SEL-787-2, -3, -4

Transformer Protection Relays

Instruction Manual

20241121

SCHWEITZER ENGINEERING LABORATORIES

PM787-02

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Preface

Manual Overview

The SEL-787 Transformer Protection Relay Instruction Manual describes common aspects of transformer relay application and use. It includes the necessary information to install, set, test, and operate the relay.

An overview of each manual section and topics follows:

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

Section 1: Introduction and Specifications. Describes the basic features and functions of the SEL-787; lists the relay specifications.

Section 2: Installation. Describes how to mount and wire the SEL-787; illustrates wiring connections for various applications.

Section 3: PC Interface. Describes the built-in web server and its features, including settings, metering and monitoring, reports, and firmware upgrade. Also describes the features, installation methods, and types of help available with the ACSELERATOR QuickSet SEL-5030 Software.

Section 4: Protection and Logic Functions. Describes the operating characteristic of each protection element, using logic diagrams and text, and explains how to calculate element settings; describes contact output logic, automation, and report settings.

Section 5: Metering and Monitoring. Describes the operation of each metering function; describes the monitoring functions.

Section 6: Settings. Describes how to view, enter, and record settings for protection, control, communications, logic, and monitoring.

Section 7: Communications. Describes how to connect the SEL-787 to a PC for communication; shows serial port pinouts; lists and defines serial port commands. Describes the communications port interfaces and protocols supported by the relay for serial and Ethernet.

Section 8: Front-Panel Operations. Explains the features and use of the front panel, including front-panel command menu, default displays, and automatic messages. Describes in detail the two-line display (2 x 16 characters) and the touchscreen display (5-inch, color, 800 x 480 pixels).

Section 9: Bay Control. Describes how to configure and design the bay control screens for SEL-787 Relays with the touchscreen display (5-inch, color, 800 x 480 pixels).

Section 10: Analyzing Events. Describes event type, messages, event summary data, standard event reports, and Sequential Events Recorder (SER) report.

Section 11: Testing and Troubleshooting. Describes relay test procedures, relay self-test, and relay troubleshooting.

Appendix A: Firmware, ICD, and Manual Versions. Lists the current relay firmware version and details differences between the current and previous versions. Provides a record of changes made to the manual since the initial release.

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

Appendix C: SEL Communications Processors. Provides examples of how to use the SEL-787 with the SEL communications processors for total substation automation solutions.

Appendix D: DNP3 Communications. Describes the DNP3 protocol support provided by the SEL-787.

Appendix E: Modbus Communications. Describes the Modbus protocol support provided by the SEL-787.

Appendix F: EtherNet/IP Communications. Describes the EtherNet/IP support provided by the SEL-787.

Appendix G: IEC 61850 Communications. Describes IEC 61850 implementation in the SEL-787.

Appendix H: IEC 60870-5-103 Communications. Describes IEC 60870-5-103 protocol support provided by the SEL-787.

Appendix I: DeviceNet Communications. Describes the use of DeviceNet (data-link and application protocol) over a Controller Area Network (CAN) (hardware protocol).

Appendix J: MIRRORED BITS Communications. Describes how SEL protective relays and other devices can directly exchange information quietly, securely, and with minimum cost.

Appendix K: Synchrophasors. Describes the phasor measurement and control unit (PMCU), and accessing synchrophasor data via ASCII command (**MET PM**) and IEEE C37.118 Protocol.

Appendix L: Relay Word Bits. Lists and describes the Relay Word bits (outputs of protection and control elements).

Appendix M: Analog Quantities. Lists and describes the analog quantities (outputs of analog elements).

Appendix N: Cybersecurity Features. Describes a number of features to help meet cybersecurity design requirements.

Appendix O: Protection Application Examples. Describes transformer winding and CT connection compensation settings examples.

SEL-787-2, -3, -4 Relay Command Summary. Briefly describes the serial port commands that are fully described in *Section 7: 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

⚠CAUTION There is danger of explosion if the battery is incorrectly replaced. Replace only with Rayovac no. BR2330A 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 BR2330A ou un produit équivalent recommandé par le fabricant. Voir le guide d'utilisateur pour les instructions de sécurité. La pile utilisée dans cet appareil peut présenter un risque d'incendie ou de brûlure chimique si vous en faites mauvais usage. Ne pas recharger, démonter, chauffer à plus de 100°C ou incinérer. Éliminez les vieilles piles suivant les instructions du fabricant. Gardez la pile hors de la portée des enfants.
⚠CAUTION To ensure proper safety and operation, the equipment ratings, installation instructions, and operating instructions must be checked before commissioning or maintenance of the equipment. The integrity of any protective conductor connection must be checked before carrying out any other actions. It is the responsibility of the user to ensure that the equipment is installed, operated, and used for its intended function in the manner specified in this manual. If misused, any safety protection provided by the equipment may be impaired.	⚠ATTENTION Pour assurer la sécurité et le bon fonctionnement, il faut vérifier les classements d'équipement ainsi que les instructions d'installation et d'opération avant la mise en service ou l'entretien de l'équipement. Il faut vérifier l'intégrité de toute connexion de conducteur de protection avant de réaliser d'autres actions. L'utilisateur est responsable d'assurer l'installation, l'opération et l'utilisation de l'équipement pour la fonction prévue et de la manière indiquée dans ce manuel. Une mauvaise utilisation pourrait diminuer toute protection de sécurité fournie par l'équipement.
For use in Pollution Degree 2 environment.	Pour l'utilisation dans un environnement de Degré de Pollution 2.
Ambient air temperature shall not exceed 50°C (122°F).	La température de l'air ambiant ne doit pas dépasser 50°C (122°F).
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 75°C (167°F) copper conductors only. Tightening Torque Terminal Block: 0.9–1.4 Nm (8–12 in-lb) Compression Plug: 0.5–1.0 Nm (4.4–8.8 in-lb) Compression Plug Mounting Ear Screw: 0.18–0.25 Nm (1.6–2.2 in-lb)	Spécifications des bornes Type de filage Utiliser seulement des conducteurs en cuivre spécifiés à 75°C (167°F). Couple de serrage Bornier : 0,9–1,4 Nm (8–12 livres-pouce) Fiche à compression : 0,5–1,0 Nm (4,4–8,8 livres-pouce) Vis à oreille de montage de la fiche à compression : 0,18–0,25 Nm (1,6–2,2 livres-pouce)

Hazardous Locations Safety Marks

⚠WARNING – EXPLOSION HAZARD Open circuit before removing cover.	⚠AVERTISSEMENT – DANGER D'EXPLOSION Ouvrir le circuit avant de déposer le couvercle.
⚠WARNING – EXPLOSION HAZARD Substitution of components may impair suitability for Class I, Division 2.	⚠AVERTISSEMENT – DANGER D'EXPLOSION La substitution de composants peut détériorer la conformité à Classe I, Division 2.
Ambient air temperature shall not exceed –20°C ≤ Ta ≤ +50°C.	La température de l'air ambiant ne doit pas dépasser –20°C ≤ Ta ≤ +50°C.

Compliance Approvals

Hazardous Locations Approvals

The SEL-787 is UL certified for hazardous locations to Canadian and U.S. standards. In North America, the relay is approved for Hazardous Locations Class I, Division 2, Groups A, B, C, and D, and temperature class T3C in the maximum surrounding air temperature of 50°C.

The SEL-787 shall be installed in an indoor or outdoor (extended) locked enclosure that provides a degree of protection to personnel against access to hazardous parts. In either environment, the relay shall be protected from direct sunlight, precipitation, and full wind pressure.

To comply with the requirements of the European ATEX standard for hazardous location, the SEL-787 shall be installed in an ATEX-certified enclosure with a tool-removable door or cover that provides a degree of protection not less than IP54, in accordance with EN 60079-0. The enclosure shall be limited to the surrounding air temperature range of –20°C ≤ Ta ≤ +50°C. The enclosure should be certified to these requirements or be tested for compliance as part of the complete assembly. The enclosure must be marked “WARNING—Do not open when a explosive atmosphere is present.”

Other Safety Marks (Sheet 1 of 2)

⚠**DANGER** Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.	⚠**DANGER** Débrancher tous les raccordements externes avant d’ouvrir cet appareil. Tout contact avec des tensions ou courants internes à l’appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠**DANGER** Contact with instrument terminals can cause electrical shock that can result in injury or death.	⚠**DANGER** Tout contact avec les bornes de l’appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠**WARNING** Use of this equipment in a manner other than specified in this manual can impair operator safety safeguards provided by this equipment.	⚠**AVERTISSEMENT** L’utilisation de cet appareil suivant des procédures différentes de celles indiquées dans ce manuel peut désarmer les dispositifs de protection d’opérateur normalement actifs sur cet équipement.
⚠**WARNING** Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.	⚠**AVERTISSEMENT** Seules des personnes qualifiées peuvent travailler sur cet appareil. Si vous n’êtes pas qualifiés pour ce travail, vous pourriez vous blesser avec d’autres personnes ou endommager l’équipement.
⚠**WARNING** Always isolate the relay control circuits before performing any modifications to the relay.	⚠**AVERTISSEMENT** Il faut toujours isoler les circuits de commande du relais avant d'apporter des modifications au relais.
⚠**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** This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.	⚠**AVERTISSEMENT** Cet appareil est expédié avec des mots de passe par défaut. A l’installation, les mots de passe par défaut devront être changés pour des mots de passe confidentiels. Dans le cas contraire, un accés non-autorisé á l’équipement peut être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accés non-autorisé.

Other Safety Marks (Sheet 2 of 2)

⚠WARNING To install an option card, the relay must be de-energized and then re-energized. When re-energized, the relay will reboot. Therefore, de-energize the protected equipment before installing the option card to prevent damage to the equipment.	⚠AVERTISSEMENT Pour installer une carte à option, le relais doit être éteint et ensuite rallumé. Quand il est rallumé, le relais redémarrera. Donc, il faut éteindre l'équipement protégé avant d'installer la carte à option pour empêcher des dégats à l'équipement.
⚠WARNING Do not perform any procedures or adjustments that this instruction manual does not describe.	⚠AVERTISSEMENT Ne pas appliquer une procédure ou un ajustement qui n'est pas décrit explicitement dans ce manuel d'instruction.
⚠WARNING During installation, maintenance, or testing of the optical ports, use only test equipment qualified for Class 1 laser products.	⚠AVERTISSEMENT Durant l'installation, la maintenance ou le test des ports optiques, utilisez exclusivement des équipements de test homologués comme produits de type laser de Classe 1.
⚠WARNING Overtightening the mounting nuts may permanently damage the relay chassis.	⚠AVERTISSEMENT Une pression excessive sur les écroux de montage peut endommager de façon permanente le chassis du relais
⚠CAUTION Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.	⚠ATTENTION Les composants de cet équipement sont sensibles aux décharges électrostatiques (DES). Des dommages permanents non-décelables peuvent résulter de l'absence de précautions contre les DES. Raccordez-vous correctement à la terre, ainsi que la surface de travail et l'appareil avant d'en retirer un panneau. Si vous n'êtes pas équipés pour travailler avec ce type de composants, contacter SEL afin de retourner l'appareil pour un service en usine.
⚠CAUTION 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 Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.	⚠ATTENTION L'utilisation de commandes ou de réglages, ou l'application de tests de fonctionnement différents de ceux décrits ci-après peuvent entraîner l'exposition à des radiations dangereuses.
⚠CAUTION Do not connect power to the relay until you have completed these procedures and receive instruction to apply power. Equipment damage can result otherwise.	⚠ATTENTION Ne pas mettre le relais sous tension avant d'avoir complété ces procédures et d'avoir reçu l'instruction de brancher l'alimentation. Des dommages à l'équipement pourraient survenir autrement.

General Information

Typographic Conventions

There are three ways to communicate with the SEL-787:

- Using a command line interface on a PC terminal emulation window.
- Using the front-panel menus and pushbuttons.
- Using QuickSet.

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.

Example	Description
<Ctrl+D>	Multiple/combination keystroke on a PC keyboard.
Start > Settings	PC dialog boxes and menu selections. The > character indicates submenus.
ENABLE	Relay front- or rear-panel labels and pushbuttons.
`Main > Meters`	Relay front-panel LCD menus and relay responses. The > character indicates submenus.

Trademarks

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

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

acSELerator Architect®	SEL-2407®
acSELerator QuickSet®	SELogic®
DeviceNet™	Synchrowave®
Mirrored Bits®	synchroWAVe®

Examples

This instruction manual uses several example illustrations and instructions to explain how to effectively operate the SEL-787. 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-787.

LED Emitter

⚠CAUTION
Looking into optical connections, fiber ends, or bulkhead connections can result in hazardous radiation exposure.

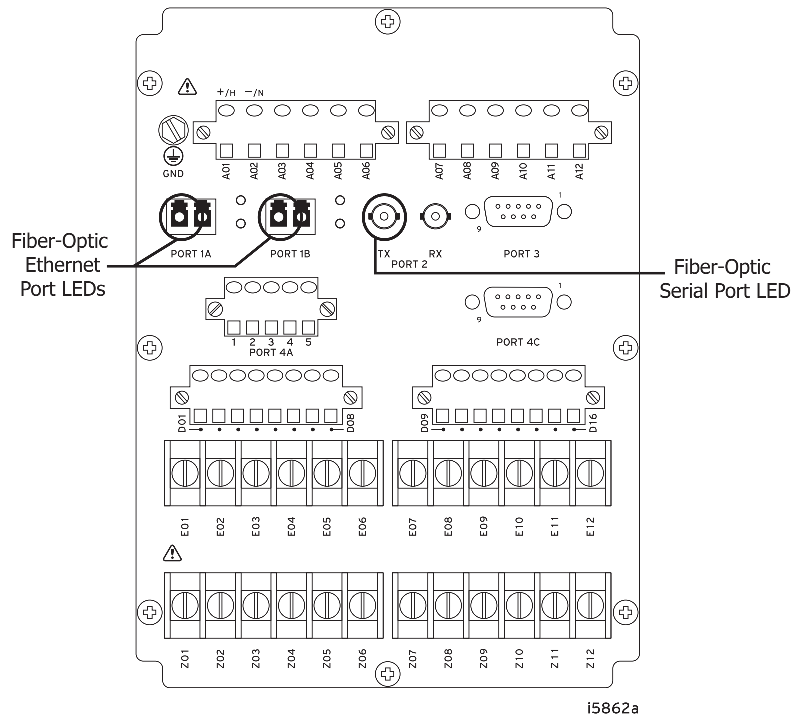
⚠CAUTION
Use of controls, adjustments, or performance of procedures other than those specified herein may result in hazardous radiation exposure.

The following table shows LED information specific to the SEL-787 (see *Figure 2.9* for the location of fiber-optic Ethernet PORT 1 (or 1A, 1B) and PORT 2, the ports using these LEDs, on the relay).

SEL-787 LED Information

Item	Fiber-Optic Ethernet PORT 1 (1A, 1B)	PORT 2
Mode	Multimode	Multimode
Wavelength	1300 nm	820 nm
Source	LED	LED
Connector type	LC	ST
Typical Output power	–15.7 dBm	–16 dBm

The following figure shows the LED location specific to the SEL-787 (see *Figure 2.9* for the complete rear-panel drawing).



SEL-787 LED Locations

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, use only test equipment classified as Class 1 laser products.
- Incorporated components such as transceivers and LED emitters are not user serviceable. Units must be returned to SEL for repair or replacement.

Environmental Conditions and Voltage Information

The following table lists important environmental and voltage information.

Condition	Range/Description
Indoor/outdoor use	Indoor
Altitude[a]	To 2000 m
Temperature	
IEC Performance Rating (per IEC/EN 60068-2-1 and IEC/EN 60068-2-2)	–40° to +85°C
Relative humidity	5% to 95%
Main supply voltage fluctuations	To ±10% of nominal voltage
Overvoltage	Category II
Pollution	Degree 2
Atmospheric pressure	80 to 110 kPa

[a] Consult the factory for derating specifications for higher altitude applications.

Wire Sizes and Insulation

For standard wiring connections, use 105°C-rated wiring. 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. Refer to SEL Application Note AN2014-08 for wiring and termination guidance. Strip the wires 8 mm (0.31 in) for installation and termination.

NOTE: Terminal blocks are best suited to accept 10 AWG wire size. Make sure to select the appropriate lug size that is compatible with the SEL relay terminal block. All SEL qualification testing of the terminal blocks is performed with ring or fork terminals for wire sizes as high as 12 AWG.

