence voltage magnitude
METMSQI1	SeqV.c2.instCVal.ang.f	V2FA	Negative-sequence voltage angle
METMSQI1	SeqV.seqT	0	Sequence type (0 = pos-neg-zero [V1-V2-3V0])
Functional Constraint = ST			
DCZBAT1	BatHi.stVal	DCHI	DC supply overvoltage (Boolean)
DCZBAT1	BatLo.stVal	DCLO	DC supply undervoltage (Boolean)

[a] MX values contain instantaneous attributes (instMag and instCVal), which are updated whenever the source updates and other attributes which are only updated when the source goes outside the points deadband (mag and cVal). Only the instantaneous values are shown in the table.

Table P.27 shows the LNs associated with control elements, defined as Logical Device CON. See *Appendix D: Relay Word Bits* for descriptions.

Table P.27 Logical Device: CON (Remote Control) (Sheet 1 of 2)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = CO			
RBGGIO1	SPCSO01.Oper.ctlVal–SPCSO08.Oper.ctlVal	RB1–RB8	Remote bit control (RB1–RB8)
RBGGIO2	SPCSO09.Oper.ctlVal–SPCSO16.Oper.ctlVal	RB9–RB16	Remote bit control (RB9–RB16)
RBGGIO3	SPCSO17.Oper.ctlVal–SPCSO24.Oper.ctlVal	RB17–RB24	Remote bit control (RB17–RB24)
RBGGIO4	SPCSO25.Oper.ctlVal–SPCSO32.Oper.ctlVal	RB25–RB32	Remote bit status (RB25–RB32)
Functional Constraint = ST			
RBGGIO1	SPCSO01.stVal–SPCSO08.stVal	RB1–RB8	Remote bit status (RB1–RB8)
RBGGIO2	SPCSO09.stVal–SPCSO16.stVal	RB9–RB16	Remote bit status (RB9–RB16)

Table P.27 Logical Device: CON (Remote Control) (Sheet 2 of 2)

Logical Node	Attribute	Data Source	Comment
RBGGIO3	SPCSO17.stVal–SPCSO24.stVal	RB17–RB24	Remote bit status (RB17–RB24)
RBGGIO4	SPCSO25.stVal–SPCSO32.stVal	RB25–RB32	Remote bit status (RB25–RB32)

Table P.28 shows the LNs associated with the annunciation element, defined as Logical Device ANN. See *Appendix D: Relay Word Bits* and *Appendix E: Analog Quantities* for descriptions.

Table P.28 Logical Device: ANN (Annunciation) (Sheet 1 of 2)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = ST			
ALMGGIO18	Ind01.stVal	HALARM	Indication of a diagnostic failure or warning that warrants an ALARM
ALMGGIO18	Ind02.stVal	HALARML	Latches in for relay diagnostic failures
ALMGGIO18	Ind03.stVal	HALARMP	Pulses for five seconds when a warning diagnostic condition occurs
ALMGGIO18	Ind04.stVal	HALARMA	Pulses for five seconds every minute until reset when a hardware diagnostic warning occurs
ALMGGIO18	Ind05.stVal	0	Reserved for future use
ALMGGIO18	Ind06.stVal	ALRMOUT	Output contact ALARM asserted
ALMGGIO18	Ind07.stVal	ACCESS	Asserted while any user is logged in at access Level B or higher
ALMGGIO18	Ind08.stVal	SALARM	Indication of software or user activity that warrants an ALARM
ALMGGIO18	Ind09.stVal	BADPASS	Pulses for one second whenever a user enters three successive bad passwords in an SEL ASCII terminal session or web session
ALMGGIO18	Ind10.stVal	CHGPASS	Pulses for one second whenever a password changes
ALMGGIO18	Ind11.stVal	SETCHG	Pulses for one second whenever settings are changed
ALMGGIO18	Ind12.stVal	0	Reserved for future use
ALMGGIO18	Ind13.stVal	ACCESSP	Pulses for one second when any user increases their access level to B or higher
ALMGGIO18	Ind14.stVal	PASNVAL	Pulses for one second when an incorrect password is entered when attempting to Access Level B or higher, or when changing passwords
ALMGGIO18	Ind15.stVal–Ind32.stVal	0	Reserved for future use
BKGGIO22	Ind01.stVal	52A	Breaker status, closed
BKGGIO22	Ind02.stVal	3PO	Three pole open condition
H2BLKGGIO21	Ind01.stVal	HBL2CT	C-Phase second harmonic block timed out
H2BLKGGIO21	Ind02.stVal	HBL2BT	B-Phase second harmonic block timed out
H2BLKGGIO21	Ind03.stVal	HBL2AT	A-Phase second harmonic block timed out
H2BLKGGIO21	Ind04.stVal	HBL2T	Combined-phase second harmonic block timed out
H2BLKGGIO21	Ind05.stVal	0	Reserved for future use
H2BLKGGIO21	Ind06.stVal	0	Reserved for future use
IN1GGIO1	Ind01.stVal–Ind06.stVal	IN101–IN106	Digital inputs
IN2GGIO2	Ind01.stVal–Ind16.stVal	IN201–IN216	Digital inputs
LBGGIO16	Ind01.stVal–Ind16.stVal	LB1–LB16	Local bits

Table P.28 Logical Device: ANN (Annunciation) (Sheet 2 of 2)

Logical Node	Attribute	Data Source	Comment
LTGGIO7	Ind01.stVal–Ind16.stVal	LT1–LT16	Latch bits
LVGGIO8	Ind01.stVal–Ind32.stVal	LV1–LV32	Logic variables
MBOKGGIO17	Ind01.stVal	ROKA	MIRRORED BITS receive OK, channel A
MBOKGGIO17	Ind02.stVal	RBADA	MIRRORED BITS receive bad, channel A
MBOKGGIO17	Ind03.stVal	CBADA	MIRRORED BITS channel bad, channel A
MBOKGGIO17	Ind04.stVal	LBOKA	MIRRORED BITS loopback OK, channel A
MBOKGGIO17	Ind05.stVal	ROKB	MIRRORED BITS receive OK, channel B
MBOKGGIO17	Ind06.stVal	RBADB	MIRRORED BITS receive bad, channel B
MBOKGGIO17	Ind07.stVal	CBADB	MIRRORED BITS channel bad, channel B
MBOKGGIO17	Ind08.stVal	LBOKB	MIRRORED BITS loopback OK, channel B
OUT1GGIO3	Ind01.stVal–Ind07.stVal	OUT101–OUT107	Digital outputs
OUT1GGIO3	Ind08.stVal	ALARM	Digital output—Inverse of ALRMOUT
OUT2GGIO4	Ind01.stVal–Ind12.stVal	OUT201–OUT212	Digital outputs
RMBAGGIO9	Ind01.stVal–Ind08.stVal	RMB1A–RMB8A	Receive MIRRORED BITS, channel A
RMBBGGIO11	Ind01.stVal–Ind08.stVal	RMB1B–RMB8B	Receive MIRRORED BITS, channel B
SGGGIO15	Ind01.stVal–Ind06.stVal	SG1–SG6	Setting group selected
SGGGIO15	Ind07.stVal	GRPSW	Group switch indication
SVGGIO5	Ind01.stVal–Ind16.stVal	SV1–SV16	SELOGIC variables
SVTGGIO6	Ind01.stVal–Ind16.stVal	SV1T–SV16T	SELOGIC variable timers
TLEDGGIO13	Ind01.stVal	EN	Relay **EN** LED status
TLEDGGIO13	Ind02.stVal	TRIP_LED	**TRIP** target LED status
TLEDGGIO13	Ind03.stVal	INST	**INST** target LED status
TLEDGGIO13	Ind04.stVal	COMM	**COMM** target LED status
TLEDGGIO13	Ind05.stVal	SOTF	**SOTF** target LED status
TLEDGGIO13	Ind06.stVal	50	**50** target LED status
TLEDGGIO13	Ind07.stVal	51	**51** target LED status
TLEDGGIO13	Ind08.stVal	81	**81** target LED status
TLEDGGIO13	Ind09.stVal	A	**A** target LED status
TLEDGGIO13	Ind10.stVal	B	**B** target LED status
TLEDGGIO13	Ind11.stVal	C	**C** target LED status
TLEDGGIO13	Ind12.stVal	G	**G** target LED status
TLEDGGIO13	Ind13.stVal	N	**N** target LED status
TLEDGGIO13	Ind14.stVal	RS	**RS** LED status
TLEDGGIO13	Ind15.stVal	CY	**CY** LED status
TLEDGGIO13	Ind16.stVal	LO	**LO** LED status
TMBAGGIO10	Ind01.stVal–Ind08.stVal	TMB1A–TMB8A	Transmit MIRRORED BITS, channel A
TMBBGGIO12	Ind01.stVal–Ind08.stVal	TMB1B–TMB8B	Transmit MIRRORED BITS, channel B
VBGGIO14	Ind001.stVal–Ind128.stVal	VB001–VB128[a]	Virtual bits

[a] Virtual bits retain state until overwritten, a new CID file is loaded, or the device is restarted.