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
Contact I/O	18 AWG (0.80 mm^2)	14 AWG (2.10 mm^2)	300 V min
RTD[a]	28 AWG (0.08 mm^2)	16 AWG (1.30 mm^2)	300 V min
Other	18 AWG (0.80 mm^2)	14 AWG (2.10 mm^2)	300 V min

[a] See Table 2.25: Typical Maximum RTD Lead Length.

Instructions for Cleaning and Decontamination

Use a mild soap or detergent solution and a damp cloth to carefully clean the SEL-787 chassis when necessary. Avoid using abrasive materials, polishing compounds, and harsh chemical solvents (such as xylene or acetone) on any surface of the relay.

Copyrighted Software

The product includes copyrighted software licensed under the TI BSD End User Agreement, reproduced as follows:

Software License Agreement

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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

Overview

The SEL-787 Transformer Protection Relay is designed to provide current differential, restricted earth fault (REF), and overcurrent protection to transformers with as many as four windings/terminals. Based on the selected cards identified in *Table 1.1*, the relay can be configured to provide both current and voltage elements for comprehensive protection of the transformer. All relay model configurations provide monitoring functions. In addition to transformer protection, the relay is suitable for other differential protection such as busbar, generator, etc.

This manual contains the information needed to install, set, test, operate, and maintain any SEL-787. You need not review the entire manual to perform specific tasks. In this document, SEL-787, in general, refers to all the models in *Table 1.1*. For protection functions specific to a given model, the relay is referred to as SEL-787-21, SEL-787-2E, SEL-787-2X, SEL-787-3E, SEL-787-3S, or SEL-787-4X explicitly, where needed. Model option SEL-787-2X is considered the base model. *Table 1.2* presents the protection elements available across different models.

For additional technical references on applications and testing (i.e., technical papers, application guides), visit selinc.com and click Support.

Features

Protection Features

The SEL-787 protection features depend on the model selected. The models can be configured with specific current/voltage input cards. The current/voltage input cards are located in Slot Z and Slot E of the relay. The SEL-787 supports both conventional current and potential transformer inputs and low-energy analog sensor inputs.

Slot Z cards are assigned a two-digit code beginning with the number 8 or the letter L in the SEL-787 Model Options Table (MOT, see *Models on page 1.5*). For example, 81 in the MOT for Slot Z indicates a SELECT 6 ACI card with Winding 1 and Winding 2 at 1 A nominal. L0 in the MOT for Slot Z indicates a 6 ACI card with Winding 1 and Winding 2 with six Rogowski coil or low-power current inputs. The current channels on the LEA card accept an RJ45 connector input.

Slot E cards are assigned a two-digit code beginning with the number 7 or the letter L for the SEL-787-3E and SEL-787-3S models and with the letter A for the SEL-787-21, SEL-787-2E, and SEL-787-4X models in the SEL-787 MOT. For example, 71 in the MOT for Slot E indicates a SELECT 3 ACI/4 AVI card with the three-phase ac current inputs (1 A nominal), three-phase ac voltage inputs (300 Vac), and Vsync/Vbat input (300 Vac/Vdc). For example, L1 in the MOT for Slot E indicates a SELECT 3 ACI/4 AVI LEA card with three Rogowski coil or low-power current inputs and four LEA voltage sensor inputs. The current and voltage channels on the LEA card accept an RJ45 connector input. Note that you can order the SEL-787-2X model with optional I/O cards for Slot E.

Table 1.1 presents the current and voltage inputs for the different available models. Current inputs are 1 A and 5 A nominal rating and voltage inputs are 300 V continuous rating.

Table 1.1 Current (ACI) and Voltage (AVI) Card Selection for SEL-787 Models

Model	Description/Application	Slot Z Card (MOT Digits)	Slot Z Inputs	Slot E Card (MOT Digits)	Slot E Inputs
787-2X	2 Winding/Terminal Current Differential	6 ACI (81, 82, 85, L0)	IAW1, IBW1, ICW1, IAW2, IBW2, ICW2		
787-21	2 Winding/Terminal Current Differential 1 Neutral Current Input	6 ACI (81, 82, 85, L0)	IAW1, IBW1, ICW1, IAW2, IBW2, ICW2	1 ACI (A6, A7, L6)	IN
787-2E	2 Winding/Terminal Current Differential 1 Neutral Current Input 3 Voltage Inputs (Phase)	6 ACI (81, 82, 85, L0)	IAW1, IBW1, ICW1, IAW2, IBW2, ICW2	1 ACI/3 AVI (78, 79, L8)	IN, VA, VB, VC
787-3E	3 Winding/Terminal Current Differential 1 Neutral Current Input 3 Voltage Inputs (Phase)	6 ACI (81, 82, 85, L0)	IAW1, IBW1, ICW1, IAW2, IBW2, ICW2	4 ACI/3 AVI (72, 73, 76, 77, L2)	IAW3, IBW3, ICW3, IN, VA, VB, VC
787-3S	3 Winding/Terminal Current Differential 3 Voltage Inputs (Phase) 1 Voltage Input (Vsync or Vbat)	6 ACI (81, 82, 85, L0)	IAW1, IBW1, ICW1, IAW2, IBW2, ICW2	3 ACI/4 AVI (71, 75, L1)	IAW3, IBW3, ICW3, VS/VBAT, VA, VB, VC
787-4X	4 Winding/Terminal Current Differential	6 ACI (81, 82, 85, L0)	IAW1, IBW1, ICW1, IAW2, IBW2, ICW2	6 ACI (A1, A2, A5, L0)	IAW3, IBW3, ICW3, IAW4, IBW4, ICW4

The SEL-787 offers an extensive variety of protection features, depending on the model and options selected.

Table 1.2 SEL-787 Protection Elements (Sheet 1 of 2)

Protection Elements		2 Windings	2 Windings With IN Channel	2 Windings With IN Channel and 3-Phase Voltages	3 Windings With IN Channel and 3-Phase Voltages	3 Windings With VS/VBAT Channel and 3-Phase Voltages	4 Windings
		SEL-787-2X	SEL-787-21	SEL-787-2E	SEL-787-3E	SEL-787-3S	SEL-787-4X
87	Phase Differential	X	X	X	X	X	X
87Q	Negative-Sequence Differential	X	X	X	X	X	X
REF	Restricted Earth Fault		X[a]	X[a]	X[a]	X[a]	X[a]
50P	Phase Overcurrent	X	X	X	X	X	X
50Q	Neg.-Seq. Overcurrent	X	X	X	X	X	X
50G	Ground Overcurrent	X	X	X	X	X	X
50N	Neutral Overcurrent		X	X	X		

Table 1.2 SEL-787 Protection Elements (Sheet 2 of 2)

Protection Elements		2 Windings SEL-787-2X	2 Windings With IN Channel SEL-787-21	2 Windings With IN Channel and 3-Phase Voltages SEL-787-2E	3 Windings With IN Channel and 3-Phase Voltages SEL-787-3E	3 Windings With VS/VBAT Channel and 3-Phase Voltages SEL-787-3S	4 Windings SEL-787-4X
51P	Phase Time-Overcurrent	X	X	X	X	X	X
51Q	Neg.-Seq. Time-Overcurrent	X	X	X	X	X	X
51G	Ground Time-Overcurrent	X	X	X	X	X	X
51PC	Combined Winding Phase Time-Overcurrent				X	X	X
51GC	Combined Winding Ground Time-Overcurrent				X	X	X
51N	Neutral Time-Overcurrent		X	X	X		
27P	Phase Undervoltage			X	X	X	
27PP	Phase-to-Phase Undervoltage			X	X	X	
27S	VS Channel Undervoltage					X	
27I	Inverse-Time Undervoltage			X	X	X	
59P	Phase Overvoltage			X	X	X	
59PP	Phase-to-Phase Overvoltage			X	X	X	
59Q	Neg.-Seq. Overvoltage			X	X	X	
59G	Ground Overvoltage			X	X	X	
59S	VS Channel Overvoltage					X	
59I	Inverse-Time Overvoltage			X	X	X	
24	Volts/Hz			X	X	X	
25	Synchronism Check					X	
32	Directional Power			X	X	X	
49RTD	RTDs	X	X	X	X	X	X
60LOP	Loss of Potential			X	X	X	
81	Over- and Underfrequency			X	X	X	
BF	Breaker Failure	X	X	X	X	X	X

[a] Refer to Table 1.4 for the available REF elements.

Front-Panel Options

The SEL-787 offers two front-panel HMI layouts that are model and option dependent. *Table 1.3* lists the HMI options for the SEL-787 front panel. For ordering options, refer to the SEL-787 MOT.

Table 1.3 SEL-787 Front-Panel Options

Model/Display Description	Front-Panel Option (MOT String Digit Number 18)	Number of Pushbuttons	LED Type
SEL-787 With Two-Line Display (2 x 16 characters)	0	8	Tricolor
SEL-787 With Touchscreen Display (5-inch, color, 800 x 480 pixels)	A	8	Tricolor

Monitoring Features

- Event summaries that contain relay ID, date and time, trip cause, and current/voltage magnitudes
- Event reports including filtered and raw analog data
- Sequential Events Recorder (SER)
- Compatibility with SEL-3010 Event Messenger
- Transformer Through-Fault Event Monitor
- Breaker Wear Monitor
- Load Profile Report
- Station DC Battery Monitor
- A complete suite of accurate metering functions

Communications and Control Features

- EIA-232, front-panel port
- EIA-232, EIA-485, Ethernet (single/dual copper or fiber-optic), and SEL-2812 compatible ST fiber-optic rear-panel port
- Built-in web server
- IRIG-B time-code input
- Modbus RTU Slave, Modbus TCP/IP, DNP3 serial or LAN/WAN, Ethernet FTP, Telnet, Simple Network Time Protocol (SNTP), IEEE 1588-2008 firmware-based Precision Time Protocol (PTP), MIRRORED BITS, IEC 61850 Edition 2, IEC 60870-5-103, DeviceNet, EtherNet/IP, Synchrophasors with IEEE C37.118 Protocol, Parallel Redundancy Protocol (PRP), and Rapid Spanning Tree Protocol (RSTP)
- SEL ASCII, Compressed ASCII, Fast Meter, Fast Operate, Fast SER, Fast Message Protocols, and Event Messenger Protocol
- Programmable Boolean and math operators, logic functions, and analog compare

Language Support

- The standard relay front-panel overlay is in English; a Spanish overlay is available as an ordering option. Text displayed on the HMI will correspond to the ENGLISH or SPANISH ordering option.
- All of the ASCII commands can be displayed in multiple languages (English or Spanish). When you set the port setting LANG to either ENGLISH or SPANISH (see *Table 4.64*), the SEL-787 displays the ASCII commands in the corresponding language.
- The web server reports can be displayed in English or Spanish by setting the Ethernet Port 1 setting LANG to either ENGLISH or SPANISH.

Models, Options, and Accessories

Models

Complete ordering information is not provided in this instruction manual. See the latest Model Option Tables for the SEL-787 with the two-line display and the SEL-787 with the touchscreen display at selinc.com on the SEL-787 product page under Documentation > Ordering Information. Options and accessories are as listed below.

SEL-787 Base Unit

- Front panel with the two-line display or touchscreen display
  - Eight programmable pushbuttons, each with two tricolor LEDs
  - Eight target tricolor LEDs (six programmable)
  - Operator control interface
  - EIA-232 port
- Power supply card with two digital inputs and three digital outputs (Slot **A**)
- Processor and communications card (Slot **B**)
  - EIA-232 serial port
  - Multimode (ST) fiber-optic serial port (SEL-2812 compatible)
  - IRIG-B time-code input
- Six ac current inputs card in Slot **Z**
- Three expansion slots for optional cards (Slots **C**, **D**, **E**)
- Protocols
  - Modbus RTU
  - SEL ASCII and Compressed ASCII
  - SEL Fast Meter, Fast Operate, Fast SER, Fast Message
  - Ymodem File Transfer
  - SEL MIRRORED BITS
  - Event Messenger
  - Synchrophasors with IEEE C37.118

Options

- AC Current Option (1 A or 5 A nominal)
- Voltage Option
  - Four-wire wye
  - Open-delta
  - Single phase connected
- Input/Output (I/O) Option
  - Additional digital I/O (4 DI/4 DO, 4 DI/3 DO, 8 DI, 8 DO, 3 DI/4 DO/1 AO, 14 DI)
  - Additional analog I/O (4 AI/4 AO, 8 AI)
- RTD-Based Protection
  - As many as ten (10) RTDs can be monitored when an internal RTD card is used
  - As many as twelve (12) RTDs can be monitored when an external SEL-2600 RTD Module with the ST option (SEL-2812 compatible) is used. There are separate Trip and Warn settings for each RTD.
- Front-Panel HMI Options (see *Table 1.3*)
- Communications Options (Protocols/Ports)
  - EIA-485/EIA-232/Ethernet ports (single/dual, copper or fiber-optic)
  - SNTP
  - PTP (firmware-based)
  - PRP
  - RSTP
  - Modbus TCP/IP
  - IEC 61850 Edition 2
  - IEC 60870-5-103
  - EtherNet/IP
  - DNP3 serial and LAN/WAN
  - DeviceNet (**Note:** This option has been discontinued and is no longer available as of September 25, 2017.)
- Language Options
  - The relay supports English or Spanish language as an ordering option
- Conformal coating for chemically harsh and/or high-moisture environments

Accessories

Contact your Technical Service Center or the SEL factory for additional detail and ordering information for the following accessories:

- External RTD protection
  - SEL-2600 RTD Module (with ST option only)
  - A simplex 62.5/125 µm fiber-optic cable with ST connector for connecting the external RTD module to the SEL-787
- SEL-2505 Remote I/O Module (with SEL-2812 compatible ST fiber-optic port) for connection to relay fiber-optic serial Port 2, or use SEL-2505 with EIA-232 (DB-9) serial port to connect to EIA-232 Port 3 on the relay
- SEL-787 Configurable Labels
- Rack-Mounting Kits
  - For one relay
  - For two relays
  - For one relay and a test switch
- Wall-Mounting Kits
- Bezels for Retrofit
- Replacement Euro Connector Kit
- Ring Terminal Kit (for all connections to the relay)
- Relay Wire Termination Kits—See *Application Note AN2014-08*
- Dust Protection Kit

For all SEL-787 mounting accessories for competitor products' replacement, including adapter plates, visit selinc.com/app/mounting-selector/.

Applications

Refer to *Section 2: Installation* for various applications and their related connection diagrams. The following is a list of possible application scenarios.

- Two-, three-, or four-winding transformer protection with current differential and overcurrent elements and through-fault monitor
- Two- or three-winding transformer protection with current differential and overcurrent elements and through-fault monitor with optional restricted earth fault protection (REF) and neutral-overcurrent protection
- Two- or three-winding transformer protection with current differential and overcurrent elements and through-fault monitor with voltage, power, and frequency elements as well as synchronism check or the station battery monitor function.
- Two-, three-, or four-winding transformer protection with current differential and overcurrent elements and through-fault monitor with internal or external RTD inputs module

The relay allows Winding 3 to be configured for either differential or REF protection. *Table 1.4* identifies available REF elements based on the configuration of Winding 3.

Table 1.4 Available Differential and REF Elements

Elements	SEL-787-2X	SEL-787-21	SEL-787-2E	SEL-787-3E	SEL-787-3S	SEL-787-4X
Differential Protection Windings (Standard)	2	2	2	3	3	4
REF Elements (Standard)	0	1	1	1	0	0
Differential Protection Windings (Winding 3 Configured for REF)				2	2	3
REF Elements (Winding 3 Configured for REF)				2	2	2

Getting Started

Understanding basic relay operation principles and methods will help you use the SEL-787 effectively. This section presents the fundamental knowledge you need to operate the SEL-787, organized by task. These tasks help you become familiar with the relay and include the following:

- ➤ *Powering the Relay*
- ➤ *Establishing Communication*
- ➤ *Checking the Relay Status*
- ➤ *Setting the Date and Time*

Perform these tasks to gain a fundamental understanding of relay operation.

Powering the Relay

Power the SEL-787 with 110–240 Vac, 110–250 Vdc or 24/48 Vdc, depending on the part number.

- ➤ Observe proper polarity, as indicated by the **+/H** (terminal **A01**) and the **–/N** (terminal **A02**) on the power connections.
- ➤ Connect the ground lead.
- ➤ Once connected to power, the relay does an internal self-check and the **ENABLED** LED illuminates.

Establishing Communication

The SEL-787 base model has two EIA-232 serial communications ports. The following steps require PC terminal emulation software and an SEL-C662 Cable (or equivalent) to connect the SEL-787 to the PC. See *Table 1.5* for further information on serial communications connections and the required cable pinout.

Step 1. Connect the PC and the SEL-787 using the serial communications cable.

Step 2. Apply power to both the PC and the relay.

Step 3. Start the PC terminal emulation program.

Step 4. Set the PC terminal emulation program to the communications port settings listed in the Default Value column of *Table 1.5*. Also, set the terminal program to emulate either VT100 or VT52 terminals.

Step 5. Press the **<Enter>** key on the PC keyboard to check the communications link.

You should see the = prompt at the left side of the computer screen.

If you do not see the = prompt, check the cable connections, and confirm that the settings in the terminal emulation program are the default values in *Table 1.5*.

Table 1.5 SEL-787 Serial Port Settings

Description	Setting Label	Default Value
SPEED	SPEED	9600
DATA BITS	BITS	8
PARITY	PARITY	N
STOP BITS	STOP	1
PORT TIMEOUT	T_OUT	5
HWDR HANDSHAKING	RTSCTS	N

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

You should see a computer screen display similar to *Figure 1.1*. If you see jumbled characters, change the terminal emulation type in the PC terminal emulation program.

```
=>QUIT <Enter>
Transformer xyz          Date: 03/10/2014  Time: 10:31:43
Station 1            Time Source: Internal
=
```

Figure 1.1 Response Header

Step 7. Type **ACC <Enter>** and the appropriate password (see *Table 7.39* for factory-default passwords) to go to Access Level 1.

Checking the Relay Status

Use the **STA** serial port command to view the SEL-787 operational status. Analog channel dc offset and monitored component status are listed in the status report depicted in *Figure 1.2*.

```
=>>STA <Enter>

SEL-787-4X                                 Date: 09/09/2014   Time: 11:58:42.261
SEL-787-4-X225                             Time Source: Internal

Serial Num = 3122690016     FID = SEL-787-4-X225-V0-Z001001-D20140907
CID = FFE9                  PART NUM = 07874XE1B1X0XA585063X

SELF TESTS (W=Warn)
  FPGA  GPSB  HMI   RAM   ROM   CR_RAM  NON_VOL  CLOCK  CID_FILE  +0.9V  +1.2V
  OK    OK    OK    OK    OK    OK      OK       OK     OK        0.90   1.20

  +1.5V  +1.8V  +2.5V  +3.3V  +3.75V  +5.0V  -1.25V  -5.0V   BATT
  1.50   1.80   2.50   3.34   3.72    4.97   -1.26   -4.98   3.00
```

Figure 1.2 STA Command Response—No DeviceNet Communications Card or EIA-232/EIA-485 Communications Card

```
Option Cards
  CARD_C  CARD_D  CARD_E  CURRENT
  OK      OK      OK      OK

Offsets
  IAW1  IBW1  ICW1  IAW2  IBW2  ICW2  IAW3  IBW3  ICW3  IAW4  IBW4  ICW4
  0     0     0     0     0     0     0     0     0     0     0     0

  Relay Enabled

=>>
```

Figure 1.2 STA Command Response—No DeviceNet Communications Card or EIA-232/EIA-485 Communications Card (Continued)

If a communications card with the DeviceNet protocol is present, the status report depicted in *Figure 1.3* applies. If a communications card with Modbus RTU protocol is present, the status report depicted in *Figure 1.2* applies.

```
=>>STA <Enter>

SEL-787-4X                                  Date: 09/09/2014   Time: 11:59:03.877
SEL-787-4-X225                              Time Source: Internal

Serial Num = 3122690016     FID = SEL-787-4-X225-V0-Z001001-D20140907
CID = FFE9                  PART NUM = 07874XE1BA30XA585063X

SELF TESTS (W=Warn)
  FPGA  GPSB  HMI   RAM   ROM   CR_RAM  NON_VOL  CLOCK  CID_FILE  +0.9V  +1.2V
  OK    OK    OK    OK    OK    OK      OK       OK     OK        0.90   1.20

  +1.5V  +1.8V  +2.5V  +3.3V  +3.75V  +5.0V  -1.25V  -5.0V   BATT
  1.50   1.81   2.50   3.34   3.72    4.97   -1.26   -4.98   3.00

Option Cards
  CARD_C  CARD_D  CARD_E  CURRENT
  OK      OK      OK      OK

DeviceNet
  DN_MAC_ID     ASA      DN_RATE   DN_STATUS
  5          1a25 df41h  AUTO      0000 0000

Offsets
  IAW1  IBW1  ICW1  IAW2  IBW2  ICW2  IAW3  IBW3  ICW3  IAW4  IBW4  ICW4
  0     0     0     0     0     0     0     0     0     0     0     0

  Relay Enabled

=>>
```

Figure 1.3 STA Command Response—With DeviceNet Communications Card

Table 7.52 provides the definition of each status report designator and *Table 11.13* shows all the self-tests performed by the relay. The beginning of the status report printout (see *Figure 1.2*) contains the relay serial number, firmware identification (FID) string, and checksum (CID) string. These strings uniquely identify the relay and the version of the operating firmware.

Setting the Date and Time

DAT (Date Command)

Viewing the Date

Type **DAT <Enter>** at the prompt to view the date stored in the SEL-787. If the date stored in the relay is February 28, 2014, and the DATE_F setting is MDY, the relay displays:

```
2/28/2014
```

If the DATE_F setting is YMD, the relay displays:

```
2014/2/28
```

If the DATE_F setting is DMY, the relay displays:

```
28/2/2014
```

Changing the Date

Type **DAT** followed by the correct date at the prompt to change the date stored in the relay. For example, to change the date to May 2, 2014 (DATE_F = MDY), enter the following at the action prompt:

```
DAT 5/2/14
```

You can separate the month, day, and year parameters with spaces, commas, slashes, colons, and semicolons.

TIM (Time Command)

Viewing the Time

Enter **TIM** at the prompt to view the time stored in the SEL-787. The relay displays the stored time:

```
13:52:44
```

This time is 1:52 p.m. (and 44 seconds).

Changing the Time

Enter **TIM** followed by the correct time at the action prompt to change the time stored in the relay. For example, to change the time to 6:32 a.m., enter the following at the prompt:

```
TIM 6:32:00
```

You can separate the hours, minutes, and seconds parameters with spaces, commas, slashes, colons, and semicolons.

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

49 CFR 15B, Class A

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.

CE Mark in accordance with the requirements of the European Union

RCM Mark in accordance with the requirements of Australia

UKCA Mark in accordance with the requirements of United Kingdom

Normal Locations

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

Hazardous Locations

UL Certified Hazardous Locations to U.S. and Canadian standards CL 1, DIV 2; GP A, B, C, D; T3C, maximum surrounding air temperature of 50°C (File E470448)

EU

II 3 G
Ex ec nC IIC T3 Gc
DEMKO 18 ATEX 2081X

EN 60079-0:2012 + A11:2013, EN 60079-7:2015, EN 60079-15:2010, EN 60079-11:2012

Ambient air temperature shall not exceed –20°C ≤ Ta ≤ +50°C.

Note: Where marked, ATEX and UL Hazardous Locations Certification tests are applicable to rated supply specifications only and do not apply to the absolute operating ranges, continuous thermal, or short circuit duration specifications.

General

AC Current Input

I_{NOM} = 1 A or 5 A secondary depending on the model

Measurement Category: II

Phase and Neutral Currents

I_{NOM} = 5 A

Continuous Rating:	3 • I_{NOM} @ 85°C 4 • I_{NOM} @ 55°C
A/D Measurement Limit:	217 A peak (154 A rms symmetrical)
Saturation Current Rating:	Linear to 96 A symmetrical
1-Second Thermal:	500 A
Burden (per phase):	<0.1 VA @ 5 A

I_{NOM} = 1 A

Continuous Rating:	3 • I_{NOM} @ 85°C 4 • I_{NOM} @ 55°C
A/D Measurement Limit:	43 A peak (31 A rms symmetrical)
Saturation Current Rating:	Linear to 19.2 A symmetrical
1-Second Thermal:	100 A
Burden (per phase):	<0.01 VA @ 1 A

Rogowski Coil-Based AC Current Inputs—Phase and Neutral Current

Continuous Rating:	30 Vrms
Nominal Input Voltage:	65 mV to 4.16 Vrms
Number of Gain Ranges:	6
Full-Scale Voltage:	4, 8, 16, 32, 64, 128 Vrms
A/D Measurement Limit:	±185 Vpeak @ 60 Hz
10-Second Thermal:	200 Vac
Input Impedance:	2 MΩ‖50 pF
Standard Compliance:	IEC 61869-6 IEC 61869-13

Low-Power Current Transformer (LPCT) Inputs—Phase and Neutral Current

Continuous Rating:	4 Vrms
Nominal Input Voltage:	16 mV to 260 mVrms
Number of Gain Ranges:	4
Full-Scale Voltage:	1, 2, 4, 8 Vrms
A/D Measurement Limit:	±11.3 Vpeak
10-Second Thermal:	200 Vac
Input Impedance:	2 MΩ‖50 pF
Standard Compliance:	IEC 61869-6 IEC 61869-13

AC Voltage Inputs

V_{NOM} (kV L-L)/PT Ratio Range:	100–250 V (if DELTA_Y := DELTA) 100–480 V (if DELTA_Y := WYE)
Rated Continuous Voltage:	300 Vac
10-Second Thermal:	600 Vac
Burden:	<0.1 VA
Input Impedance:	4 MΩ differential (phase-to-phase) 7 MΩ common mode (phase-to-chassis)

Low-Energy Analog Voltage Sensor Inputs (RJ45 Input)

Continuous Rating:	8 Vrms
Nominal Input Voltage:	0.5–6.8 Vrms
Full-Scale Voltage:	8 Vrms
A/D Measurement Limit:	±12 Vpeak
10-Second Thermal:	200 Vac
Input Impedance:	2 MΩ‖50 pF
Standard Compliance:	IEC 61869-6 IEC 61869-13

Power Supply

Relay Start-Up Time: Approximately 5–10 seconds (after power is applied until the **ENABLED** LED turns on)

High-Voltage Supply

Rated Supply Voltage:	110–240 Vac, 50/60 Hz 110–250 Vdc
Input Voltage Range (Design Range):	85–264 Vac 85–300 Vdc
Power Consumption:	<50 VA (ac) <25 W (dc)
Interruptions:	50 ms @ 125 Vac/Vdc 100 ms @ 250 Vac/Vdc

Low-Voltage Supply

Rated Supply Voltage:	24–48 Vdc
Input Voltage Range (Design Range):	19.2–60.0 Vdc

Power Consumption: <25 W (dc)

Interruptions: 10 ms @ 24 Vdc
50 ms @ 48 Vdc

Fuse Ratings

LV Power Supply Fuse

Rating: 3.15 A

Maximum Rated Voltage: 300 Vdc, 250 Vac

Breaking Capacity: 1500 A at 250 Vac

Type: Time-lag T

HV Power Supply Fuse

Rating: 3.15 A

Maximum Rated Voltage: 300 Vdc, 250 Vac

Breaking Capacity: 1500 A at 250 Vac

Type: Time-lag T

Output Contacts

General

The relay supports Form A, B, and C outputs.

Dielectric Test Voltage: 2500 Vac

Impulse Withstand Voltage (U_{IMP}): 5000 V

Mechanical Durability: 100,000 no-load operations

Standard Contacts

Pickup/Dropout Time: ≤8 ms (coil energization to contact closure)

DC Output Ratings

Rated Operational Voltage: 250 Vdc

Rated Voltage Range: 19.2–275 Vdc

Rated Insulation Voltage: 300 Vdc

Make: 30 A @ 250 Vdc per IEEE C37.90

Continuous Carry: 6 A @ 70°C
4 A @ 85°C

1-Second Thermal: 50 A

Contact Protection: 360 Vdc, 115 J MOV protection across open contacts

Breaking Capacity (10,000 Operations) per IEC 60255-0-20:1974:

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

Cyclic (2.5 Cycles/Second) per IEC 60255-0-20:1974:

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

AC Output Ratings

Maximum Operational Voltage (U_e) Rating: 240 Vac

Insulation Voltage (U_i) Rating (excluding EN 61010-1): 300 Vac

1-Second Thermal: 50 A

Contact Rating Designation: B300

B300 (5 A Thermal Current, 300 Vac Max)			
	Maximum Current		Max VA
Voltage	120 Vac	240 Vac	—
Make	30 A	15 A	3600
Break	3 A	1.5 A	360
PF <0.35, 50–60 Hz			

Utilization Category: AC-15

AC-15		
Operational Voltage (Ue)	120 Vac	240 Vac
Operational Current (Ie)	3 A	1.5 A
Make Current	30 A	15 A
Break Current	3 A	1.5 A
Electromagnetic loads >72 VA, PF <0.3, 50–60 Hz		

Voltage Protection Across Open Contacts: 270 Vac, 115 J

Fast Hybrid (High-Speed, High-Current Interrupting)

DC Output Ratings

Rated Operational Voltage: 250 Vdc

Rated Voltage Range: 19.2–275 Vdc

Rated Insulation Voltage: 300 Vdc

Make: 30 A @ 250 Vdc per IEEE C37.90

Carry: 6 A @ 70°C
4 A @ 85°C

1-Second Thermal: 50 A

Open State Leakage Current: <500 µA

MOV Protection (maximum voltage): 250 Vac/330 Vdc

Pickup Time: <50 µs, resistive load

Dropout Time: <8 ms, resistive load

Breaking Capacity (10,000 Operations) per IEC 60255-0-20:1974:

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

Cyclic Capacity (4 Cycles in 1 Second, Followed by 2 Minutes Idle for Thermal Dissipation) per IEC 60255-0-20:1974:

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

AC Output Ratings

See *AC Output Ratings* for *Standard Contacts*.

Optoisolated Control Inputs

When Used With DC Control Signals

Pickup/Dropout Time: Depends on the input debounce settings

250 V: ON for 200–312.5 Vdc
OFF below 150 Vdc

220 V: ON for 176–275 Vdc
OFF below 132 Vdc

125 V: ON for 100–156.2 Vdc
OFF below 75 Vdc

110 V: ON for 88–137.5 Vdc
OFF below 66 Vdc

48 V: ON for 38.4–60 Vdc
OFF below 28.8 Vdc

24 V: ON for 15–30 Vdc
OFF for below 5 Vdc

When Used With AC Control Signals

Pickup Time: 2 ms

Dropout Time: 16 ms

250 V: ON for 170.6–312.5 Vac
OFF below 106 Vac

220 V: ON for 150.2–275 Vac
OFF below 93.3 Vac

125 V: ON for 85–156.2 Vac
OFF below 53 Vac

110 V:	ON for 75.1–137.5 Vac OFF below 46.6 Vac	
48 V:	ON for 32.8–60 Vac OFF below 20.3 Vac	
24 V:	ON for 14–30 Vac OFF below 5 Vac	
Current draw at nominal dc voltage:	2 mA (at 220–250 V) 4 mA (at 48–125 V) 10 mA (at 24 V)	
Rated Impulse Withstand Voltage (U_{imp}):	4000 V	

Analog Output (Optional)

	1A0	4A0
Current:	4–20 mA	±20 mA
Voltage:	—	±10 V
Load at 1 mA:	—	0–15 kΩ
Load at 20 mA:	0–300 Ω	0–750 Ω
Load at 10 V:	—	>2000 Ω
Refresh Rate:	100 ms	100 ms
% Error, Full Scale, at	<±1%	<±0.55%
Select From:	Analog quantities available in the relay	

Analog Inputs (Optional)

Maximum Input Range:	±20 mA ±10 V Operational range set by user
Input Impedance:	200 Ω (current mode) >10 kΩ (voltage mode)
Accuracy at 25°C:	
With user calibration:	0.05% of full scale (current mode) 0.025% of full scale (voltage mode)
Without user calibration:	Better than 0.5% of full scale at 25°C
Accuracy Variation With Temperature:	±0.015% per °C of full-scale (±20 mA or ±10 V)

Frequency and Phase Rotation

System Frequency:	50, 60 Hz
Phase Rotation:	ABC, ACB
Frequency Tracking:	15–70 Hz (requires ac voltage inputs)

Time-Code Input

Format:	Demodulated IRIG-B
On (1) State:	$V_{ih} \geq 2.2$ V
Off (0) State:	$V_{il} \leq 0.8$ V
Input Impedance:	2 kΩ