Table P.29 shows the LNs associated with the configuration element, defined as Logical Device CFG.

Table P.29 Logical Device: CFG (Configuration)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = DC			
DevIDLPHD1	PhyNam.serNum	SERNUM	Relay serial number (string format)
LLN0	NamPlt.swRev	FID	Firmware revision

Protocol Implementation Conformance Statement: SEL-351

The tables below are as shown in the IEC 61850 standard, Part 8-1, Section 24. Note that because the standard explicitly dictates which services and functions must be implemented to achieve conformance, only the optional services and functions are listed.

Table P.30 PICS for A-Profile Support

Profile		Client	Server	Value/Comment
A1	Client/Server	N	Y	
A2	GOOSE/GSE management	Y	Y	Only GOOSE, not GSE management
A3	GSSE	N	N	
A4	Time Sync	N	Y	

Table P.31 PICS for T-Profile Support

Profile		Client	Server	Value/Comment
T1	TCP/IP	N	Y	
T2	OSI	N	N	
T3	GOOSE/GSE	Y	Y	Only GOOSE, not GSE
T4	GSSE	N	N	
T5	Time Sync	N	Y	

Refer to the *ACSI Conformance Statements* on page P.51 for information on the supported services.

MMS Conformance

The Manufacturing Message Specification (MMS) stack provides the basis for many IEC 61850 protocol services. *Table P.33* defines the service support requirement and restrictions of the MMS services in SEL-351 devices. Generally, only those services whose implementation is not mandatory are shown. Refer to the IEC 61850 standard, Part 8-1 for more information.

Table P.32 MMS Service Supported Conformance (Sheet 1 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
status		Y
getNameList		Y
identify		Y
rename		

Table P.32 MMS Service Supported Conformance (Sheet 2 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
read		Y
write		Y
getVariableAccessAttributes		Y
defineNamedVariable		
defineScatteredAccess		
getScatteredAccessAttributes		
deleteVariableAccess		
defineNamedVariableList		
getNamedVariableListAttributes		Y
deleteNamedVariableList		
defineNamedType		
getNamedTypeAttributes		
deleteNamedType		
input		
output		
takeControl		
relinquishControl		
defineSemaphore		
deleteSemaphore		
reportPoolSemaphoreStatus		
reportSemaphoreStatus		
initiateDownloadSequence		
downloadSegment		
terminateDownloadSequence		
initiateUploadSequence		
uploadSegment		
terminateUploadSequence		
requestDomainDownload		
requestDomainUpload		
loadDomainContent		
storeDomainContent		
deleteDomain		
getDomainAttributes		Y
createProgramInvocation		
deleteProgramInvocation		
start		
stop		
resume		
reset		
kill		
getProgramInvocationAttributes		

Table P.32 MMS Service Supported Conformance (Sheet 3 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
obtainFile		Y
defineEventCondition		
deleteEventCondition		
getEventConditionAttributes		
reportEventConditionStatus		
alterEventConditionMonitoring		
triggerEvent		
defineEventAction		
deleteEventAction		
alterEventEnrollment		
reportEventEnrollmentStatus		
getEventEnrollmentAttributes		
acknowledgeEventNotification		
getAlarmSummary		
getAlarmEnrollmentSummary		
readJournal		
writeJournal		
initializeJournal		
reportJournalStatus		
createJournal		
deleteJournal		
fileOpen		Y
fileRead		Y
fileClose		Y
fileRename		
fileDirectory		Y
unsolicitedStatus		
informationReport		Y
eventNotification		
attachToEventCondition		
attachToSemaphore		
conclude		Y
cancel		Y
getDataExchangeAttributes		
exchangeData		
defineAccessControlList		
getAccessControlListAttributes		
reportAccessControlledObjects		
deleteAccessControlList		
alterAccessControl		
reconfigureProgramInvocation		

Table P.33 lists specific settings for the MMS parameter Conformance Building Block (CBB).

Table P.33 MMS Parameter CBB

MMS Parameter CBB	Client-CR Supported	Server-CR Supported
STR1		Y
STR2		Y
VNAM		Y
VADR		
VALT		Y
TPY		
VLIS		Y
CEI		

The following variable access conformance statements are listed in the order specified in the IEC 61850 standard, Part 8-1. Generally, only those services whose implementation is not mandatory are shown. Refer to the IEC 61850 standard, Part 8-1 for more information.

Table P.34 AlternateAccessSelection Conformance Statement

AlternateAccessSelection	Client-CR Supported	Server-CR Supported
accessSelection		Y
component		Y
index		
indexRange		
allElements		
alternateAccess		Y
selectAccess		Y
component		Y
index		
indexRange		
allElements		

Table P.35 VariableAccessSpecification Conformance Statement

VariableAccessSpecification	Client-CR Supported	Server-CR Supported
listOfVariable		Y
variableSpecification		Y
alternateAccess		Y
variableListName		Y

Table P.36 VariableSpecification Conformance Statement

VariableSpecification	Client-CR Supported	Server-CR Supported
name		Y
address		
variableDescription		
scatteredAccessDescription		
invalidated		

Table P.37 Read Conformance Statement

Read	Client-CR Supported	Server-CR Supported
Request		
specificationWithResult		
variableAccessSpecification		
Response		
variableAccessSpecification		Y
listOfAccessResult		Y

Table P.38 GetVariableAccessAttributes Conformance Statement

GetVariableAccessAttributes	Client-CR Supported	Server-CR Supported
Request		
name		
address		
Response		
mmsDeletable		
address		
typeSpecification		

Table P.39 DefineNamedVariableList Conformance Statement

DefineVariableAccessAttributes	Client-CR Supported	Server-CR Supported
Request		
variableListName		
listOfVariable		
variableSpecification		
alternateAccess		
Response		

Table P.40 GetNamedVariableListAttributes Conformance Statement

GetNamedVariableListAttributes	Client-CR Supported	Server-CR Supported
Request		
ObjectName		
Response		
mmsDeletable		Y
listOfVariable		Y
variableSpecification		Y
alternateAccess		Y

Table P.41 DeleteNamedVariableList Conformance Statement

DeleteNamedVariableList	Client-CR Supported	Server-CR Supported
Request		
Scope		
listOfVariableListName		
domainName		
Response		
numberMatched		
numberDeleted		
DeleteNamedVariableList-Error		

GOOSE Services Conformance Statement

Table P.42 GOOSE Conformance

	Subscriber	Publisher	Value/Comment
GOOSE Services	Y	Y	
SendGOOSEMessage		Y	
GetGoReference			
GetGOOSEElementNumber			
GetGoCBValues		Y	
SetGoCBValues			
GSENotSupported			
GOOSE Control Block (GoCB)		Y	

ACSI Conformance Statements

Table P.43 ACSI Basic Conformance Statement

Services		Client/Subscriber	Server/Publisher	SEL-351 Support
Client-Server Roles				
B11	Server side (of Two-Party Application-Association)	–	c1[a]	YES
B12	Client side (of Two-Party Application-Association)	c1[a]	–	
SCMS Supported				
B21	SCSM: IEC 61850-8-1 used			YES
B22	SCSM: IEC 61850-9-1 used			
B23	SCSM: IEC 61850-9-2 used			
B24	SCSM: other			
Generic Substation Event Model (GSE)				
B31	Publisher side	–	O[b]	YES
B32	Subscriber side	O[b]	–	YES
Transmission of Sampled Value Model (SVC)				
B41	Publisher side	–	O[b]	
B42	Subscriber side	O[b]	–	

[a] c1 is mandatory if support for LOGICAL-DEVICE model has been declared.
[b] O: Optional.