Synchronization Accuracy

Internal Clock:	±1 µs
Synchrophasor Reports (e.g., **MET PM**):	±10 µs
All Other Reports:	±5 ms
SNTP Accuracy:	±1 ms (in an ideal network)
PTP Accuracy:	±1 ms
Unsynchronized Clock Drift Relay Powered:	2 minutes per year, typically

Communications Ports

Standard EIA-232 (2 Ports)

Location:	Front Panel Rear Panel
Data Speed:	300–38400 bps

EIA-485 Port (Optional)

Location:	Rear Panel
Data Speed:	300–19200 bps

Ethernet Port (Optional)

Single/Dual 10/100BASE-T copper (RJ45 connector)

Single/Dual 100BASE-FX (LC connector)

Standard Multimode Fiber-Optic Port

Location:	Rear Panel
Data Speed:	300–38400 bps

Fiber-Optic Ports Characteristics

PORT 1 (or 1A, 1B) Ethernet

Wavelength:	1300 nm
Optical Connector Type:	LC
Fiber Type:	Multimode
Link Budget:	16.1 dB
Typical TX Power:	–15.7 dBm
RX Min. Sensitivity:	–31.8 dBm
Fiber Size:	62.5/125 µm
Approximate Range:	~6.4 km
Data Rate:	100 Mbps
Typical Fiber Attenuation:	–2 dB/km

PORT 2 Serial (SEL-2812 Compatible)

Wavelength:	820 nm
Optical Connector Type:	ST
Fiber Type:	Multimode
Link Budget:	8 dB
Typical TX Power:	–16 dBm
RX Min. Sensitivity:	–24 dBm
Fiber Size:	62.5/125 µm
Approximate Range:	~1 km
Data Rate:	5 Mbps
Typical Fiber Attenuation:	–4 dB/km

Optional Communications Cards

Option 1:	EIA-232 or EIA-485 communications card
Option 2:	DeviceNet communications card (the DeviceNet option has been discontinued and is no longer available as of September 25, 2017)

Communications Protocols

SEL, Modbus RTU and TCP/IP, DNP3 serial and LAN/WAN, FTP, Telnet, SNTP, IEEE 1588-2008 firmware-based PTP, IEC 61850 Edition 2, IEC 60870-5-103, EtherNet/IP, IEC 62439-3 PRP, IEEE 802.1Q-2014 RSTP, MIRRORED BITS, EVMSG, IEEE C37.118 (synchrophasors), and DeviceNet

Operating Temperature

IEC Performance Rating:	–40° to +85°C (–40° to +185°F) (per IEC/EN 60068-2-1 and 60068-2-2)

Note: Not applicable to UL applications.

Note: The front-panel display is impaired for temperatures below –20°C and above +70°C.

DeviceNet Communications Card Rating:	+60°C (140°F) maximum
Optoisolated Control Inputs:	As many as 26 inputs are allowed in ambient temperatures of 85°C or less. As many as 34 inputs are allowed in ambient temperatures of 75°C or less. As many as 44 inputs are allowed in ambient temperatures of 65°C or less.

Operating Environment

Insulation Class:	I
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 Rating):	2000 m

Dimensions

144.0 mm (5.67 in) x 192.0 mm (7.56 in) x 147.4 mm (5.80 in)

Weight

2.7 kg (6.0 lb)

Relay Mounting Screws (#8–32) Tightening Torque

Minimum:	1.4 Nm (12 in-lb)
Maximum:	1.7 Nm (15 in-lb)

Terminal Connections

Terminal Block

Screw Size:	#6
Ring Terminal Width:	0.310 in maximum

Terminal Block Tightening Torque

Minimum:	0.9 Nm (8 in-lb)
Maximum:	1.4 Nm (12 in-lb)

Compression Plug Tightening Torque

Minimum:	0.5 Nm (4.4 in-lb)
Maximum:	1.0 Nm (8.8 in-lb)

Compression Plug Mounting Ear Screw Tightening Torque

Minimum:	0.18 Nm (1.6 in-lb)
Maximum:	0.25 Nm (2.2 in-lb)

RTD Compression Plug Tightening Torque

Maximum:	0.25 Nm (2.2 in-lb)

Product Standards

Electromagnetic Compatibility:	IEC 60255-26:2013 IEC 60255-27:2013 UL 508 CSA C22.2 No. 14-05

Type Tests

Environmental Tests

Enclosure Protection:	IEC 60529:2001 + CRDG:2003 IP65 enclosed in panel (2-line display models) IP54 enclosed in panel (touchscreen models) IP50-rated terminal dust protection assembly (SEL Part #915900170). The 10°C temperature derating applies to the temperature specifications of the relay. IP10 for terminals and the relay rear panel IP20 for terminals and the relay rear panel with optional terminal block cover

Note: If rear terminals are accessible during normal use,the product must be mounted in a locked enclosure or restricted area accessible by trained maintenance or operation personnel only.

Vibration Resistance:	IEC 60255-21-1:1988 IEC 60255-27:2013, Section 10.6.2.1 Endurance: Class 2 Response: Class 2
Shock Resistance:	IEC 60255-21-2:1988 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 60255-21-3:1993 IEC 60255-27:2013, Section 10.6.2.4 Response: Class 2
Cold:	IEC 60068-2-1:2007 IEC 60255-27:2013, Section 10.6.1.2 IEC 60255-27:2013, Section 10.6.1.4 –40°C, 16 hours
Dry Heat:	IEC 60068-2-2:2007 IEC 60255-27:2013, Section 10.6.1.1 IEC 60255-27:2013, Section 10.6.1.3 85°C, 16 hours
Damp Heat, Steady State:	IEC 60068-2-78:2001 IEC 60255-27:2013, Section 10.6.1.5 Severity Level: 93% relative humidity minimum 40°C, 10 days
Damp Heat, Cyclic:	IEC 60068-2-30:2001 IEC 60255-27:2013, Section 10.6.1.6 Test Db; Variant 2; 25°–55°C, 6 cycles, 95% relative humidity minimum
Change of Temperature:	IEC 60068-2-14:2009 IEC 60255-1:2010, Section 6.12.3.5 –40° to +85°C, ramp rate 1°C/min, 5 cycles

Dielectric Strength and Impulse Tests

Dielectric (HiPot):	IEC 60255-27:2013, Section 10.6.4.3 IEEE C37.90-2005 1.0 kVac on analog outputs, Ethernet ports 2.0 kVdc on IRIG port 2.0 kVac on analog inputs 820 Vac on LEA inputs 2.5 kVac on contact I/O 3.6 kVdc on power supply, current, and voltage inputs
Impulse:	IEC 60255-27:2013, Section 10.6.4.2 Severity Level: 0.5 J, 5 kV on power supply, contact I/O, ac current, and voltage inputs 0.5 J, 530 V on analog outputs IEEE C37.90:2005 Severity Level: 0.5 J, 5 kV 0.5 J, 1.5 kV on LEA inputs 0.5 J, 530 V on analog outputs

RFI and Interference Tests

EMC Immunity

Electrostatic Discharge Immunity:	IEC 61000-4-2:2008 IEC 60255-26:2013, Section 7.2.3 IEEE C37.90.3:2001 Severity Level 4 8 kV contact discharge 15 kV air discharge
Radiated RF Immunity:	IEC 61000-4-3:2010 IEC 60255-26:2013, Section 7.2.4 10 V/m IEEE C37.90.2-2004 20 V/m

Fast Transient, Burst Immunity:	IEC 61000-4-4:2012 IEC 60255-26:2013, Section 7.2.5 4 kV @ 5.0 kH 2 kV @ 5.0 kHz for comm. ports
Surge Immunity:	IEC 61000-4-5:2005 IEC 60255-26:2013, Section 7.2.7 2 kV line-to-line 4 kV line-to-earth **Note:** Front port serial cable (non-fiber) length assumed to be <3 m. **Note:** Voltage elements (27, 59) time delay ≥ 30 ms. LEA ports compliant with IEC 61869-13 tested to 1 kV, 1 MHz line-to-earth only
Surge Withstand Capability Immunity:	IEC 61000-4-18:2010 IEC 60255-26:2013, Section 7.2.6 2.5 kV common mode 1 kV differential mode 1 kV common mode on comm. ports IEEE C37.90.1-2002 2.5 kV oscillatory 4 kV fast transient **Note:** Front port serial cable (non-fiber) length assumed to be <3 m.
Conducted RF Immunity:	IEC 61000-4-6:2008 IEC 60255-26:2013, Section 7.2.8 10 Vrms
Magnetic Field Immunity:	IEC 61000-4-8:2009 IEC 60225-26:2013, Section 7.2.10 Severity Level: 1000 A/m for 3 seconds 100 A/m for 1 minute; 50/60 Hz IEC 61000-4-9:2001 Severity Level: 1000 A/m IEC 61000-4-10:2001 Severity Level: 100 A/m (100 kHz and 1 MHz)
Power Supply Immunity:	IEC 61000-4-11:2004 IEC 61000-4-17:1999 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

EMC Emissions

Conducted Emissions:	IEC 60255-26:2013 Class A FCC 47 CFR Part 15.107 Class A Canada ICES-001 (A) / NMB-001 (A) EN 55011:2009 + A1:2010 Class A EN 55022:2010 + AC:2011 Class A EN 55032:2012 + AC:2013 Class A CISPR 11:2009 + A1:2010 Class A CISPR 22:2008 Class A CISPR 32:2015 Class A
Radiated Emissions:	IEC 60255-26:2013 Class A FCC 47 CFR Part 15.109 Class A Canada ICES-001 (A) / NMB-001 (A) EN 55011:2009 + A1:2010 Class A EN 55022:2010 + AC:2011 Class A EN 55032:2012 + AC:2013 Class A CISPR 11:2009 + A1:2010 Class A CISPR 22:2008 Class A CISPR 32:2015 Class A

Processing Specifications and Oscillography

AC Voltage and Current Inputs:	32 samples per power system cycle
Frequency Tracking Range:	15–70 Hz (requires ac voltage inputs option)
Digital Filtering:	One-cycle cosine after low-pass analog filtering. Net filtering (analog plus digital) rejects dc and all harmonics greater than the fundamental.
Protection and Control Processing:	Processing interval is 4 times per power system cycle (except for math variables and analog quantities, which are processed every 25 ms). The 51 elements are processed 2 times per power system cycle. Analog quantities for rms data are determined through use of data averaged over the previous 8 cycles.

Oscillography

Length:	15, 64, or 180 cycles
Sampling Rate:	32 samples per cycle unfiltered 4 samples per cycle filtered
Trigger:	Programmable with Boolean expression
Format:	ASCII and Compressed ASCII Binary COMTRADE (32 samples/cycle unfiltered)
Time-Stamp Resolution:	1 ms
Time-Stamp Accuracy:	±5 ms

Sequential Events Recorder

Time-Stamp Resolution:	1 ms
Time-Stamp Accuracy (With Respect to Time Source) for all Relay Word bits except those corresponding to digital inputs (IN*xxx*):	±5 ms
Time-Stamp Accuracy (With Respect to Time Source) for Relay Word bits corresponding to digital inputs (IN*xxx*):	1 ms

Functional Requirements

Over- and Undercurrent Protection:	IEC 60255-151:2009
Over- and Undervoltage Protection:	IEC 60255-127:2010
Frequency Protection:	IEC 60255-181:2019
Differential Protection:	IEC 60255-187-1:2021

Relay Elements

Instantaneous/Definite-Time Overcurrent (50P, 50G, 50N, 50Q)

Supported and Effective Setting Range, A secondary

5 A Model:	0.25–96.00 A, 0.01 A steps
1 A Model:	0.05–19.20 A, 0.01 A steps
Accuracy:	±3% of setting plus ±0.02 • I_{NOM} A secondary (steady state) ±5% of setting plus ±0.02 • I_{NOM} A secondary (transient) ±6% of setting plus ±0.02 • I_{NOM} A secondary (transient for 50Q)
Time Delay:	0.00–5.00 seconds, 0.01-second steps 0.10–120.00 seconds, 0.01-second steps (50Q)
Accuracy:	±0.5% plus ±0.25 cycle
Pickup/Dropout Time:	<1.75 cycles (with fast hybrid output contacts)
Reset Ratio:	95% for setting ≥ 0.1 • INOM 90% for setting < 0.1 • INOM

Transient Overreach:	<15% for X/R = 10–120
Overshoot Time:	5 ms

Inverse-Time Overcurrent (51P, 51G, 51N, 51Q)

Supported Setting Range, A secondary	
5 A Model:	0.25–16.00 A, 0.01 A steps
1 A Model:	0.05–3.20 A, 0.01 A steps
Effective Setting Range (IEC), A secondary	
5 A Model:	0.500–5.165 A, 0.01 A steps
1 A Model:	0.10–1.03 A, 0.01 A steps
Lowest Value of Input Energizing Quantity for which the Relay Is Guaranteed to Operate (GT):	1.20 • setting
Threshold at which the Relay Switches from Dependent Time Operation to Independent Time Operation (GD):	>30 • setting
Accuracy:	±5% of setting plus ±0.02 • I_{NOM} A secondary (steady-state pickup)
Time Dial	
U.S.:	0.50–15.00, 0.01 steps
IEC:	0.05–1.00, 0.01 steps
Accuracy:	±1.5 cycles plus ±4% between 2 and 30 multiples of pickup (within A/D measurement limit)
Accuracy (Reset Time):	±1.5 cycles, ±4% between 0.5 and 0.0 multiple of pickup
Reset Ratio:	95% for setting ≥ 0.1 • I_{NOM} 90% for setting < 0.1 • I_{NOM}
Transient Overreach:	<15% for X/R = 10–120
Overshoot Time:	5–30 ms

Differential (87)

Unrestrained Pickup Range:	1.0–20.0 in per unit of TAP
Restrained Pickup Range:	0.10–1.00 in per unit of TAP
Pickup Accuracy (A secondary)	
5 A Model:	±5% plus ±0.10 A
1 A Model:	±5% plus ±0.02 A
Unrestrained Element	
Pickup Time:	1.05/1.25/2.15 cycles (Min/Typ/Max) (with fast hybrid output contacts)
Restrained Element (With Harmonic Blocking)	
Pickup Time:	1.75/1.85/2.45 cycles (Min/Typ/Max) (with fast hybrid output contacts)
Restrained Element (With Harmonic Restraint)	
Pickup Time:	2.87/2.97/3.11 cycles (Min/Typ/Max) (with fast hybrid output contacts)

Negative-Sequence Differential (87Q)

Pickup Range:	0.20–1.00 in per unit of TAP
Pickup Accuracy (A secondary)	
5 A Model:	±5% plus ±0.10 A
1 A Model:	±5% plus ±0.02 A
Pickup Time Delay:	0.01–99.99 seconds
Accuracy:	±0.5% plus ±0.25 cycle

Harmonics

Pickup Range (% of fundamental):	5%–100%
Pickup Accuracy (A secondary)	
5 A Model:	±5% plus ±0.10 A
1 A Model:	±5% plus ±0.02 A
Time Delay Accuracy:	±0.5% plus ±0.25 cycle

Restricted Earth Fault (REF)

Pickup Range (per unit of I_{NOM} of neutral current inputs, IN, and/or Winding 3):	0.05–3.00 per unit, 0.01 per-unit steps
Pickup Accuracy (A secondary)	
5 A Model:	±5% plus ±0.10 A
1 A Model:	±5% plus ±0.02 A
Timing Accuracy	
Directional Output Maximum Pickup/ Dropout Time:	<2.0 cycles (with fast hybrid output contacts)
ANSI Extremely Inverse TOC Curve (U4 With 0.5 Time Dial):	±5 cycles plus ±5% between 2 and 30 multiples of pickup (within rated range of current)

Undervoltage (27P, 27PP, 27S)

Supported and Effective Setting Range:	OFF, 12.50–300.00 V (phase elements, phase-to-phase elements with delta inputs or synchronism voltage input) OFF, 12.50–520.00 V (phase-to-phase elements with wye inputs)
Accuracy:	±1% of setting plus ±0.5 V
Pickup/Dropout Time:	<1.75 cycles (with fast hybrid output contacts)
Time Delay:	0.00–120.00 seconds, 0.01-second steps
Accuracy:	±0.5% plus ±0.25 cycle
Reset Ratio:	106% for setting ≤ 10 V 101% for setting > 10 V
Overshoot Time:	35 ms

Overvoltage (59P, 59PP, 59G, 59Q, 59S)

Supported and Effective Setting Range:	OFF, 12.50–300.00 V (phase elements, phase-to-phase elements with delta inputs or synchronism voltage input) OFF, 12.50–520.00 V (phase-to-phase elements with wye inputs)
Accuracy:	±1% of setting plus ±0.5 V
Pickup/Dropout Time:	<1.75 cycles (with fast hybrid output contacts)
Time Delay:	0.00–120.00 seconds, 0.01-second steps
Accuracy:	±0.5% plus ±0.25 cycle
Reset Ratio:	96% for setting ≤ 10 V 99% for setting > 10 V
Overshoot Time:	35 ms

Inverse-Time Undervoltage (27I)

Supported and Effective Setting Range	OFF, 2.00-300.00 V (phase elements, positive-sequence elements with delta inputs or synchronism-check voltage input) OFF, 2.00-520.00 V (phase-to-phase elements with wye inputs)
Accuracy:	±1% of setting plus ±0.5 V
Pickup/Dropout Time:	<1.75 cycles (with fast hybrid output contacts)
Time Dial:	0.00–16.00 s

Accuracy:	±1.5 cyc plus ±4% between 0.95 and 0.1 multiples of pickup
Pickup/Dropout Time:	<1.75 cycles (with fast hybrid output contacts)
Reset Ratio:	103% for setting ≤ 10 V 102% for setting > 10 V
Overshoot Time:	5–30 ms

Inverse-Time Overvoltage (59I)

Supported and Effective Setting Range:	OFF, 2.00–300.00 V (phase elements, sequence elements, or phase-to-phase elements with delta inputs or synchronism voltage input) OFF, 2.00–520.00 V (phase-to-phase elements with wye inputs)
Accuracy:	±1% of setting plus ±0.5 V
Pickup/Dropout Time:	<1.75 cycles (with fast hybrid output contacts)
Time Dial:	0.00–16.00 s
Accuracy:	±1.5 cyc plus ±4% between 1.05 and 5.5 multiples of pickup
Reset Ratio:	96% for setting ≤ 10 V 99% for setting > 10 V
Overshoot Time:	5–30 ms

Volts/Hertz (24)

Definite-Time Element

Pickup Range:	100%–200%
Steady-State Pickup Accuracy:	±1% of set point
Pickup Time:	25 ms @ 60 Hz (Max)
Time-Delay Range:	0.00–400.00 s
Time-Delay Accuracy:	±0.1% plus ±4.2 ms @ 60 Hz
Reset Time Range:	0.00–400.00 s

Inverse-Time Element

Pickup Range:	100%–200%
Steady-State Pickup Accuracy:	±1% of set point
Pickup Time:	25 ms @ 60 Hz (Max)
Curve:	0.5, 1.0, or 2.0
Factor:	0.1–10.0 s
Timing Accuracy:	±4% plus ±25 ms @ 60 Hz, for V/Hz above 1.05 multiples (Curve 0.5 and 1.0) or 1.10 multiples (Curve 2.0) of pickup setting, and for operating times >4 s
Reset Time Range:	0.00–400.00 s

Composite-Time Element

Combination of definite-time and inverse-time specifications

User-Definable Curve Element

Pickup Range:	100%–200%
Steady-State Pickup Accuracy:	±1% of set point
Pickup Time:	25 ms @ 60 Hz (Max)
Reset Time Range:	0.00–400.00 s

Directional Power (32)

Instantaneous/Definite-Time, 3 Phase Elements

Type:	+W, –W, +VAR, –VAR
Pickup Settings Range, VA secondary	
5 A Model:	1.0–6500.0 VA, 0.1 VA steps
1 A Model:	0.2–1300.0 VA, 0.1 VA steps
Accuracy:	±0.10 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) ±0.02 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)
Pickup/Dropout Time:	<10 cycles
Time Delay:	0.00–240.00 seconds, 0.01-second steps
Accuracy:	±0.5% plus ±0.25 cycle

Frequency (81)

Setting Range:	OFF, 15.00–70.00 Hz
Accuracy:	±0.01 Hz (V1 > 60 V) with voltage tracking
Pickup/Dropout Time:	<5.5 cycles (with fast hybrid output contacts)
Time Delay:	0.00–400.00 seconds, 0.01-second steps
Accuracy:	±0.5% plus ±0.25 cycle
Reset Hysteresis:	<0.02 Hz

RTD Protection

Setting Range:	OFF, 1°–250°C
Accuracy:	±2°C
RTD Open-Circuit Detection:	>250°C
RTD Short-Circuit Detection:	<–50°C
RTD Types:	PT100, NI100, NI120, CU10
RTD Lead Resistance:	25 ohm max. per lead
Update Rate:	<3 s
Noise Immunity on RTD Inputs:	To 1.4 Vac (peak) at 50 Hz or greater frequency
RTD Fault/Alarm/Trip Time Delay:	Approx. 12 s

Synchronism Check (25)

Pickup Range, Secondary Voltage:	0.00–300.00 V
Pickup Accuracy, Secondary Voltage:	±1% plus ±0.5 volts (over the range of 2.00–300.00 V)
Slip Frequency Pickup Range:	0.05 Hz–0.50 Hz
Slip Frequency Pickup Accuracy:	±0.02 Hz
Phase Angle Range:	0°–80°
Phase Angle Accuracy:	±4°

Station Battery Voltage Monitor

Operating Range:	0–350 Vdc (300 Vdc for UL purposes)
Pickup Range:	20.00–300.00 Vdc
Pickup Accuracy:	±2% of setting plus ±2 Vdc

Timers

Setting Range:	Various
Accuracy:	±0.5% of setting plus ±1/4 cycle

Metering Accuracy

Accuracies are specified at 20°C, nominal frequency, ac currents within (0.2–20.0) • I_{NOM} A secondary, and ac voltages within 50–250 V secondary unless otherwise noted.

Phase Currents

Magnitude Accuracy:	±1.0% (I_{NOM} = 1 A or 5 A)
Phase Accuracy:	±1.0° (I_{NOM} = 5 A), ±1.0° at 0.5–20.0 times I_{NOM} (I_{NOM} = 1 A), ±2.5° at 0.2–0.5 times I_{NOM} (I_{NOM} = 1 A)
Differential Quantities:	±5% of reading plus ±0.1 A (5 A nominal), ±0.02 A (1 A nominal)
Current Harmonics:	±5% of reading plus ±0.1 A (5 A nominal), ±0.02 A (1 A nominal)
I1 Positive-Sequence Current:	±2% of reading
IG (Residual Current):	±2% of reading, ±2° (±5.0° at 0.2–0.5 A for relays with I_{NOM} = 1 A)
IN (Neutral Current):	±1% of reading, ±1° (±2.5° at 0.2–0.5 A for relays with I_{NOM} = 1 A)
3I2 Negative-Sequence Current:	±2% of reading
System Frequency:	±0.01 Hz of reading for frequencies within 15–70 Hz (requires ac voltage inputs, V1 > 60 V)
Line-to-Line Voltages:	±1% of reading, ±1° for voltages within 24–264 V
Line-to-Ground Voltages:	±1% of reading, ±1° for voltages within 24–264 V
Voltage Harmonics:	±5% of reading plus ±0.5 V
V1 Positive-Sequence Voltage:	±2% of reading for voltages within 24–264 V
3V2 Negative-Sequence Voltage:	±2% of reading for voltages within 24–264 V
Real Three-Phase Power (kW):	±3% of reading for 0.10 < pf < 1.00
Reactive Three-Phase Power (kVAR):	±3% of reading for 0.00 < pf < 0.90
Apparent Three-Phase Power (kVA):	±3% of reading
Power Factor:	±2% of reading for 0.86 ≤ pf ≤ 1
RTD Temperatures:	±2°C

Synchrophasor Accuracy

Maximum Message Rate

Nominal 60 Hz System:	60 messages per second
Nominal 50 Hz System:	50 messages per second

The following are the accuracy specifications for voltages and currents for the SEL-787-3E and SEL-787-3S models. Note that the SEL-787-4X model does not track frequency, so the accuracy specifications are only applicable when the applied signal frequency equals FNOM.

Accuracy for Voltages

Level 1 compliant as specified in IEEE C37.118 under the following conditions for the specified range.

Conditions

- At maximum message rate
- When phasor has the same frequency as the positive-sequence voltage
- Frequency-based phasor compensation is enabled (PHCOMP := Y)
- The narrow bandwidth filter is selected (PMAPP := N)

Range

Frequency:	±5.0 Hz of nominal (50 or 60 Hz)
Magnitude:	30 V–250 V
Phase Angle:	–179.99° to 180°
Out-of-Band Interfering Frequency (Fs):	10 Hz ≤ Fs ≤ (2 • FNOM)

Accuracy for Currents

Level 1 compliant as specified in IEEE C37.118 under the following conditions for the specified range.

Conditions

- At maximum message rate
- When phasor has the same frequency as the positive-sequence voltage
- Frequency-based phasor compensation is enabled (PHCOMP := Y)
- The narrow bandwidth filter is selected (PMAPP := N)

Range

Frequency:	±5.0 Hz of nominal (50 or 60 Hz)
Magnitude:	(0.4–2) • I_{NOM} (I_{NOM} = 1 A or 5 A)
Phase Angle:	–179.99° to 180°
Out-of-Band Interfering Frequency (Fs):	10 Hz ≤ Fs ≤ (2 • FNOM)

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Section 2
Installation

Overview

The first steps in applying the SEL-787 Transformer Protection Relay are installing and connecting the relay. This section describes common installation features and requirements.

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

This section contains drawings of typical ac and dc connections to the SEL-787. Use these drawings as a starting point for planning your particular relay application.

The instructions for using the versatile front-panel custom label option are available on the SEL-787 product page on the SEL website. This allows you to use SELOGIC control equations and slide-in configurable front-panel labels to change the function and identification of target LEDs.

Relay Placement

Proper placement of the SEL-787 helps to ensure years of trouble-free protection. Use the following guidelines for proper physical installation of the SEL-787.

Physical Location

The SEL-787 is EN 61010-1 certified at Installation/Overvoltage Category II and Pollution Degree 2. This allows mounting of the relay in a sheltered indoor environment that does not exceed the temperature and humidity ratings for the relay. The SEL-787 is required to be mounted in an indoor or outdoor (extended) locked enclosure that provides a degree of protection to personnel against access to hazardous parts. In either environment, the relay shall be protected from direct sunlight, precipitation, and full wind pressure.

You can place the relay in extreme temperature and humidity locations. (See *Operating Temperature* and *Operating Environment on page 1.15*.) For EN 61010-1 certification, the SEL-787 rating is 2000 m (6562 ft) above mean sea level.

To comply with the requirements of the European ATEX standard for hazardous locations, the SEL-787 shall be installed in an ATEX-certified enclosure with a tool-removable door or cover that provides a degree of protection not less than IP54, in accordance with EN 60079-0. The enclosure shall be limited to the surrounding air temperature range of –20°C ≤ Ta ≤ +50°C. The enclosure should be certified to these requirements or be tested for compliance as part of the complete assembly. The enclosure must be marked “WARNING—Do not open when an explosive atmosphere is present." In North America, the relay is approved for Hazardous Locations Class I, Division 2, Groups A, B, C, and D, and temperature class T3C with a maximum surrounding air temperature of 50°C.

Relay Mounting

To flush mount the SEL-787 in a panel, cut a rectangular hole with the dimensions shown in *Figure 2.1*. Use the supplied front-panel gasket for protection against dust and water ingress into the panel. The relay is rated IP65 when the two-line display model is enclosed in a panel and rated IP54 when the touchscreen display model is enclosed in a panel.

For extremely dusty environments, use the optional IP50-rated terminal dust-protection assembly (protection against solid foreign objects only) (SEL Part #915900170). The 10°C-temperature derating applies to the temperature specifications of the relay.

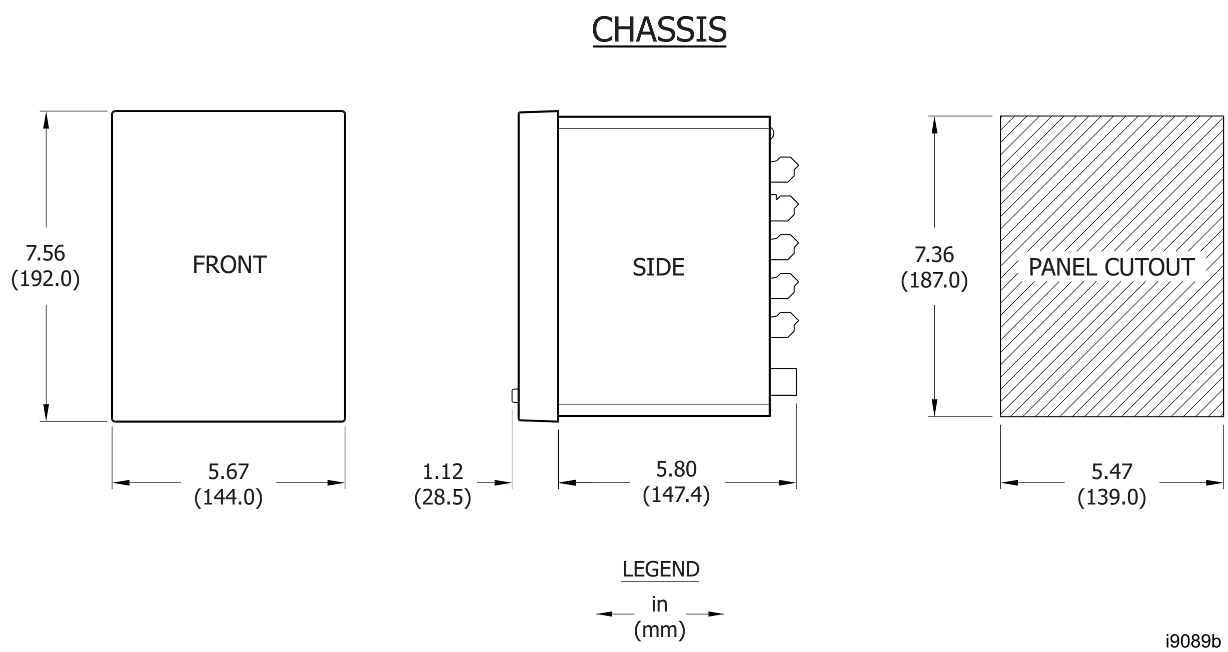


Figure 2.1 Relay Panel-Mount Dimensions

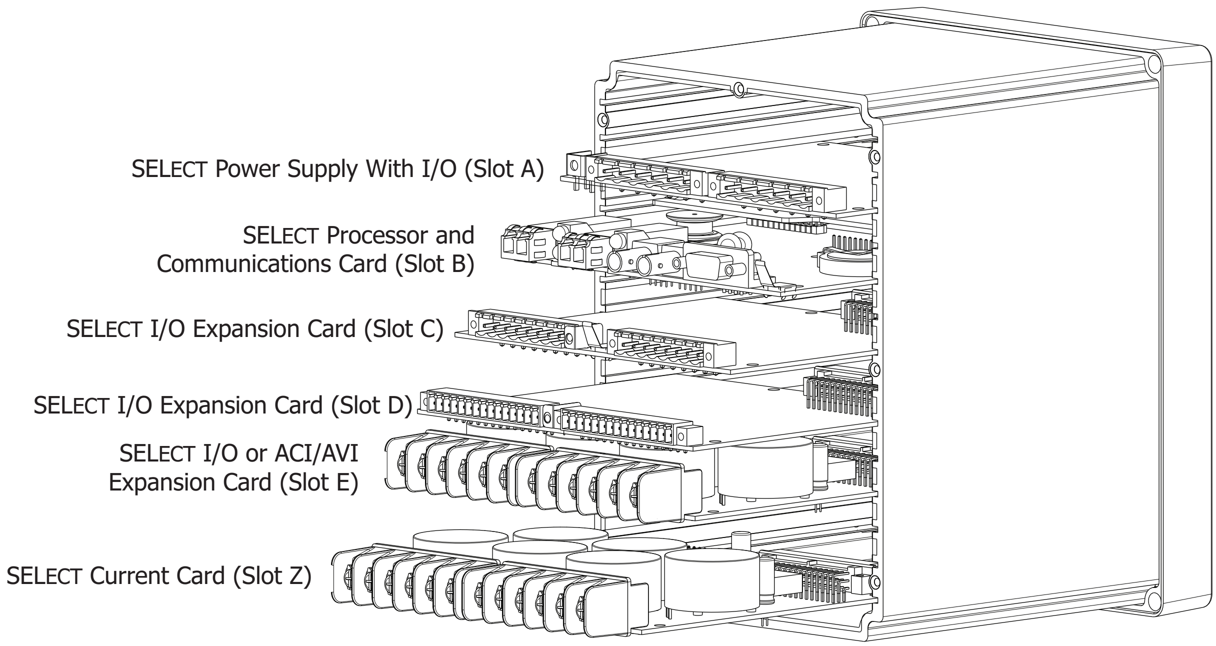
Refer to *Section 1: Introduction and Specifications*, *Models, Options, and Accessories* for information on mounting accessories.