Table P.44 ACSI Models Conformance Statement (Sheet 1 of 2)

Models		Client/Subscriber	Server/Publisher	SEL-351 Support
If Server Side (B11) Supported				
M1	Logical device	c2[a]	c2[a]	YES
M2	Logical node	c3[b]	c3[b]	YES
M3	Data	c4[c]	c4[c]	YES
M4	Dataset	c5[d]	c5[d]	YES
M5	Substitution	O[e]	O[e]	
M6	Setting group control	O[e]	O[e]	
Reporting				
M7	Buffered report control	O[e]	O[e]	YES
M7-1	sequence-number			YES
M7-2	report-time-stamp			YES
M7-3	reason-for-inclusion			YES
M7-4	data-set-name			YES
M7-5	data-reference			YES
M7-6	buffer-overflow			YES
M7-7	entryID			YES
M7-8	BufTm			YES
M7-9	IntgPd			YES
M7-10	GI			YES

Table P.44 ACSI Models Conformance Statement (Sheet 2 of 2)

Models		Client/Subscriber	Server/Publisher	SEL-351 Support
M8	Unbuffered report control	O[e]	O[e]	YES
M8-1	sequence-number			YES
M8-2	report-time-stamp			YES
M8-3	reason-for-inclusion			YES
M8-4	data-set-name			YES
M8-5	data-reference			YES
M8-6	BufTm			YES
M8-7	IntgPd			YES
M8-8	GI			YES
	Logging	O[e]	O[e]	
M9	Log control	O[e]	O[e]	
M9-1	IntgPd			
M10	Log	O[e]	O[e]	
M11	Control	M[f]	M[f]	YES
If GSE (B31/32) Is Supported				
M12	GOOSE	O[e]	O[e]	YES
M12-1	entryID			YES
M12-2	DataReflnc			YES
M13	GSSE	O[e]	O[e]	
If GSE (B41/42) Is Supported				
M14	Multicast SVC	O[e]	O[e]	
M15	Unicast SVC	O[e]	O[e]	
M16	Time	M[f]	M[f]	YES
M17	File Transfer	O[e]	O[e]	YES

[a] c2 is "M" if support for LOGICAL-NODE model has been declared.
[b] c3 is "M" if support for DATA model has been declared.
[c] c4 is "M" if support for DATA-SET, Substitution, Report, Log Control, or Time model has been declared.
[d] c5 is "M" if support for Report, GSE, or SV models has been declared.
[e] O: Optional.
[f] M: Mandatory.

Table P.45 ACSI Services Conformance Statement (Sheet 1 of 4)

Services		AA: TP/MC	Client/ Subscriber	Server/Publisher	SEL-351 Support
Server (Clause 6)					
S1	ServerDirectory	TP		M[a]	YES
Application Association (Clause 7)					
S2	Associate		M[a]	M[a]	YES
S3	Abort		M[a]	M[a]	YES
S4	Release		M[a]	M[a]	YES
Logical Device (Clause 8)					
S5	LogicalDeviceDirectory	TP	M[a]	M[a]	YES

Table P.45 ACSI Services Conformance Statement (Sheet 2 of 4)

Services		AA: TP/MC	Client/ Subscriber	Server/Publisher	SEL-351 Support
Logical Node (Clause 9)					
S6	LogicalNodeDirectory	TP	M[a]	M[a]	YES
S7	GetAllDataValues	TP	O[b]	M[a]	YES
Data (Clause 10)					
S8	GetDataValues	TP	M[a]	M[a]	YES
S9	SetDataValues	TP	O[b]	O[b]	
S10	GetDataDirectory	TP	O[b]	M[a]	YES
S11	GetDataDefinition	TP	O[b]	M[a]	YES
Dataset (Clause 11)					
S12	GetDataSetValues	TP	O[b]	M[a]	YES
S13	SetDataSetValues	TP	O[b]	O[b]	
S14	CreateDataSet	TP	O[b]	O[b]	
S15	DeleteDataSet	TP	O[b]	O[b]	
S16	GetDataSetDirectory	TP	O[b]	O[b]	YES
Substitution (Clause 12)					
S17	SetDataValues	TP	M[a]	M[a]	
Setting Group Control (Clause 13)					
S18	SelectActiveSG	TP	O[b]	O[b]	
S19	SelectEditSG	TP	O[b]	O[b]	
S20	SetSGvalues	TP	O[b]	O[b]	
S21	ConfirmEditSGVal	TP	O[b]	O[b]	
S22	GetSGValues	TP	O[b]	O[b]	
S23	GetSGCBValues	TP	O[b]	O[b]	
Reporting (Clause 14)					
Buffered Report Control Block (BRCB)					
S24	Report	TP	c6[c]	c6[c]	YES
S24-1	data-change (dchg)				YES
S24-2	qchg-change (qchg)				YES
S24-3	data-update (dupd)				
S25	GetBRCBValues	TP	c6[c]	c6[c]	YES
S26	SetBRCBValues	TP	c6[c]	c6[c]	YES
Unbuffered Report Control Block (URCB)					
S27	Report	TP	c6[c]	c6[c]	YES
S27-1	data-change (dchg)				YES
S27-2	qchg-change (qchg)				YES
S27-3	data-update (dupd)				
S28	GetURCBValues	TP	c6[c]	c6[c]	YES
S29	SetURCBValues	TP	c6[c]	c6[c]	YES

Table P.45 ACSI Services Conformance Statement (Sheet 3 of 4)

Services		AA: TP/MC	Client/ Subscriber	Server/Publisher	SEL-351 Support
Logging (Clause 14)					
Log Control Block					
S30	GetLCBValues	TP	M[a]	M[a]	
S31	SetLCBValues	TP	O[b]	M[a]	
LOG					
S32	QueryLogByTime	TP	c7[d]	M[a]	
S33	QueryLogByEntry	TP	c7[d]	M[a]	
S34	GetLogStatusValues	TP	M[a]	M[a]	
Generic Substation Event Model (GSE) (Clause 14.3.5.3.4.)					
GOOSE-Control-Block					
S35	SendGOOSEMessage	MC	c8[e]	c8[e]	YES
S36	GetReference	TP	O[b]	c9[f]	
S37	GetGOOSEElementNumber	TP	O[b]	c9[f]	
S38	GetGoCBValues	TP	O[b]	O[b]	YES
S39	SetGoCBValues	TP	O[b]	O[b]	
GSSE-Control-Block					
S40	SendGSSEMessage	MC	c8[e]	c8[e]	
S41	GetReference	TP	O[b]	c9[f]	
S42	GetGSSEElementNumber	TP	O[b]	c9[f]	
S43	GetGsCBValues	TP	O[b]	O[b]	
S44	SetGsCBValues	TP	O[b]	O[b]	
Transmission of Sample Value Model (SVC) (Clause 16)					
Multicast SVC					
S45	SendMSVMessage	MC	c10[g]	c10[g]	
S46	GetMSVCBValues	TP	O[b]	O[b]	
S47	SetMSVCBValues	TP	O[b]	O[b]	
Unicast SVC					
S48	SendUSVMessage	MC	c10[g]	c10[g]	
S49	GetUSVCBValues	TP	O[b]	O[b]	
S50	SetUSVCBValues	TP	O[b]	O[b]	
Control (Clause 16.4.8)					
S51	Select		M[a]	O[b]	
S52	SelectWithValue	TP	M[a]	O[b]	YES
S53	Cancel	TP	O[b]	M[a]	YES
S54	Operate	TP	M[a]	M[a]	YES
S55	Command-Termination	TP	M[a]	M[a]	YES
S56	TimeActivated-Operate	TP	O[b]	O[b]	

Table P.45 ACSI Services Conformance Statement (Sheet 4 of 4)

Services		AA: TP/MC	Client/ Subscriber	Server/Publisher	SEL-351 Support
File Transfer (Clause 20)					
S57	GetFile	TP	O[b]	M[a]	YES
S58	SetFile	TP	O[b]	O[b]	YES
S59	DeleteFile	TP	O[b]	O[b]	
S60	GetFileAttributeValues	TP	O[b]	M[a]	YES
Time (Clause 5.5)					
T1	Time resolution of internal clock (nearest negative power of 2 in seconds)			2–10 (1 ms)	T1
T2	Time accuracy of internal clock				10/9
	T1				YES
	T2				YES
	T3				YES
	T4				YES
	T5				YES
T3	Supported TimeStamp resolution (nearest negative power of 2 in seconds)			2–10 (1 ms)	10

[a] M: Mandatory.
[b] O: Optional.
[c] c6 declares support for at least one (BRCB or URCB).
[d] c7 declares support for at least one (QueryLogByTime or QueryLogAfter).
[e] c8 declares support for at least one (SendGOOSEMessage or SendGSSEMessage).
[f] c9 declares support if TP association is available.
[g] c10 declares support for at least one (SendMSVMessage or SendUSVMessage).

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APPENDIX Q

Cybersecurity Features

Introduction and Security Environment

Product Function

The SEL-351 is a protective relay which can be configured to have up to seven communications ports. The serial ports allow users to access five access levels for the device. The communications protocols available on the SEL-351 allow the device to periodically communicate information like relay status or metering quantities to other devices such as a SCADA client. The available communications protocols also allow for local engineering access via a terminal connection.

Security Requirements

The SEL-351 was designed to be applied in secure environments like substation control houses, switchyards, or similar control facilities. Only permit authorized personnel physical or remote access to the relay. Restrict communications to the SEL-351 to trusted network segments that are isolated from the internet.

Version Information

Obtaining Version Information

To determine the firmware version in your relay, view the status report by using the serial port **STATUS** command or the front panel **STATUS** pushbutton. The status report displays the Firmware Identification (FID) number. An example FID is shown here.