I/O Configuration

Your SEL-787 offers flexibility in tailoring I/O to your specific application. In total, the SEL-787 has six rear-panel slots, labeled as Slots **A**, **B**, **C**, **D**, **E**, and **Z**. Slots **A**, **B**, and **Z** are base unit slots, each associated with a specific function. Optional digital and analog I/O, communications, RTD, and current/voltage cards are available for the SEL-787. *Figure 2.2* shows the slot allocations for the cards.

The SEL-787 comes with an orange Euro connector on the Slot A card for the 24–48 Vdc low-voltage power supply and C, D, or E slots with the 24–48 Vdc/Vac digital input options. Relays manufactured after May 18, 2022, will be provided with an orange Euro connector for the low-voltage power supply and digital inputs. Refer to *Figure 2.15* and *Figure 2.16* for orange Euro connector examples.

Because installations differ substantially, the SEL-787 offers a variety of card configurations to provide options for the many diverse applications. Choose the combination of option cards most suited for your application from the following selection.



	Rear-Panel Slot					
	A	B	C	D	E	Z
Software Reference	1 (e.g., OUT101)		3 (e.g., IN301)	4 (e.g., OUT401)	5 (e.g., 3 ACI/ 4 AVI)	
Description	Power supply and I/O card[a]	CPU/comm. card[b]	Comm. or input/ output[c] card	Input/output[c] or RTD card	Current/voltage card in base unit	Current card in base unit
Card Type						
SELECT EIA-232/485			●	—	—	—
SELECT DeviceNet			●	—	—	—
SELECT 3 DI/4 DO/1 AO (one card per relay)			●	●	●	—
SELECT 4 DI/4 DO			●	●	●	—
SELECT 4 DI/3 DO (2 Form C, 1 Form B)			●	●	●	—
SELECT 8 DI			●	●	●	—
SELECT 14 DI			●	●	●	—
SELECT 8 DO			●	●	●	—
SELECT 4 AI/4 AO (one card per relay)			●	●	●	—
SELECT 10 RTD			—	●	—	—
SELECT 6 ACI (Slot E)						
(1 A Winding 3, 1 A Winding 4) (MOT...4X...A1...)			—	—	●	—
(1 A Winding 3, 5 A Winding 4) (MOT...4X...A2...)			—	—	●	—
(5 A Winding 3, 5 A Winding 4) (MOT...4X...A5...)			—	—	●	—
(LEA Windings 3 and 4) (MOT...4X...L0...)			—	—	●	—

	Rear-Panel Slot					
	A	B	C	D	E	Z
Software Reference	1 (e.g., OUT101)		3 (e.g., IN301)	4 (e.g., OUT401)	5 (e.g., 3 ACI/ 4 AVI)	
Description	Power supply and I/O card[a]	CPU/comm. card[b]	Comm. or input/ output[c] card	Input/output[c] or RTD card	Current/voltage card in base unit	Current card in base unit
Card Type						
SELECT 4 ACI/3 AVI						
(1 A neutral, 1 A Winding 3) (MOT...3E...72...)			—	—	●	—
(5 A neutral, 5 A Winding 3) (MOT...3E...76...)			—	—	●	—
(1 A neutral, 5 A Winding 3) (MOT...3E...73...)			—	—	●	—
(5 A neutral, 1 A Winding 3) (MOT...3E...77...)			—	—	●	—
(LEA neutral, LEA Winding 3) (LEA Voltages) (MOT...3E...L2...)			—	—	●	—
SELECT 3 ACI/4 AVI						
(1 A Winding 3) (MOT...3S...71...)			—	—	●	—
(5 A Winding 3) (MOT...3S...75...)			—	—	●	—
(LEA Winding 3) (LEA Voltages) (MOT...3S...L1...)			—	—	●	—
SELECT 1 ACI/3 AVI						
(1 A neutral) (MOT...2E...78...)			—	—	●	—
(5 A neutral) (MOT...2E...79...)			—	—	●	—
(LEA Neutral) (LEA Voltages) (MOT...2E...L8...)			—	—	●	—
SELECT 1 ACI						
(1 A neutral) (MOT...21...A6...)			—	—	●	—
(5 A neutral) (MOT...21...A7...)			—	—	●	—
(LEA Neutral) (MOT...21...L6...)			—	—	●	—
SELECT 6 ACI (Slot Z)						
(1 A Winding 1, 1 A Winding 2) (MOT...81...)			—	—	—	●
(1 A Winding 1, 5 A Winding 2) (MOT...82...)			—	—	—	●
(5 A Winding 1, 5 A Winding 2) (MOT...85...)			—	—	—	●
(LEA Windings 1 and 2) (MOT...L0...)			—	—	—	●

[a] Power supply, two inputs, and three outputs.
[b] IRIG-B, EIA-232/485, fiber-optic serial and/or Ethernet ports.
The IRIG-B input option is available on terminals B01, B02 for all models except models with fiber-optic Ethernet port (P1) and dual copper Ethernet port (P1). IRIG-B is also supported via fiber-optic serial port (PORT 2) and rear-panel EIA-232 serial port (PORT 3). You can use only one input at a time.
[c] Digital or analog.

Figure 2.2 Slot Allocations for Different Cards

Power Supply Card PSIO/2 DI/3 DO (Slot A)

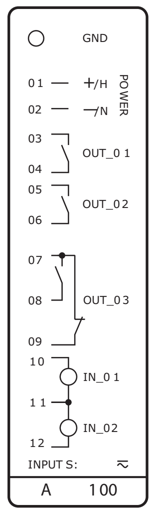
Select the appropriate power supply option for the application:

- High Voltage: 110–240 Vac, 110–250 Vdc, 50/60 Hz
- Low Voltage: 24–48 Vdc

Select the appropriate digital input voltage option: 125 Vdc/Vac, 24 Vdc/Vac, 48 Vdc/Vac, 110 Vdc/Vac, 220 Vdc/Vac, or 250 Vdc/Vac.

This card is supported in Slot A of the SEL-787 Relay. It has two digital inputs and three digital outputs (two normally open Form A contact outputs and one Form C output). *Table 2.1* shows the terminal designation for the PSIO/2 DI/3 DO card.

Table 2.1 Power Supply Inputs (PSIO/2 DI/3 DO) Card Terminal Designations

Side-Panel Connections Label	Terminal Number	Description
	⏚	Ground connection
	A01, A02	Power supply input terminals
	A03, A04	OUT101, driven by OUT101 SELOGIC control equation
	A05, A06	OUT102, driven by OUT102 SELOGIC control equation
	A07, A08, A09	OUT103, driven by OUT103 SELOGIC control equation
	A10, A11	IN101, drives IN101 element
	A12, A11	IN102, drives IN102 element

Communications Ports (Slot B)

Select the communications ports necessary for your application from the options shown in *Table 2.2*.

Table 2.2 Communications Ports

Port	Location	Feature	Description
F	Front Panel	Standard	Nonisolated EIA-232 serial port
1	Rear Panel	Optional	(Single/Dual) Isolated 10/100BASE-T Ethernet copper port or 100BASE-FX Ethernet fiber-optic port
2	Rear Panel	Standard	Isolated multimode fiber-optic serial port with ST connectors (with IRIG-B)
3	Rear Panel	Standard	Either nonisolated EIA-232 (with IRIG-B) or isolated EIA-485 serial port

PORT F supports the following protocols:

- SELBOOT
- Modbus RTU Slave
- SEL ASCII and Compressed ASCII
- Event Messenger
- IEEE C37.118 (Synchrophasor Data)

PORT 1 (Ethernet) supports the following protocols:

- Modbus TCP/IP
- DNP3 LAN/WAN
- IEC 61850
- EtherNet/IP
- Simple Network Time Protocol (SNTP)
- IEEE 1588-2008 firmware-based Precision Time Protocol (PTP)
- Parallel Redundancy Protocol (PRP)
- Rapid Spanning Tree Protocol (RSTP)
- FTP
- Telnet
- IEEE C37.118 (Synchrophasor Data)

PORT 2 and **PORT 3** support the following protocols:

- Modbus RTU Slave
- SEL ASCII and Compressed ASCII
- SEL Fast Meter
- SEL Fast Operate
- SEL Fast SER
- SEL Fast Message Unsolicited Write
- SEL MIRRORED BITS (MBA, MBB, MB8A, MB8B, MBTA, MBTB)
- Event Messenger
- DNP3 Level 2 Outstation
- IEEE C37.118 (Synchrophasor Data)
- IEC 60870-5-103

Communications Card (Slot C)

NOTE: After any change, be sure to thoroughly test the settings.

Either the DeviceNet (see *Appendix I: DeviceNet Communications*) or the EIA-232/EIA-485 communications card is supported in Slot **C**. The EIA-232/EIA-485 card provides one serial port with one of the following two serial port interfaces:

- **Port 4A**, an isolated EIA-485 serial port interface
- **Port 4C**, nonisolated EIA-232 serial port interface, supporting the +5 Vdc interface

Select either EIA-232 or EIA-485 functionality using the **Port 4** Setting COMM Interface. *Table 2.3* shows the port number, interface, and type of connector for the two protocols.

Table 2.3 Communications Card Interfaces and Connectors

Port	Interface	Connectors
4A	EIA-485	5-pin Euro
4C	EIA-232	D-sub

The communications card supports all of the following protocols:

- Modbus RTU Slave
- SEL ASCII and Compressed ASCII
- SEL Fast Meter
- SEL Fast Operate
- SEL Fast SER
- SEL Fast Message Unsolicited Write
- SEL Settings File Transfer
- SEL MIRRORED BITS (MBA, MBB, MB8A, MB8B, MBTB, MBTA)
- Event Messenger
- DNP3 Level 2 Outstation
- IEEE C37.118 (Synchrophasor Data)
- IEC 60870-5-103

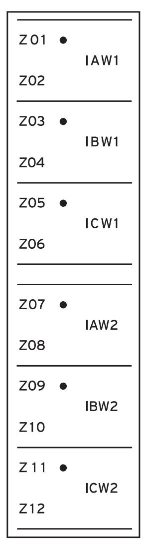
Current Card (Slot Z, 6 ACI)

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

Supported in Slot Z, this card provides Winding 1 and Winding 2 current inputs for three-phase CTs. With this card installed, the SEL-787 samples the currents 32 times per cycle. You can order the following secondary current ratings:

- 1 A Winding 1, 1 A Winding 2 (MOT ...x81x...)
- 1 A Winding 1, 5 A Winding 2 (MOT ...x82x...)
- 5 A Winding 1, 5 A Winding 2 (MOT ...x85x...)

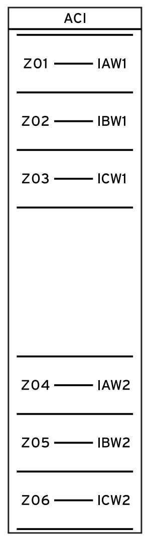
Table 2.4 Slot Z Current Inputs (6 ACI) Card Inputs Terminal Designations

Side-Panel Connections Label	Terminal Number	Description
	Z01, Z02	IAW1, Phase A Winding 1 current input
	Z03, Z04	IBW1, Phase B Winding 1 current input
	Z05, Z06	ICW1, Phase C Winding 1 current input
	Z07, Z08	IAW2, Phase A Winding 2 current input
	Z09, Z10	IBW2, Phase B Winding 2 current input
	Z11, Z12	ICW2, Phase C Winding 2 current input

Supported in Slot **Z**, this card provides Winding 1 and Winding 2 current inputs for three-phase Rogowski coil or LPCT inputs. You can order the LEA inputs with the following MOT:

➤ LEA Windings 1 and 2 (MOT ...xL0x...)

Table 2.5 Slot Z Current Inputs (6 ACI) Card Inputs Terminal Designations

Side-Panel Connections Label	Terminal Number	Description
	**Z01**	IAW1, Phase A Winding 1 current input
	Z02	IBW1, Phase B Winding 1 current input
	Z03	ICW1, Phase C Winding 1 current input
	Z04	IAW2, Phase A Winding 2 current input
	Z05	IBW2, Phase B Winding 2 current input
	Z07	ICW2, Phase C Winding 2 current input

Current Card (Slot E, 6 ACI)

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

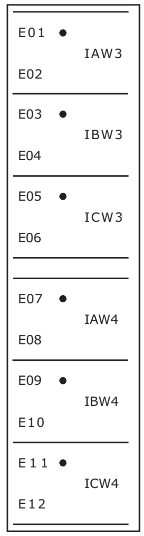
Supported in Slot **E**, this card provides Winding 3 and Winding 4 current inputs for three-phase CTs. With this card installed, the SEL-787 samples the currents 32 times per cycle. You can order the following secondary current ratings:

➤ 1 A Winding 3, 1 A Winding 4 (MOT ...xA1x...)

➤ 1 A Winding 3, 5 A Winding 4 (MOT ...xA2x...)

➤ 5 A Winding 3, 5 A Winding 4 (MOT ...xA5x...)

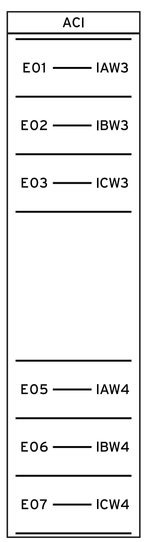
Table 2.6 Slot E Current Inputs (6 ACI) Card Inputs Terminal Designations

Side-Panel Connections Label	Terminal Number	Description
	E01, E02	IAW3, Phase A Winding 3 current input
	E03, E04	IBW3, Phase B Winding 3 current input
	E05, E06	ICW3, Phase C Winding 3 current input
	E07, E08	IAW4, Phase A Winding 4 current input
	E09, E10	IBW4, Phase B Winding 4 current input
	E11, E12	ICW4, Phase C Winding 4 current input

Supported in Slot **E**, this card provides Winding 3 and Winding 4 current inputs for three-phase Rogowski coil or LPCT inputs. You can order the LEA inputs with the following MOT:

➤ LEA Windings 3 and 4 (MOT ...xL0x...)

Table 2.7 Slot E Current Inputs (6 ACI) Card Inputs Terminal Designations

Side-Panel Connections Label	Terminal Number	Description
	E01	IAW3, Phase A Winding 3 current input
	E02	IBW3, Phase B Winding 3 current input
	E03	ICW3, Phase C Winding 3 current input
	E05	ICW3, Phase C Winding 3 current input
	E06	IAW4, Phase A Winding 4 current input
	E07	IBW4, Phase B Winding 4 current input

Current/Voltage Card (Slot E, 4 ACI/3 AVI)

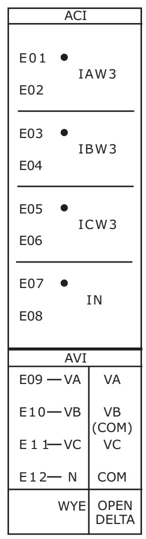
⚠WARNING
Before working on a CT circuit, first apply a short to the secondary winding of the CT.

⚠WARNING
Voltage measurement circuits have high input impedance and will respond to stray signals when left open (disconnected). Always isolate the relay control circuit before opening the voltage input test switches or performing work on the voltage circuit.

Supported in Slot E only, this card provides Winding 3 current inputs for three-phase CTs, neutral current CT input, and voltage inputs for three-phase (wye or delta) PTs. With this card installed, the SEL-787 samples the currents/voltages 32 times per cycle. You can order the following secondary current ratings:

- ➤ 1 A Winding 3, 1 A Neutral (MOT ...x72x...)
- ➤ 5 A Winding 3, 1 A Neutral (MOT ...x73x...)
- ➤ 5 A Winding 3, 5 A Neutral (MOT ...x76x...)
- ➤ 1 A Winding 3, 5 A Neutral (MOT ...x77x...)

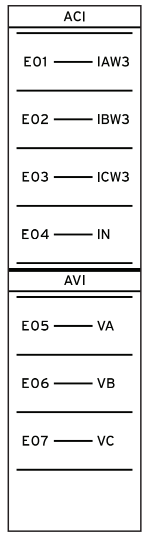
Table 2.8 Slot E Current/Voltage (4 ACI/3 AVI) Card Inputs Terminal Designations

Side-Panel Connections Label	Terminal Number	Description
	E01, E02	IAW3, Phase A Winding 3 current input
	E03, E04	IBW3, Phase B Winding 3 current input
	E05, E06	ICW3, Phase C Winding 3 current input
	E07, E08	IN, neutral current input
	E09	VA, Phase A voltage input
	E10	VB, Phase B voltage input
	E11	VC, Phase C voltage input
	E12	N, common connection for VA, VB, VC

Supported in Slot E, this card provides Winding 3 current inputs for three phase and neutral Rogowski coil or LPCT inputs and LEA voltage sensor inputs for three-phase PTs. You can order the LEA inputs with the following MOT:

- ➤ LEA Neutral, LEA Winding 3 (MOT ...x3Ex...xL2x...)

Table 2.9 Slot E Current/Voltage (4 ACI/3 AVI) LEA Card Inputs Terminal Designations

Side-Panel Connections Label	Terminal Number	Description
	E01	IAW3, Phase A Winding 3 current input
	E02	IBW3, Phase B Winding 3 current input
	E03	ICW3, Phase C Winding 3 current input
	E04	IN, neutral current input
	E05	VA, Phase A voltage input
	E06	VB, Phase B voltage input
	E07	VC, Phase C voltage input

Current/Voltage Card (Slot E, 3 ACI/4 AVI)

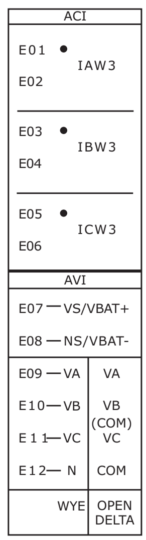
⚠WARNING
Before working on a CT circuit, first apply a short to the secondary winding of the CT.

⚠WARNING
Voltage measurement circuits have high input impedance and will respond to stray signals when left open (disconnected). Always isolate the relay control circuit before opening the voltage input test switches or performing work on the voltage circuit.

Supported in Slot E only, this card provides Winding 3 current inputs for three-phase CTs, voltage inputs for three-phase (wye or delta) PTs, and voltage input for synchronism check or station dc battery monitor. With this card installed, the SEL-787 samples the currents/voltages 32 times per cycle. You can order the following secondary current ratings:

- 1 A Winding 3 (MOT ...x71x...)
- 5 A Winding 3 (MOT ...x75x...)

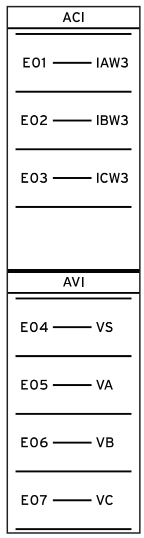
Table 2.10 Slot E Current/Voltage (3 ACI/4 AVI) Card Inputs Terminal Designations

Side-Panel Connections Label	Terminal Number	Description
	E01, E02	IAW3, Phase A Winding 3 current input
	E03, E04	IBW3, Phase B Winding 3 current input
	E05, E06	ICW3, Phase C Winding 3 current input
	E07	VS, synchronism-check voltage input or VBAT+, station dc battery input
	E08	NS, common connection for synchronism-check voltage input or VBAT–, station battery monitor input
	E09	VA, Phase A voltage input
	E10	VB, Phase B voltage input
	E11	VC, Phase C voltage input
	E12	N, common connection for VA, VB, VC

Supported in Slot **E**, this card provides Winding 3 current inputs for three-phase Rogowski coil or LPCT inputs and LEA voltage sensor inputs for three-phase PTs and synchronism check. You can order the LEA inputs with the following MOT:

- ➤ LEA Winding 3, LEA Voltages (MOT ...x3Sx...xL1x...)

Table 2.11 Slot E Current/Voltage (3 ACI/4 AVI) Card Inputs Terminal Designations

Side-Panel Connections Label	Terminal Number	Description
	**E01**	IAW3, Phase A Winding 3 current input
	E02	IBW3, Phase B Winding 3 current input
	E03	ICW3, Phase C Winding 3 current input
	E04	VS, synchronism-check voltage input
	E05	VA, Phase A voltage input
	E06	VB, Phase B voltage input
	E07	VC, Phase C voltage input

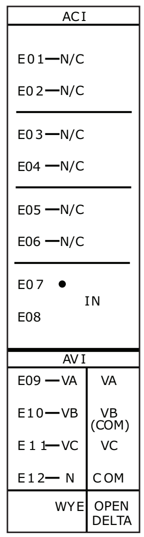
Current/Voltage Card (Slot E, 1 ACI/3 AVI)

⚠WARNING
Voltage measurement circuits have high input impedance and will respond to stray signals when left open (disconnected). Always isolate the relay control circuit before opening the voltage input test switches or performing work on the voltage circuit.

Supported in Slot E only, this card provides neutral current CT input and voltage inputs for three-phase (wye or delta) PTs. With this card installed, the SEL-787 samples the neutral current/voltages 32 times per cycle. You can order the following secondary current ratings:

- 1 A Neutral (MOT...x78x...)
- 5 A Neutral (MOT...x79x...)

Table 2.12 Slot E Current/Voltage (1 ACI/3 AVI) Card Inputs Terminal Designations

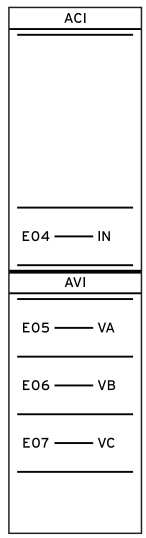


Side-Panel Connections Label	Terminal Number	Description
	E07, E08	IN, Neutral current input
	E09	VA, Phase A voltage input
	E10	VB, Phase B voltage input
	E11	VC, Phase C voltage input
	E12	N, Common connection for VA, VB, VC

Supported in Slot E, this card provides neutral Rogowski coil or LPCT current input and LEA voltage sensor inputs for three-phase PTs. You can order the LEA inputs with the following MOT:

- ➤ LEA Neutral, LEA Voltages (MOT ...x2Ex...xL8x...)

Table 2.13 Slot E Current/Voltage (1 ACI/3 AVI) Card Inputs Terminal Designations

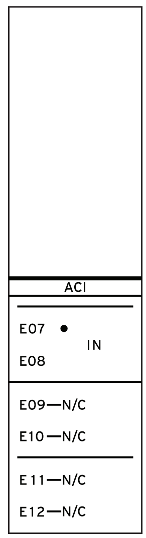
<table>
<tr><th>Side-Panel Connections Label</th><th>Terminal Number</th><th>Description</th></tr>
<tr><td rowspan="4">
</td><td>E04</td><td>IN, Neutral current input</td></tr>
<tr><td>E05</td><td>VA, Phase A voltage input</td></tr>
<tr><td>E06</td><td>VB, Phase B voltage input</td></tr>
<tr><td>E07</td><td>VC, Phase C voltage input</td></tr>
</table>

Current Card (Slot E, 1 ACI)

Supported in Slot **E** only, this card provides neutral current CT input. With this card installed, the SEL-787 samples the neutral current 32 times per cycle. You can order the following secondary current ratings:

- 1 A Neutral (MOT...xA6x...)
- 5 A Neutral (MOT...xA7x...)

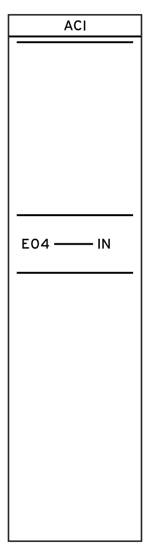
Table 2.14 Slot E Current (1 ACI) Card Input Terminal Designation

Side-Panel Connections Label	Terminal Number	Description
	E07, E08	IN, Neutral current input

Supported in Slot **E**, this card provides neutral Rogowski coil or LPCT current input. You can order the LEA input with the following MOT:

- 1 ACI (MOT...xL6x...)

Table 2.15 Slot E Current (1 ACI) Card Input Terminal Designation

Side-Panel Connections Label	Terminal Number	Description
	E04	IN, Neutral current input

Analog Input/Output Card (4 AI/4 AO)

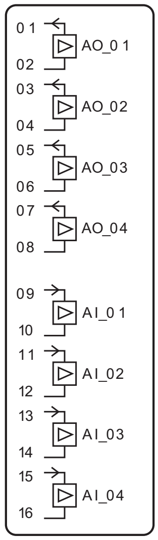
NOTE: Analog inputs cannot provide loop power. Each analog output is self-powered and has an isolated power supply.

NOTE: Analog outputs are isolated from each other and from the chassis ground.

NOTE: The requirements of IEC 60255-26 and IEC 60255-27 are met for connection lengths less than 10 meters for analog inputs and outputs.

Supported in only one of the nonbase unit Slots **C**, **D**, or **E**, this card has four analog inputs and four analog outputs. *Table 2.16* shows the terminal designations.

Table 2.16 Four Analog Inputs/Four Analog Outputs (4 AI/4 AO) Card Terminal Designations



Side-Panel Connections Label	Terminal Number	Description[a]
	01, 02	AO*x*01, Analog Output *x*01
	03, 04	AO*x*02, Analog Output *x*02
	05, 06	AO*x*03, Analog Output *x*03
	07, 08	AO*x*04, Analog Output *x*04
	09, 10	AI*x*01, Transducer Input *x*01
	11, 12	AI*x*02, Transducer Input *x*02
	13, 14	AI*x*03, Transducer Input *x*03
	15, 16	AI*x*04, Transducer Input *x*04

[a] x = 3, 4, or 5 if the card is installed in Slot C, D, or E, respectively.

I/O Card (3 DI/4 DO/1 AO)

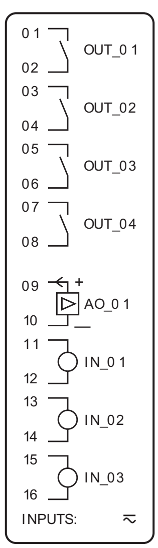
NOTE: All digital input and digital output (including hybrid high-speed, high-current interrupting) connections are polarity neutral.

NOTE: Analog output is self powered and has an isolated power supply.

NOTE: The requirements of IEC 60255-26 and IEC 60255-27 are met for connection lengths less than 10 meters for analog inputs and outputs.

Supported in only one of the nonbase unit Slots **C**, **D**, or **E**, this card has three digital inputs, four digital outputs (normally open), and one analog output. *Table 2.17* shows the terminal designations.

Table 2.17 Three Digital Input/Four Digital Outputs/One Analog Output (3 DI/4 DO/1 AO) Card Terminal Designations



Side-Panel Connections Label	Terminal Number	Description[a]
	01, 02	OUT*x*01, driven by OUT*x*01 SELogic control equation
	03, 04	OUT*x*02, driven by OUT*x*02 SELogic control equation
	05, 06	OUT*x*03, driven by OUT*x*03 SELogic control equation
	07, 08	OUT*x*04, driven by OUT*x*04 SELogic control equation
	09, 10	AO*x*01, Analog Output Number 1
	11, 12	IN*x*01, drives IN*x*01 element
	13, 14	IN*x*02, drives IN*x*02 element
	15, 16	IN*x*03, drives IN*x*03 element

[a] x = 3, 4, or 5 if the card is installed in Slot C, D, or E, respectively.

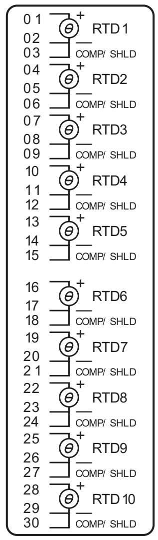
RTD Card (10 RTD)

Supported in Slot **D** only, this card has 10 three-wire RTD inputs. *Table 2.18* shows the terminal designations.

NOTE: All comp/shield terminals are internally connected to relay chassis and ground.

NOTE: Use passive resistors to simulate temperatures to test the RTD inputs. Use of an RTD simulator can damage the relay.

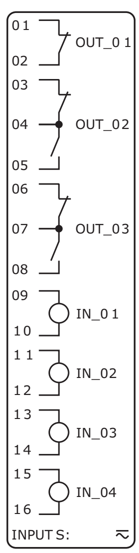
Table 2.18 RTD (10 RTD) Card Terminal Designations

Side-Panel Connections Label	Terminal Number	Description
	01	RTD01 (+)
	02	RTD01 (–)
	03	RTD01 Comp/Shield
	04	RTD02 (+)
	05	RTD02 (–)
	06	RTD02 Comp/Shield
	07	RTD03 (+)
	08	RTD03 (–)
	09	RTD03 Comp/Shield
	•	•
	•	•
	•	•
	28	RTD10 (+)
	29	RTD10 (–)
	30	RTD10 Comp/Shield

I/O Card (4 DI/3 DO)

Supported in nonbase unit Slots **C**, **D**, or **E**, this card has four digital inputs, one Form B digital output (normally closed) and two Form C digital output contacts. *Table 2.19* shows the terminal designations.

Table 2.19 Four Digital Inputs/Three Digital Outputs (4 DI/3 DO) Card Terminal Designations

Side-Panel Connections Label	Terminal Number	Description[a]
	01, 02	OUT*x*01, driven by OUTx01 SELOGIC control equation
	03, 04, 05	OUT*x*02, driven by OUTx02 SELOGIC control equation
	06, 07, 08	OUT*x*03, driven by OUTx03 SELOGIC control equation
	09, 10	IN*x*01, drives IN*x*01 element
	11, 12	IN*x*02, drives IN*x*02 element
	13, 14	IN*x*03, drives IN*x*03 element
	15, 16	IN*x*04, drives IN*x*04 element

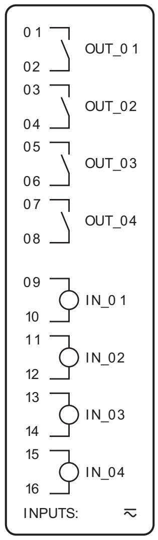
[a] x = 3, 4, or 5 if the card is installed in Slot C, D, or E, respectively.

I/O Card (4 DI/4 DO)

Supported in nonbase unit Slots **C**, **D**, or **E**, this card has four digital inputs and four digital outputs (all normally open). Optionally, the four outputs can be all fast hybrid (high-speed, high-current interrupting) outputs. *Table 2.20* shows the terminal designations.

NOTE: All digital inputs and digital outputs (including hybrid high-speed, high-current interrupting) connections are polarity neutral.

Table 2.20 Four Digital Inputs/Four Digital Outputs (4 DI/4 DO) Card Terminal Designations

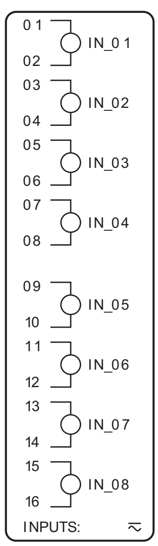
Side-Panel Connections Label	Terminal Number	Description[a]
	01, 02	OUT*x*01, driven by OUTx01 SELOGIC control equation
	03, 04	OUT*x*02, driven by OUTx02 SELOGIC control equation
	05, 06	OUT*x*03, driven by OUTx03 SELOGIC control equation
	07, 08	OUT*x*04, driven by OUTx04 SELOGIC control equation
	09, 10	IN*x*01, drives IN*x*01 element
	11, 12	IN*x*02, drives IN*x*02 element
	13, 14	IN*x*03, drives IN*x*03 element
	15, 16	IN*x*04, drives IN*x*04 element

[a] x = 3, 4, or 5 if the card is installed in Slot C, D, or E, respectively.

Input Card (8 DI)

Supported in nonbase unit Slots **C**, **D**, or **E**, this card has eight digital inputs. *Table 2.21* shows the terminal designations.

Table 2.21 Eight Digital Inputs (8 DI) Card Terminal Designations

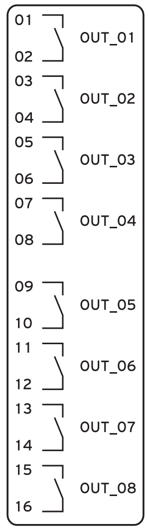
Side-Panel Connections Label	Terminal Number	Description[a]
	01, 02	IN*x*01, drives IN*x*01 element
	03, 04	IN*x*02, drives IN*x*02 element
	05, 06	IN*x*03, drives IN*x*03 element
	07, 08	IN*x*04, drives IN*x*04 element
	09, 10	IN*x*05, drives IN*x*05 element
	11, 12	IN*x*06, drives IN*x*06 element
	13, 14	IN*x*07, drives IN*x*07 element
	15, 16	IN*x*08, drives IN*x*08 element

[a] x = 3, 4, or 5 if the card is installed in Slot C, D, or E, respectively.