FID = SEL-351-*x*-R500-V0-Z001001-D*xxxxxxxx*

The date code is after the D. The single *x* after the "SEL-351" is the firmware version number and will be a 5, 6, or 7, depending on the firmware features ordered with the relay.

x = 5	Basic Features
x = 6	Standard (includes Mirrored Bits communications and Load Profile)
x = 7	Standard, plus Power Elements and Voltage Sag/Swell/Interrupt Elements

Appendix A: Firmware, ICD, and Manual Versions includes the release notes for every firmware version. More firmware version information, including identification of the current version and identification of compatible SELBOOT version, is available at selinc.com/products/firmware/.

Integrity Indicators

The **STATUS** command displays the firmware checksum identifier (CID) specific for each version of SEL-351 firmware. SEL also provides firmware hashes as an additional tool to verify the integrity of firmware files. Visit selinc.com/products/firmware/ to verify firmware CID and hash values.

Commissioning and Decommissioning

Commissioning

All communications ports of the SEL-351 are enabled by default. Serial Port (Port 1, 2, 3, or F) and Ethernet Port (Port 5) setting EPORT allows users to enable or disable communications for each individual port.

Secure Operation Recommendations

The SEL-351 provides a physical ALARM output contact that you can use to monitor relay diagnostic failures or access to the relay. If a diagnostic self-test results in the relay disabling protection, then the ALARM output contact asserts and provides users an external indication of the relay failure. When you log in at Access Level 2, the ALARM output contact pulses for 1 second.

Good operating practice is to always monitor the physical state of the ALARM output contact for assertions.

Decommissioning

It is often desirable to erase settings and data from a relay when it is removed from service. You can completely erase all the settings and data from the SEL-351 by using the following procedure:

Step 1. Log in at Access Level 2, and use the **CAL** command to log into Access Level C.

Step 2. Execute the **R_S** command.

Step 3. Allow the relay to restart.

Once this procedure is complete, all settings, passwords, and other data are erased; and you can return the relay to inventory, redeploy it, or dispose of it.

Returning Protective Relays for Service

When returning protective relays to SEL for service, preserve the data stored in the relay because it is needed to diagnose many problems.

One option is to leave data in the relay but specify special handling to protect the data. The online return merchandise authorization (RMA) form contains an option for special BES Cyber Asset handling. Ensure that the RMA number generated during the return process appears on the exterior of the shipping container. The shipping method you choose should provide tracking information and delivery confirmation.

If your processes do not permit the relay to be shipped with the settings intact, the other option is to export settings and data from the relay, and then erase the data from the relay as described in Decommissioning. You can send the data to SEL separately from the relay by coordinating with an SEL application engineer or customer service representative to use SEL's secure file transfer service (securefile.selinc.com). Include the RMA number for the associated product in the file name.

Prior to return shipping of your BES Cyber Asset, SEL follows NIST Special Publication 800-88 Revision 1 guidelines to ensure secure handling and destruction of all customer data before returning the unit. The returned unit will also be packaged by using tamper-evident tape or a similar device. The shipping service will provide tracking information and delivery confirmation.

External Interfaces

Ports and Services

The SEL-351 Relay has as many as seven communications ports, as shown in the table below.

Port Number	Type	Location	Standard/Optional
1	EIA-485 Serial or SEL-2812 Compatible Fiber Optic	Rear	Optional
2	EIA-232 Serial	Rear	Standard
3	EIA-232 Serial	Rear	Standard
4 or F	EIA-232 Serial	Front	Standard
5	Single Ethernet	Rear	Standard
5A/5B	Dual Ethernet	Rear	Optional
N/A	USB	Front	Optional

The SEL-351 provides the following software communications protocols.

	Port 1 EIA-485 or Fiber-Optic	Port 2 EIA-232	Port 3 EIA-232	Port 4, F EIA-232	USB	5, 5A, 5B Ethernet	Section
DNP3 Level 2	X	X	X	X		X	*Appendix L*
IEC 61850						X[a]	*Appendix P*
Modbus	X	X	X			X	*Appendix O*
C37.118 Synchrophasors	X	X	X	X		X	*Appendix N*
SEL ASCII and Compressed ASCII	X	X	X	X	X	Telnet	*Section 10*, *Appendix K*
SEL Fast Synchrophasors	X	X	X	X			*Appendix J*, *Appendix N*
SEL Fast Operate	X	X	X	X		Telnet	*Appendix J*
Other SEL Fast Message (Meter, SER,…)	X	X	X	X	X	Telnet	*Appendix J*, *Appendix M*
SEL Mirrored Bits	X	X	X	X			*Appendix H*

	Port 1 EIA-485 or Fiber-Optic	Port 2 EIA-232	Port 3 EIA-232	Port 4, F EIA-232	USB	5, 5A, 5B Ethernet	Section
SEL LMD	X	X	X	X			*Appendix J*
SEL DTA	X	X	X	X			*Section 10*
SNTP						X	*Section 10*
FTP						X	*Section 10*
Telnet						X	*Section 10*
Ping						X	*Section 10*
Web Server (HTTP)						X	*Section 10*

[a] Not available with single copper Ethernet port.

Firmware Upgrade Interface

The SEL-351 firmware upgrade interface includes a firmware loader program called SELBOOT. To upgrade firmware, use the SELBOOT program to download an SEL-supplied firmware file from a PC to the relay through one of the serial ports. Refer to *Appendix B: Firmware Upgrade Instructions for SEL-351 Relays With Ethernet* for more information.

Access Controls

Privilege Levels

The SEL-351 has five access levels. Four access levels require separate passwords that allow administrators to restrict access to users authorized for the capabilities those levels provide.

Access Levels

The SEL-351 supports five access levels which are described here. These access levels cannot be edited.

Access Level 0: The lowest access level that provides limited read-only function for unauthenticated users.

Access Level 1: Allows you to look at more information such as settings and metering, but still read only.

Access Level B: Allows you to operate output contacts or change the active setting group.

Access Level 2: Allows you to change relay settings.

Access Level C: Restricted access level for specific maintenance functions, some of which should be used under direction of SEL only.

Passwords

The SEL-351 ships with default passwords in place for each access level that you should change after installation. The factory-default passwords for Access Levels 1, B, 2, and C are:

Access Level	Factory-Default Password
1	OTTER
B	EDITH
2	TAIL
C[a]	CLARKE

[a] Use only under the direction of SEL.

Change the default passwords at installation. Failure to set non-default passwords for all access levels may allow unauthorized access. SEL is not responsible for any damage resulting from unauthorized access.

Passwords may include up to 12 characters. Upper- and lowercase letters are treated as different characters.

Alpha	A B C D E F G H I J K L M N O P Q R S T U V W X Y Z a b c d e f g h i j k l m n o p q r s t u v w x y z
Numeric	1 2 3 4 5 6 7 8 9
Special	! " # $ % & ' ( ) * , - . / : ; < = > ? @ [\ ] ^ _ ` { | } ~

X.509 Certificates

The SEL-351 does not support X.509 Certificates.

Physical Access Controls

The SEL-351 has no physical access controls. However, you can monitor physical ingress by wiring a door sensor to one of the SEL-351 contact inputs. This input can then be mapped for SCADA monitoring or added to the Sequential Events Recorder (SER) log so that you can monitor when physical access to the relay occurs. You also can wire an electronic latch to an SEL-351 contact output and then map this output for SCADA control.

Logging Features

Security Events

When you log in to the SEL-351 at Access Level 2, the ALARM Relay Word bit asserts to logical 1 for 1 second and the ALARM output contact coil is de-energized for 1 second.

The ALARM Relay Word bit can be mapped for SCADA monitoring or added to the SER report for later analysis. The ALARM output contact can be physically monitored to provide a notification of when Access Level 2 is reached.

Internal Log Storage

The SEL-351 does not provide security logs to notify users of the storage capacity of the relay or indications that the storage capacity is full. The SEL-351 self-manages its memory storage capacity for each of the event recording features by overwriting older entries first when storage is full.

The SEL-351 provides user-programable event report length and prefault length. Event report length is either 15, 20, or 60 cycles. Prefault length ranges from 1 to 59 cycles. The relay stores the most recent event report data in nonvolatile memory. Forty-four 15-cycle events, twenty-three 30 cycle events, or eleven 60 cycle event reports are maintained; if more reports are triggered, the latest event report overwrites the oldest event report.

The relay adds lines in the SER report for a change of state of a programmable condition. The SER lists date and time stamped lines of information each time a programmed condition changes state. The relay stores the latest 1024 lines of the SER report in nonvolatile memory. If the report fills up, newer rows overwrite the oldest rows in the report.

The SEL-351 -3 , -4 relay offers an additional style of event report:

Sag / Swell / Interruption (SSI) report

The SSI report (available in Firmware Versions 7) records date, time, current, voltage, and Voltage Sag / Swell / Interruption (VSSI) element status during voltage disturbances, as determined by programmable settings, VINT, VSAG, and VSWELL. When the relay is recording a disturbance, entries are automatically added to the SSI report at one of the four rates: once per quarter cycle, once per cycle, once per 64 cycles, or once per day. The most recent 3,855 SSI entries are always available from nonvolatile memory, and up to 3,855 older entries may also be available.

Syslog

The SEL-351 does not support Syslog functionality.

Alarm Contact

The alarm output contact is controlled by SELOGIC control equation ALRMOUT. The default setting for this equation is:

ALRMOUT = !(SALARM + HALARM)

With factory default settings, when the relay is operational and there are no alarm conditions, the ALARM output contact coil is energized. The alarm logic and circuitry keep the ALARM output contact coil energized. Depending on the ALARM output contact type (a or b) the ALARM output contact closes or opens. An a type output contact is open when the output contact coil is de-energized and closed when the output contact coil is energized. A b type output contact is closed when the output contact coil is de-energized and open when the output contact coil is energized.

Backup and Restore

The SEL-351 supports the backup and restoration of settings. ‘Read’ and ‘Send’ functions are available in the ACSELERATOR QuickSet software. Connect the SEL-351 to a personal computer which has the latest version of ACSELERATOR QuickSet installed. Once communications are established, settings can be read from the SEL-351 relay and saved as an .rdb file. Settings files with the .rdb extension can be opened and sent back to SEL-351 relays with the same part number and firmware configuration.

Malware Protection Features

The SEL-351 is an embedded product which does not provide for installation of additional software and has continuous health monitoring. For a full description of how this protects against malware, see selinc.com/mitigating_malware/.

Product Updates

The most recent instruction manual release is available on selinc.com for download. *Appendix A* contains the latest product updates.

The *Appendix A* entries for firmware versions released after March 1, 2022 adds the [Cybersecurity] tag to each firmware change which is related to a security vulnerability, and [Cybsecurity Enhancement] to other cybersecurity improvements.

Information for security vulnerabilities can be obtained at selinc.com/security_vulnerabilities/.

Obtaining Updates

Contact your local SEL customer service representative for firmware updates for the SEL-351.

Update Verification

A terminal **STATUS** command gives users a firmware checksum identifier (CID) for the firmware installed in a relay. Additionally, SEL provides firmware hashes as a tool to verify the integrity of firmware files. Visit selinc.com/products/firmware to verify firmware CID and hash values.

Contact SEL

For further questions or concerns about SEL product security, please contact SEL:

Email: security@selinc.com or phone +1-509-332-1890.

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APPENDIX R

Fault Location and Supplemental Fault Location and Impedance Data

Fault Location

The SEL-351 Relay calculates and reports a line-distance-to-fault location using event report voltage and current data samples to determine the impedance to the fault. See *Standard 15/30/60-Cycle Event Reports* on page 12.3 for additional information on event recording, event summaries, and fault location.

The relay scales the calculated impedance against the known line impedance and line length values entered in the Line Parameter Settings (line length setting, LL, and line impedance settings, Z1MAG, Z1ANG, Z0MAG, and Z0ANG, Z0SMAG, and Z0SANG) to determine the distance to the fault.

The fault location calculated from single-ended fault data using an impedance-based method is a best estimate. On lines with two or more active sources the following factors can affect fault location calculations:

- Fault contribution from remote sources
- Nonhomogeneous source impedances
- Load flow
- Fault resistance

The fault location calculation performed by the SEL-351 is designed to minimize the influence of these power system complexities. For further information on fault location calculations, refer to SEL technical papers listed at the end of this section.

The fault location appears in a variety of relay reports, including the following:

- Formatted and compressed event reports generated from **EVE** and **CEV** commands, respectively.
- Formatted and compressed long summary event reports generated from **SUM** and **CSU** commands, respectively,
- The Event Summaries/History report generated from the **HIS** command.
- In the *.HDR file provided with COMTRADE event reporting

The fault location is also available in the front-panel HMI events data and as a data point for communication through various protocols to master and peer devices.

Fault Location Requirements

Selected criteria must be met to provide a valid fault location (e.g., the fault location function is enabled by setting EFLOC = Y, sufficient fault data are available, appropriate protection elements are asserted, and a valid fault-type is determined). If these criteria are not met, the distance-to-fault location appears as all dollar signs ($$$$$$$) in the relay reports. For more information on fault location requirements, see *Fault Location* on page 12.8.

Supplemental Fault Location Data

The SEL-351 also calculates the impedance to the fault location (magnitude and angle) in secondary ohms and degrees, respectively, that appear in selected reports.

The front-panel HMI events data and long summary event reports (formatted and compressed) include this supplemental fault location and impedance data. The basic fault location and supplemental fault impedance data are shown graphically on an R-X impedance plane in *Figure R.1* below:

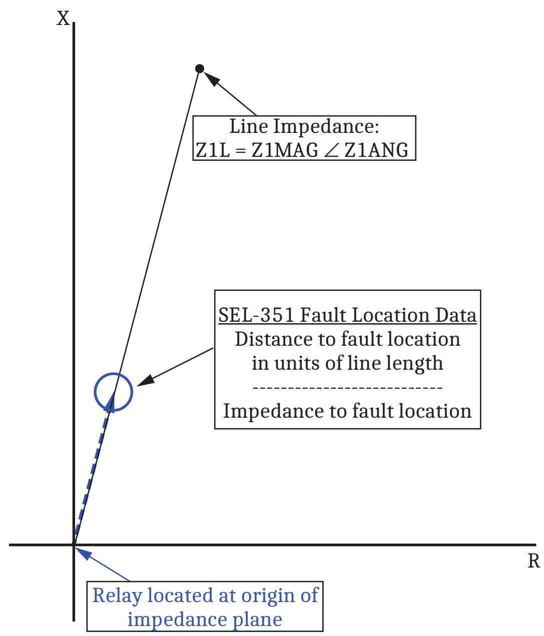

Figure R.1 Graphical Representation of SEL-351 Fault Location Data

SEL Technical Papers for Further Reading

E.O. Schweitzer, III and Jeff Roberts, “Distance Relay Element Design,” 19th Annual Western Protective Relay Conference, Spokane, Washington, October 19–22, 1992.

S.E. Zocholl, “Three-Phase Circuit Analysis and the Mysterious k0 Factor,” 48th Annual Conference for Protective Relay Engineers at Texas A&M University, College Station, Texas, April 3–5, 1995.

Joe Mooney, Jackie Peer, "Application Guidelines for Ground Fault Protection," 24th Annual Western Protective Relay Conference, Spokane, Washington, October, 1997.

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SEL-351-5, -6, -7 Command Summary

Command	Description
2AC	Enter Access Level 2. If the main board Access jumper is not in place, the relay prompts for the entry of the Access Level 2 password.
ACC	Enter Access Level 1. If the main board Access jumper is not in place, the relay prompts for the entry of the Access Level 1 password.
BAC	Enter Breaker Access Level (Access Level B). If the main board Access jumper is not in place, the relay prompts the user for the Access Level B password.
BNA	Display names of status bits in the A5D1 Fast Meter Message.
BRE	Display breaker monitor data (trips, interrupted current, wear).
BRE H	Display breaker history.
BRE R	Reset breaker monitor.
BRE W	Preload breaker wear.
CAL	Enter Access Level C. If the main board Access jumper is not in place, the relay prompts for the entry of the Access Level C password. Access Level C is reserved for SEL use only.
CAS	Display compressed ASCII configuration message.
CEV *n*	Display event report *n* in compressed ASCII format.
CHI	Display history data in compressed ASCII format.
CLO	Close circuit breaker (assert Relay Word bit CC).
COM *n*[a]	Show communications summary report (COM report) on MIRRORED BITS channel *n* (where *n* = A or B) using all failure records in the channel calculations.
COM *n row1*[a]	Show a COM report for MIRRORED BITS channel *n* using the latest *row1* failure records (*row1* = 1–255, where 1 is the most recent entry).
COM *n row1 row2*[a]	Show COM report for MIRRORED BITS channel *n* using failure records *row1*–*row2* (*row1* = 1–255).
COM *n date1*[a]	Show COM report for MIRRORED BITS channel *n* using failures recorded on date *date1* (see **DAT** command for date format).
COM *n date1 date2*[a]	Show COM report for MIRRORED BITS channel *n* using failures recorded between dates *date1* and *date2* inclusive.
COM . . . L[a]	For all **COM** commands, L causes the specified COM report records to be listed after the summary.
COM *n* C[a]	Clears communications records for MIRRORED BITS channel *n* (or both channels if *n* is not specified, **COM C** command).
CON *n*	Control Relay Word bit RB*n* (Remote Bit *n*; *n* = 1–32). Execute **CON *n*** and the relay responds: CONTROL RB*n*. Then reply with one of the following: **SRB *n*** set Remote Bit *n* (assert RB*n*). **CRB *n*** clear Remote Bit *n* (deassert RB*n*). **PRB *n*** pulse Remote Bit *n* (assert RB*n* for 1/4 cycle).
COP *m n*	Copy relay and logic settings from group *m* to group *n* (*m* and *n* are numbers 1–6).
COP D *m n*	Copy DNP map *m* to map *n* (*m* and *n* are numbers 1–3).
CST	Display relay status in compressed ASCII format.
CSU	Display summary event report in compressed ASCII format.
DAT	Show date.
DAT mm/dd/yy	Enter date in this manner if Global Date Format setting, DATE_F, is set to MDY.
DAT yy/mm/dd	Enter date in this manner if Global Date Format setting, DATE_F, is set to YMD.
DNA X or T	Display names of Relay Word bits included in the A5D1 Fast Meter message. Either X or T is mandatory and both are identical.

Command	Description
ETH	Display the Ethernet port configuration and status.
ETH C	Clear Ethernet port statistics.
EVE *n*	Show event report *n* with 4 samples per cycle (*n* = 1 to highest numbered event report, where 1 is the most recent report: see **HIS** command). If *n* is omitted (**EVE** command), most recent report is displayed.
EVE *n* A	Show event report *n* with analog section only.
EVE *n* C	Show event report *n* in compressed ASCII format with 16 samples-per-cycle analog resolution and 4 samples-per-cycle digital resolution.
EVE *n* D	Show event report *n* with digital section only.
EVE *n* L	Show event report *n* with 32 samples per cycle (similar to **EVE *n* S32**).
EVE *n* L*y*	Show first *y* cycles of event report *n* (*y* = 1 to Global setting LER).
EVE *n* M[a]	Show event report *n* with communications section only.
EVE *n* P	Show event report *n* with synchrophasor-level accuracy time adjustment.
EVE *n* R	Show event report *n* in raw (unfiltered) format with 32 samples-per-cycle resolution.
EVE *n* S*x*	Show event report *n* with *x* samples per cycle (*x* = 4, 16, 32, or 128). Must append R parameter for S128 (**EVE S128 R**)
EVE *n* V	Show event report *n* with variable scaling for analog values.
EXI	Terminate Telnet session.
FIL DIR	Display a list of available files.
FIL READ *filename*	Transfer settings file *filename* from the relay to the PC.
FIL SHOW *filename*	Display contents of file *filename*.
FIL WRITE *filename*	Transfer settings file *filename* from the PC to the relay.
GOO	Display GOOSE transmit and receive information.
GOO *k*	Display GOOSE information *k* times.
GOO S	Display a list of GOOSE subscriptions with their ID.
GOO S *n*	Display GOOSE statistics for subscription ID *n*.
GOO S ALL	Display GOOSE statistics for all subscriptions.
GOO S *n* L	Display GOOSE statistics for subscription ID *n* including error history.
GOO S ALL L	Display GOOSE statistics for all subscriptions including error history.
GOO S *n* C	Clear GOOSE statistics for subscription ID *n*.
GOO S ALL C	Clear GOOSE statistics for all subscriptions.
GRO	Display active group number.
GRO *n*	Change active group to group *n* (*n* = 1–6).
HIS *n*	Show brief summary of *n* latest event reports, where 1 is the most recent entry. If *n* is not specified, (**HIS** command) all event summaries are displayed.
HIS C	Clear all event reports from nonvolatile memory.
HIS E	Same as **HIS** command except that reports have unique identification numbers in the range 10000 to 65535.
ID	Display relay configuration.
L_D	Prepares the relay to receive new firmware.
LDP[a]	Show entire Load Profile (LDP) report.
LDP[a] ***n***	Show latest *n* rows in the LDP report (*n* = 1 to several thousand, where 1 is the most recent entry).
LDP[a] ***m n***	Show rows *m*–*n* in the LDP report (*m* = 1 to several thousand).
LDP[a] ***date1***	Show all rows in the LDP report recorded on the specified date (see **DAT** command for date format).
LDP[a] ***date1 date2***	Show all rows in the LDP report recorded between dates *date1* and *date2*, inclusive.

Command	Description
LDP[a] C	Clears the LDP report from nonvolatile memory.
LDP[a] D	Display the number of days of LDP storage capacity before data overwrite will occur.
LOO[a] *n t*	Set MIRRORED BITS channel *n* to loopback (*n* = A or B). The received MIRRORED BITS elements are forced to default values during the loopback test; *t* specifies the loopback duration in minutes (*t* = 1–5000, default is 5).
LOO[a] *n* DATA	Set MIRRORED BITS channel *n* to loopback. DATA allows the received MIRRORED BITS elements to change during the loopback test.
LOO[a] *n* R	Cease loopback on MIRRORED BITS channel *n* and return the channel to normal operation.
MAC	Display Ethernet MAC address.
MET *k*	Display instantaneous metering data. Enter *k* for repeat count (*k* = 1–32767, if not specified, default is 1).
MET X *k*	Display same as **MET** command with phase-to-phase voltages and Vbase. Enter *k* for repeat count (*k* = 1–32767, if not specified, default is 1).
MET D	Display demand and peak demand data. Select **MET RD** or **MET RP** to reset.
MET E	Display energy metering data. Select **MET RE** to reset.
MET H	Display THD and harmonic metering data.
MET M	Display maximum/minimum metering data. Select **MET RM** to reset.
MET PM *time*	Display synchrophasor measurements (available when TSOK = logical 1). Enter *time* to display the synchrophasor for an exact specified time, in 24-hour format.
MET PM *k*	Display synchrophasor measurements (available when TSOK = logical 1). Enter *k* for repeat count.
MET PM HIS	Display the most recent **MET PM** synchrophasor report.
OPE	Assert the open command Relay Word bit OC.
PAR	Change the device part number. Use only under the direction of SEL.
PAS 1	Change Access Level 1 password.
PAS B	Change Access Level B password.
PAS 2	Change Access Level 2 password.
PAS C	Change the Access Level C password.
PIN	Ping command.
PUL *n k*	Pulse output contact *n* (where *n* is one of ALARM, ALRMOUT, OUT101–OUT107, OUT201–OUT212) for *k* seconds. *k* = 1–30 seconds; if not specified, default is 1.
QUI	Quit. Returns to Access Level 0.
R_S	Restore factory default settings. Use only under the direction of SEL. Only available under certain conditions.
SER	Show entire Sequential Events Recorder (SER) report.
SER *row1*	Show latest *row1* rows in the SER report (*row1* = 1–1024, where 1 is the most recent entry).
SER *row1 row2*	Show rows *row1–row2* in the SER report.
SER *date1*	Show all rows in the SER report recorded on the specified date (see **DAT** command for date format).
SER *date1 date2*	Show all rows in the SER report recorded between dates *date1* and *date2*, inclusive.
SER C	Clears SER report from nonvolatile memory.
SET *n*	Change relay settings (overcurrent, reclosing, timers, etc.) for Group *n* (*n* = 1–6, if not specified, default is active setting group).
SET *n* L	Change SELOGIC control equation settings for Group *n* (*n* = 1–6, if not specified, default is the SELOGIC control equations for the active setting group).
SET D	Change DNP settings.
SET G	Change Global settings.
SET M	Change Modbus settings.
SET P *p*	Change serial port *p* settings (*p* = 1, 2, 3, F, or 5; if not specified, default is active port).

Command	Description
SET R	Change SER and LDP Recorder[a] settings.
SET T	Change text label settings.
SET . . . *name*	For all **SET** commands, jump ahead to specific setting by entering setting name.
SET . . . TERSE	For all **SET** commands, TERSE disables the automatic **SHO** command after settings entry.
SHO *n*	Show relay settings (overcurrent, reclosing, timers, etc.) for Group *n* (*n* = 1–6, if not specified, default is active setting group).
SHO *n* L	Show SELOGIC control equation settings for Group *n* (*n* = 1–6, if not specified, default is the SELOGIC control equations for the active setting group).
SHO D	Show DNP settings.
SHO G	Show Global settings.
SHO M	Show Modbus settings.
SHO P *p*	Show serial port *p* settings (*p* = 1, 2, 3, or F; if not specified, default is active port).
SHO R	Show SER and LDP Recorder[a] settings.
SHO T	Show text label settings.
SHO . . . *name*	For all **SHO** commands, jump ahead to specific setting by entering setting name.
SNS	Display the Fast Message name string of the SER settings.
SSI[b]	Show entire Voltage Sag/Swell/Interruption (SSI) report.
SSI[b] *row1*	Show latest *row1* rows in SSI report (*row1* = 1 to several thousand, where 1 is the most recent entry).
SSI[b] *row1 row2*	Show rows *row1*–*row2* in SSI report.
SSI[b] *date1*	Show all rows in SSI report recorded on the specified date (see **DAT** command for date format).
SSI[b] *date1 date2*	Show all rows in SSI report recorded between dates *date1* and *date2*, inclusive.
SSI[b] C	Clears SSI report from nonvolatile memory.
SSI[b] R	Resets Vbase element. See Vbase initialization.
SSI[b] T	Trigger the SSI recorder.
STA	Show relay self-test status.
STA C	Resets self-test warnings/failures and reboots the relay.
SUM *n*	Shows event report summary for event *n*.
SUM ACK	Acknowledge oldest unacknowledged summary event report.
SUM N	Shows event report summary for oldest unacknowledged report.
TAR *n k*	Display Relay Word row. If *n* = 0–67, display row *n*. If *n* is an element name (e.g., 50A1), display row containing element *n*. Enter *k* for repeat count (*k* = 1–32767, if not specified, default is 1).
TAR LIST	Shows all the Relay Word bits in all of the rows.
TAR R	Reset front-panel tripping targets.
TAR ROW. . .	Shows the Relay Word row number at the start of each line, with other selected **TARGET** commands as described above, such as *n*, *name*, *k*, and LIST.
TDP	Show the status of the SEL Livestream protocol. This feature is used for SEL testing and research. Contact SEL for more details.
TDP ON	Enable the SEL Livestream protocol stream to the last used IP address and UDP port. **Note:** If the command has not been previously used, or a TDP reset has been performed, the default IP address and UDP port are used.
TDP ON *addr*	Enable the SEL Livestream protocol stream to the designated IP address and last used UDP port. **Note:** If the command has not been previously used, or a TDP reset has been performed, the default UDP port is used.
TDP ON *addr port*	Enable the SEL Livestream protocol stream to the designated IP address and UDP port.
TDP OFF	Disable the SEL Livestream protocol stream.

Command	Description
TDP RESET	Disable the SEL Livestream protocol and reset the IP address and UDP port to defaults.
TEST DB A ***name value***	Override analog label *name* with *value* in communications interface.
TEST DB D ***name value***	Override Relay Word bit *name* with *value* in communications interface, where *value* = 0 or 1.
TIM	Show or set time (24-hour time). Show current relay time by entering **TIM**. Set the current time by entering **TIM** followed by the time of day (e.g., set time 22:47:36 by entering **TIM 22:47:36**).
TIM DST	Display daylight-saving time information.
TIM Q	Display time statistics.
TRI ***time***	Trigger an event report. Enter *time* to trigger an event at an exact specified time, in 24-hour format.
VEC	Display standard vector troubleshooting report (useful to the factory in troubleshooting).
VER	Show relay configuration and firmware version.

[a] Available in firmware versions 6 and 7.

[b] Available in firmware version 7.

Key Stroke Commands

Key Stroke	Description	Key Stroke When Using SET Command	Description
Ctrl + Q	Send **XON** command to restart communications port output previously halted by XOFF.	**<Enter>**	Retains setting and moves on to next setting.
Ctrl + S	Send **XOFF** command to pause communications port output.	**^<Enter>**	Returns to previous setting.
Ctrl + X	Send **CANCEL** command to abort current command and return to current access level prompt.	**<<Enter>**	Returns to previous setting section.
		><Enter>	Skips to next setting section.
		END <Enter>	Exits setting editing session, then prompts user to save settings.
		Ctrl + X	Aborts setting editing session without saving changes.

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SEL-351-5, -6, -7 Command Summary

Command	Description
2AC	Enter Access Level 2. If the main board Access jumper is not in place, the relay prompts for the entry of the Access Level 2 password.
ACC	Enter Access Level 1. If the main board Access jumper is not in place, the relay prompts for the entry of the Access Level 1 password.
BAC	Enter Breaker Access Level (Access Level B). If the main board Access jumper is not in place, the relay prompts the user for the Access Level B password.
BNA	Display names of status bits in the A5D1 Fast Meter Message.
BRE	Display breaker monitor data (trips, interrupted current, wear).
BRE H	Display breaker history.
BRE R	Reset breaker monitor.
BRE W	Preload breaker wear.
CAL	Enter Access Level C. If the main board Access jumper is not in place, the relay prompts for the entry of the Access Level C password. Access Level C is reserved for SEL use only.
CAS	Display compressed ASCII configuration message.
CEV *n*	Display event report *n* in compressed ASCII format.
CHI	Display history data in compressed ASCII format.
CLO	Close circuit breaker (assert Relay Word bit CC).
COM *n*[a]	Show communications summary report (COM report) on MIRRORED BITS channel *n* (where *n* = A or B) using all failure records in the channel calculations.
COM *n row1*[a]	Show a COM report for MIRRORED BITS channel *n* using the latest *row1* failure records (*row1* = 1–255, where 1 is the most recent entry).
COM *n row1 row2*[a]	Show COM report for MIRRORED BITS channel *n* using failure records *row1–row2* (*row1* = 1–255).
COM *n date1*[a]	Show COM report for MIRRORED BITS channel *n* using failures recorded on date *date1* (see **DAT** command for date format).
COM *n date1 date2*[a]	Show COM report for MIRRORED BITS channel *n* using failures recorded between dates *date1* and *date2* inclusive.
COM . . . L[a]	For all **COM** commands, L causes the specified COM report records to be listed after the summary.
COM *n* C[a]	Clears communications records for MIRRORED BITS channel *n* (or both channels if *n* is not specified, **COM C** command).
CON *n*	Control Relay Word bit RB*n* (Remote Bit *n*; *n* = 1–32). Execute **CON *n*** and the relay responds: CONTROL RB*n*. Then reply with one of the following: **SRB *n*** set Remote Bit *n* (assert RB*n*). **CRB *n*** clear Remote Bit *n* (deassert RB*n*). **PRB *n*** pulse Remote Bit *n* (assert RB*n* for 1/4 cycle).
COP *m n*	Copy relay and logic settings from group *m* to group *n* (*m* and *n* are numbers 1–6).
COP D *m n*	Copy DNP map *m* to map *n* (*m* and *n* are numbers 1–3).
CST	Display relay status in compressed ASCII format.
CSU	Display summary event report in compressed ASCII format.
DAT	Show date.
DAT mm/dd/yy	Enter date in this manner if Global Date Format setting, DATE_F, is set to MDY.
DAT yy/mm/dd	Enter date in this manner if Global Date Format setting, DATE_F, is set to YMD.
DNA X or T	Display names of Relay Word bits included in the A5D1 Fast Meter message. Either X or T is mandatory and both are identical.

Command	Description
ETH	Display the Ethernet port configuration and status.
ETH C	Clear Ethernet port statistics.
EVE *n*	Show event report *n* with 4 samples per cycle (*n* = 1 to highest numbered event report, where 1 is the most recent report: see **HIS** command). If *n* is omitted (**EVE** command), most recent report is displayed.
EVE *n* A	Show event report *n* with analog section only.
EVE *n* C	Show event report *n* in compressed ASCII format with 16 samples-per-cycle analog resolution and 4 samples-per-cycle digital resolution.
EVE *n* D	Show event report *n* with digital section only.
EVE *n* L	Show event report *n* with 32 samples per cycle (similar to **EVE *n* S32**).
EVE *n* L*y*	Show first *y* cycles of event report *n* (*y* = 1 to Global setting LER).
EVE *n* M[a]	Show event report *n* with communications section only.
EVE *n* P	Show event report *n* with synchrophasor-level accuracy time adjustment.
EVE *n* R	Show event report *n* in raw (unfiltered) format with 32 samples-per-cycle resolution.
EVE *n* S*x*	Show event report *n* with *x* samples per cycle (*x* = 4, 16, 32, or 128). Must append R parameter for S128 (**EVE S128 R**)
EVE *n* V	Show event report *n* with variable scaling for analog values.
EXI	Terminate Telnet session.
FIL DIR	Display a list of available files.
FIL READ *filename*	Transfer settings file *filename* from the relay to the PC.
FIL SHOW *filename*	Display contents of file *filename*.
FIL WRITE *filename*	Transfer settings file *filename* from the PC to the relay.
GOO	Display GOOSE transmit and receive information.
GOO *k*	Display GOOSE information *k* times.
GOO S	Display a list of GOOSE subscriptions with their ID.
GOO S *n*	Display GOOSE statistics for subscription ID *n*.
GOO S ALL	Display GOOSE statistics for all subscriptions.
GOO S *n* L	Display GOOSE statistics for subscription ID *n* including error history.
GOO S ALL L	Display GOOSE statistics for all subscriptions including error history.
GOO S *n* C	Clear GOOSE statistics for subscription ID *n*.
GOO S ALL C	Clear GOOSE statistics for all subscriptions.
GRO	Display active group number.
GRO *n*	Change active group to group *n* (*n* = 1–6).
HIS *n*	Show brief summary of *n* latest event reports, where 1 is the most recent entry. If *n* is not specified, (**HIS** command) all event summaries are displayed.
HIS C	Clear all event reports from nonvolatile memory.
HIS E	Same as **HIS** command except that reports have unique identification numbers in the range 10000 to 65535.
ID	Display relay configuration.
L_D	Prepares the relay to receive new firmware.
LDP[a]	Show entire Load Profile (LDP) report.
LDP[a] ***n***	Show latest *n* rows in the LDP report (*n* = 1 to several thousand, where 1 is the most recent entry).
LDP[a] ***m n***	Show rows *m*–*n* in the LDP report (*m* = 1 to several thousand).
LDP[a] ***date1***	Show all rows in the LDP report recorded on the specified date (see **DAT** command for date format).
LDP[a] ***date1 date2***	Show all rows in the LDP report recorded between dates *date1* and *date2*, inclusive.

Command	Description
LDP[a] C	Clears the LDP report from nonvolatile memory.
LDP[a] D	Display the number of days of LDP storage capacity before data overwrite will occur.
LOO[a] *n t*	Set MIRRORED BITS channel *n* to loopback (*n* = A or B). The received MIRRORED BITS elements are forced to default values during the loopback test; *t* specifies the loopback duration in minutes (*t* = 1–5000, default is 5).
LOO[a] *n* DATA	Set MIRRORED BITS channel *n* to loopback. DATA allows the received MIRRORED BITS elements to change during the loopback test.
LOO[a] *n* R	Cease loopback on MIRRORED BITS channel *n* and return the channel to normal operation.
MAC	Display Ethernet MAC address.
MET *k*	Display instantaneous metering data. Enter *k* for repeat count (*k* = 1–32767, if not specified, default is 1).
MET X *k*	Display same as **MET** command with phase-to-phase voltages and Vbase. Enter *k* for repeat count (*k* = 1–32767, if not specified, default is 1).
MET D	Display demand and peak demand data. Select **MET RD** or **MET RP** to reset.
MET E	Display energy metering data. Select **MET RE** to reset.
MET H	Display THD and harmonic metering data.
MET M	Display maximum/minimum metering data. Select **MET RM** to reset.
MET PM *time*	Display synchrophasor measurements (available when TSOK = logical 1). Enter *time* to display the synchrophasor for an exact specified time, in 24-hour format.
MET PM *k*	Display synchrophasor measurements (available when TSOK = logical 1). Enter *k* for repeat count.
MET PM HIS	Display the most recent **MET PM** synchrophasor report.
OPE	Assert the open command Relay Word bit OC.
PAR	Change the device part number. Use only under the direction of SEL.
PAS 1	Change Access Level 1 password.
PAS B	Change Access Level B password.
PAS 2	Change Access Level 2 password.
PAS C	Change the Access Level C password.
PIN	Ping command.
PUL *n k*	Pulse output contact *n* (where *n* is one of ALARM, ALRMOUT, OUT101–OUT107, OUT201–OUT212) for *k* seconds. *k* = 1–30 seconds; if not specified, default is 1.
QUI	Quit. Returns to Access Level 0.
R_S	Restore factory default settings. Use only under the direction of SEL. Only available under certain conditions.
SER	Show entire Sequential Events Recorder (SER) report.
SER *row1*	Show latest *row1* rows in the SER report (*row1* = 1–1024, where 1 is the most recent entry).
SER *row1 row2*	Show rows *row1–row2* in the SER report.
SER *date1*	Show all rows in the SER report recorded on the specified date (see **DAT** command for date format).
SER *date1 date2*	Show all rows in the SER report recorded between dates *date1* and *date2*, inclusive.
SER C	Clears SER report from nonvolatile memory.
SET *n*	Change relay settings (overcurrent, reclosing, timers, etc.) for Group *n* (*n* = 1–6, if not specified, default is active setting group).
SET *n* L	Change SELOGIC control equation settings for Group *n* (*n* = 1–6, if not specified, default is the SELOGIC control equations for the active setting group).
SET D	Change DNP settings.
SET G	Change Global settings.
SET M	Change Modbus settings.
SET P *p*	Change serial port *p* settings (*p* = 1, 2, 3, F, or 5; if not specified, default is active port).

Command	Description
SET R	Change SER and LDP Recorder[a] settings.
SET T	Change text label settings.
SET . . . *name*	For all **SET** commands, jump ahead to specific setting by entering setting name.
SET . . . TERSE	For all **SET** commands, TERSE disables the automatic **SHO** command after settings entry.
SHO *n*	Show relay settings (overcurrent, reclosing, timers, etc.) for Group *n* (*n* = 1–6, if not specified, default is active setting group).
SHO *n* L	Show SELOGIC control equation settings for Group *n* (*n* = 1–6, if not specified, default is the SELOGIC control equations for the active setting group).
SHO D	Show DNP settings.
SHO G	Show Global settings.
SHO M	Show Modbus settings.
SHO P *p*	Show serial port *p* settings (*p* = 1, 2, 3, or F; if not specified, default is active port).
SHO R	Show SER and LDP Recorder[a] settings.
SHO T	Show text label settings.
SHO . . . *name*	For all **SHO** commands, jump ahead to specific setting by entering setting name.
SNS	Display the Fast Message name string of the SER settings.
SSI[b]	Show entire Voltage Sag/Swell/Interruption (SSI) report.
SSI[b] *row1*	Show latest *row1* rows in SSI report (*row1* = 1 to several thousand, where 1 is the most recent entry).
SSI[b] *row1 row2*	Show rows *row1–row2* in SSI report.
SSI[b] *date1*	Show all rows in SSI report recorded on the specified date (see **DAT** command for date format).
SSI[b] *date1 date2*	Show all rows in SSI report recorded between dates *date1* and *date2*, inclusive.
SSI[b] C	Clears SSI report from nonvolatile memory.
SSI[b] R	Resets Vbase element. See Vbase initialization.
SSI[b] T	Trigger the SSI recorder.
STA	Show relay self-test status.
STA C	Resets self-test warnings/failures and reboots the relay.
SUM *n*	Shows event report summary for event *n*.
SUM ACK	Acknowledge oldest unacknowledged summary event report.
SUM N	Shows event report summary for oldest unacknowledged report.
TAR *n k*	Display Relay Word row. If *n* = 0–67, display row *n*. If *n* is an element name (e.g., 50A1), display row containing element *n*. Enter *k* for repeat count (*k* = 1–32767, if not specified, default is 1).
TAR LIST	Shows all the Relay Word bits in all of the rows.
TAR R	Reset front-panel tripping targets.
TAR ROW. . .	Shows the Relay Word row number at the start of each line, with other selected **TARGET** commands as described above, such as *n*, *name*, *k*, and LIST.
TDP	Show the status of the SEL Livestream protocol. This feature is used for SEL testing and research. Contact SEL for more details.
TDP ON	Enable the SEL Livestream protocol stream to the last used IP address and UDP port. **Note:** If the command has not been previously used, or a TDP reset has been performed, the default IP address and UDP port are used.
TDP ON *addr*	Enable the SEL Livestream protocol stream to the designated IP address and last used UDP port. **Note:** If the command has not been previously used, or a TDP reset has been performed, the default UDP port is used.
TDP ON *addr port*	Enable the SEL Livestream protocol stream to the designated IP address and UDP port.
TDP OFF	Disable the SEL Livestream protocol stream.

Command	Description
TDP RESET	Disable the SEL Livestream protocol and reset the IP address and UDP port to defaults.
TEST DB A ***name value***	Override analog label *name* with *value* in communications interface.
TEST DB D ***name value***	Override Relay Word bit *name* with *value* in communications interface, where *value* = 0 or 1.
TIM	Show or set time (24-hour time). Show current relay time by entering **TIM**. Set the current time by entering **TIM** followed by the time of day (e.g., set time 22:47:36 by entering **TIM 22:47:36**).
TIM DST	Display daylight-saving time information.
TIM Q	Display time statistics.
TRI ***time***	Trigger an event report. Enter *time* to trigger an event at an exact specified time, in 24-hour format.
VEC	Display standard vector troubleshooting report (useful to the factory in troubleshooting).
VER	Show relay configuration and firmware version.

[a] Available in firmware versions 6 and 7.

[b] Available in firmware version 7.

Key Stroke Commands

Key Stroke	Description	Key Stroke When Using SET Command	Description
Ctrl + Q	Send **XON** command to restart communications port output previously halted by XOFF.	**<Enter>**	Retains setting and moves on to next setting.
Ctrl + S	Send **XOFF** command to pause communications port output.	**^<Enter>**	Returns to previous setting.
Ctrl + X	Send **CANCEL** command to abort current command and return to current access level prompt.	**<<Enter>**	Returns to previous setting section.
		><Enter>	Skips to next setting section.
		END <Enter>	Exits setting editing session, then prompts user to save settings.
		Ctrl + X	Aborts setting editing session without saving changes.

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