Output Card (8 DO)

Supported in nonbase unit Slots **C**, **D**, or **E**, this card has eight digital outputs. *Table 2.22* shows the terminal designations.

Table 2.22 Eight Digital Outputs (8 DO) Card Terminal Designations

Side-Panel Connections Label	Terminal Number	Description[a]
	01, 02	OUTx01, driven by OUTx01 SELogic control equation
	03, 04	OUTx02, driven by OUTx02 SELogic control equation
	05, 06	OUTx03, driven by OUTx03 SELogic control equation
	07, 08	OUTx04, driven by OUTx04 SELogic control equation
	09, 10	OUTx05, driven by OUTx05 SELogic control equation
	11, 12	OUTx06, driven by OUTx06 SELogic control equation
	13, 14	OUTx07, driven by OUTx07 SELogic control equation
	15, 16	OUTx08, driven by OUTx08 SELogic control equation

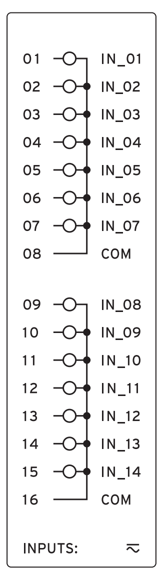
[a] x = 3, 4, or 5 if the card is installed in Slot C, D, or E, respectively.

The 8 DO card shown above is all Form A contacts. Refer to the SEL-787 Model Option Table for all the variants available (8A, 8B, 4A/4B, 2A/6B, 6A/2B).

Input Card (14 DI)

Supported in nonbase unit Slots **C**, **D**, or **E**, this card has fourteen digital inputs. *Table 2.23* shows the terminal designations.

Table 2.23 Fourteen Digital Inputs (14 DI) Card Terminal Designations

Side-Panel Connections Label	Terminal Number	Description[a]
	01	IN*x*01, drives IN*x*01 element
	02	IN*x*02, drives IN*x*02 element
	03	IN*x*03, drives IN*x*03 element
	04	IN*x*04, drives IN*x*04 element
	05	IN*x*05, drives IN*x*05 element
	06	IN*x*06, drives IN*x*06 element
	07	IN*x*07, drives IN*x*07 element
	08	COM
	09	IN*x*08, drives IN*x*08 element
	10	IN*x*09, drives IN*x*09 element
	11	IN*x*10, drives IN*x*10 element
	12	IN*x*11, drives IN*x*11 element
	13	IN*x*12, drives IN*x*12 element
	14	IN*x*13, drives IN*x*13 element
	15	IN*x*14, drives IN*x*14 element
	16	COM

[a] x = 3, 4, or 5 if the card is installed in Slot C, D, or E, respectively.

Card Configuration Procedure

Changing card positions or expanding on the initial number of cards requires no card programming; the relay detects the new hardware and updates the software accordingly (you still have to use the **SET** command to program the I/O settings).

The SEL-787 offers flexibility in tailoring I/O for your specific application. The SEL-787 has six rear-panel slots, labeled as Slots **A**, **B**, **C**, **D**, **E**, and **Z**. Slots **A**, **B**, and **Z** are base unit slots, each associated with a specific function. Optional digital/analog I/O cards are available for the SEL-787 in Slots **C**, **D**, and **E**. Optional communications cards are available only for Slot **C**, an RTD card is available only for Slot **D**, 1 A/5 A CT combinations for voltage/current cards are available only on Slot **E**, and current cards are available for Slots **E** and **Z**. *Figure 2.2* shows the slot allocations for the cards. Because installations differ substantially, the SEL-787 offers a variety of card configurations that provide options for an array of applications. Choose the combination of cards most suited for your application.

Swapping Optional I/O Cards

When an I/O card is moved from one slot to a different slot, the associated settings for the slot the card is moved from are lost. For example, if a 4 DI/4 DO card is installed in Slot **D**, the SELOGIC control equation settings OUT401–OUT404 are available. If OUT401 = IN101 AND 51P1T, and the card is moved to a different slot, then the OUT401 setting is lost. This is true for all the digital and analog I/O cards.

Adding Cards to Slots C, D, E, and Z

The SEL-787 Relay can be upgraded by adding as many as three cards.

Installation

⚠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.

NOTE: To replace the communications card in Slot C with a standard I/O card, remove the white, stick-on label on the back plate to see the correct slots for the selected I/O card.

Perform the following steps to install cards into Slots **C**, **D**, **E**, or **Z** of the base unit.

Step 1. Save the settings and event report data before installing the new card in the relay.

Step 2. Remove the power supply voltage from terminals **A01+** and **A02–** and remove the ground wire from the green ground screw.

Step 3. Disconnect all the connection plugs.

Step 4. Remove the eight screws on the rear and remove the rear cover.

Step 5. Remove the plastic filler plate covering the slot associated with the card being installed.

Step 6. Insert the card in the correct slot.

Make sure the contact fingers on the printed circuit board are bent at an approximate 130-degree angle relative to the board for proper electromagnetic interference protection.

Step 7. Before reattaching the rear cover, check for and remove any foreign material that may remain inside the SEL-787 case.

Step 8. Carefully reattach the rear cover.

Step 9. Reinstall the eight screws that secure the rear cover to the case.

Step 10. Apply power supply voltage to terminals **A01+** and **A02–**, and reconnect the ground wire to the green ground screw.

If you have a two-line display front panel, perform *Step 11* through *Step 19*; if you have a touchscreen display front panel, proceed to *Step 20*.

Step 11. If the card is in the proper slot, the front panel displays the following:

```
STATUS FAIL
X Card Failure
```

If you *do not* see this message and the **ENABLED** LED is turned on, the card was inserted into the wrong slot. Begin again at *Step 2*.

Step 12. Press the **ESC** pushbutton.

Step 13. Press the **Down Arrow** pushbutton until `STATUS` is highlighted.

Step 14. Press the **ENT** pushbutton.

The front panel displays the following:

```
STATUS
Relay Status
```

Step 15. Press the **ENT** pushbutton.

The front panel displays the following:

```
Serial Num
000000000000000000000000
```

Step 16. Press the **ENT** pushbutton.

The front panel displays the following:

```
Confirm Hardware
Config (Enter)
```

Step 17. Press the **ENT** pushbutton.

The front panel displays the following:

```
Accept New Config?
No Yes
```

Step 18. Select **Yes** and press the **ENT** pushbutton.

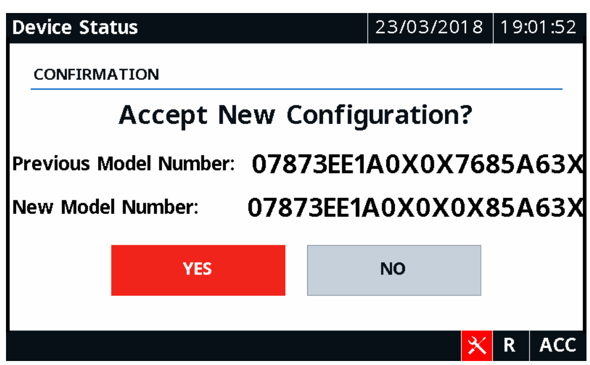
The front panel displays the following:

```
Config Accepted
Enter to Reboot
```

NOTE: If you are adding a 6 ACI, 4 ACI/3 AVI,3 ACI/4 AVI,1 ACI/3 AVI, or 1 ACI card in Slot E of the relay, perform the **R_S** command after accepting the new configuration.

Step 19. Press the **ENT** pushbutton and proceed to *Step 22*.

Step 20. Wait for the Device Status screen to appear, and then verify the new part number and tap **Yes** to confirm the new configuration.



Step 21. Tap **OK** on the notification screen to reboot the relay.

Step 22. Use the **PARTNO** command from Access Level C to enter the exact part number of the relay after the relay restarts and the **ENABLED** LED is turned on to indicate the card was installed correctly.

After reconfiguration, the relay updates the part number, except for the following indicated digits. These digits remain unchanged, i.e., these digits retain the same character as before the reconfiguration. Also, a communications card installed in Slot **C** is reflected as an empty slot in the part number. A regular 4 DI/4 DO card and a hybrid 4 DI/4 DO card have the same device ID. When interchanging these two cards, the part number for the respective slots should be updated manually. Use the **STATUS** command to view the part number.

```
PART NUM = 0 7 8 7 X X 1 A 6 X 3 A A 5 8 5 0 2 0 X
                       ↑ ↑   ↑   ↑   ↑           ↑
```

Step 23. Update the side-panel drawing with the drawing sticker provided in the option card kit. If necessary, replace the rear panel with the one applicable for the option card and attach the terminal-marking label provided with the card to the rear-panel cover. Also, contact SEL for an updated product serial number label with the updated part number.

Step 24. Reconnect all connection plugs, and add any additional wiring/ connectors required by the new card.

Slot B CPU Card Replacement

When replacing the Slot **B** card, do the following:

1. Ensure that the card has the latest firmware from the factory.
2. Review the firmware revision history for the changes that were made; note that new settings added, if any, might affect existing settings in the relay or its application.
3. Save all the settings and event reports before replacing the card.
4. If the IEC 61850 protocol option was used previously, verify that the IEC 61850 protocol is still operational after the replacement. If not, reenable it. Refer to *Protocol Verification for Relays With IEC 61850 Option* in *Appendix B: Firmware Upgrade Instructions*.

Perform the following steps to replace the existing CPU board with a new board:

Step 1. Turn off the power to the relay.

Step 2. Use a ground strap between yourself and the relay.

Step 3. Disconnect the terminal blocks and CT/PT wires.

Step 4. Remove the rear panel.

Step 5. Remove the main board from its slot and insert the new board.

Step 6. Attach the rear panel (new if applicable) and reconnect the terminal blocks and CT/PT wires.

Step 7. Apply new side stickers to the relay.

Step 8. Turn on the relay and log in via the terminal emulation software.

Step 9. Issue the **STA** command and accept the new configuration.

Step 10. From Access Level 2, type **CAL** to enter Access Level C.

Do not modify any settings other than those listed in this procedure.

The default password for Access Level C is CLARKE.

Step 11. From Access Level C, issue the **SET C** command.

Step 12. Update the serial number and part number to the appropriate values, type **END**, and then save the settings.

Step 13. Issue the **STA C** command to reboot the relay.

Step 14. Issue the **STA** command to verify that the serial number and part number of your relay are correct.

Slot A Power Supply Card

If you are replacing the power supply card, change the part number accordingly using the **PARTNO** command from Access Level C. Install new side stickers on the side of the relay.

Analog Input (AI) Voltage/Current Jumper Selection

Figure 2.3 shows the circuit board of an analog I/O board. Jumper *x* (*x* = 5–8) determines the nature of each channel. For a current channel, insert Jumper *x* in Position 1–2; for a voltage channel, insert Jumper *x* in Position 2–3.

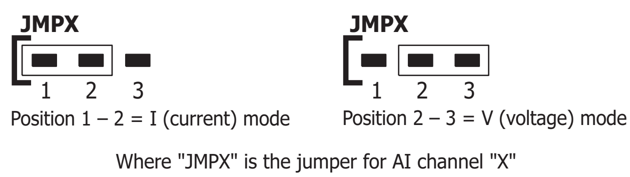


Figure 2.3 Circuit Board of Analog I/O Board, Showing Jumper Selection

Analog Output (AO) Voltage/Current Jumper Selection

Figure 2.4 shows the locations of JMP1 through JMP4 on an analog output board. You can select each of the four analog output channels as either a current analog output or a voltage analog output.

NOTE: Analog inputs cannot provide loop power. Each analog output is self-powered and has an isolated power supply.

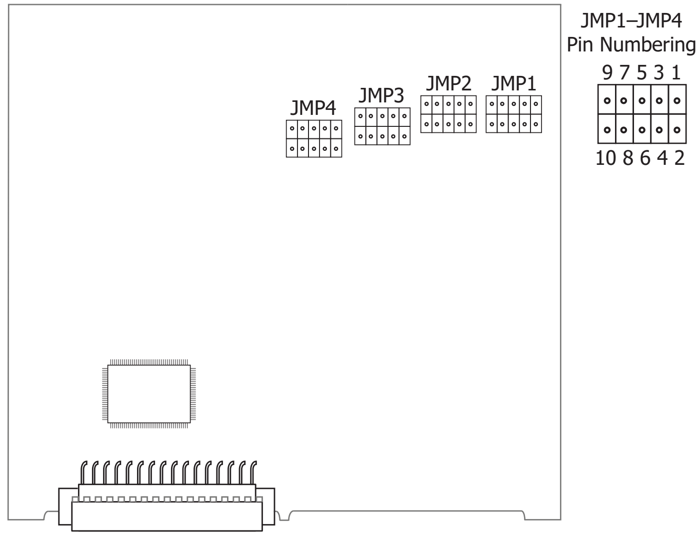


Figure 2.4 JMP1 Through JMP4 Locations on 4 AI/4 AO Board

You need to insert three jumpers for a current analog output selection and two jumpers for a voltage analog output selection. For a current analog output selection, insert a jumper between Pins 1 and 2, Pins 5 and 6, and Pins 9 and 10. For a voltage analog output selection, insert a jumper between Pins 3 and 4, and Pins 7 and 8. *Figure 2.5* shows JMP4 selected as a current analog output. The current analog output selection is the default setting for JMP1 through JMP4. *Figure 2.6* shows JMP1 selected as a voltage analog output.

NOTE: There is no jumper between Pins 5 and 6 for a voltage analog output selection.

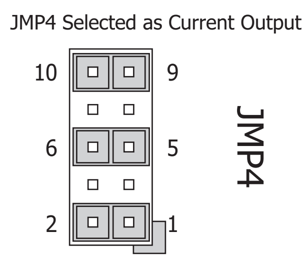


Figure 2.5 Current Output Jumpers

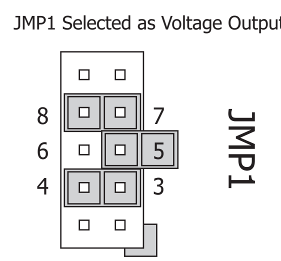


Figure 2.6 Voltage Output Jumpers

Password, Breaker Control, and SELBOOT Jumper Selection

Figure 2.7 shows the major components of the Slot B card in the base unit. Notice the three sets of pins labeled A, B, and C.

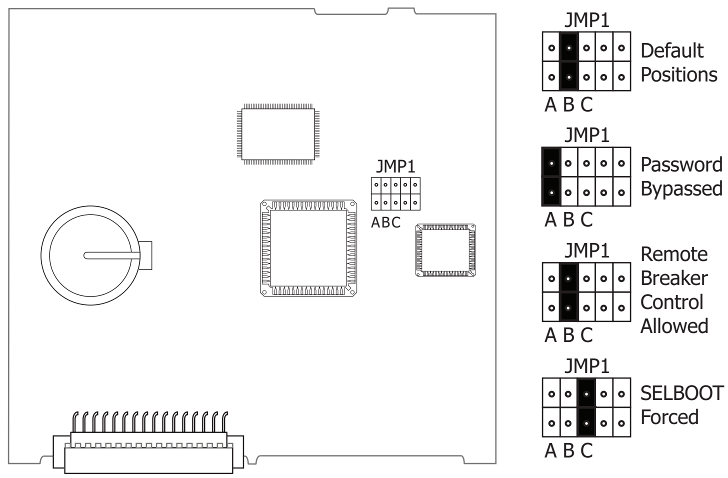


Figure 2.7 Pins for Password Jumper, Breaker Control Jumper, and SELBOOT Jumper

Pins labeled A bypass the password requirement, pins labeled B enable breaker control, and pins labeled C force the relay to the SEL operating system called SELBOOT. In the unlikely event that the SEL-787 experiences an internal failure, communication with the relay may be compromised. Forcing the relay to SELBOOT provides you with a way to download new firmware. To force the relay to SELBOOT, place the jumper in Position C, as shown in *Figure 2.7* (SELBOOT Forced). After the relay is forced to SELBOOT, you can only communicate with it via the front-panel port.

To gain access to the Level 1, 2, or C command levels without passwords, position the jumper in Position A, as shown in *Figure 2.7* (Password Bypassed). Note that you can only access command levels without passwords to the access level set for the MAXACC setting for the port through which you are communicating. Although you gain access to Level 2 without a password, the alarm contact still closes momentarily when accessing Level 2 and Level C. See *Table 2.24* for the functions of the three sets of pins and their jumper default positions.

Table 2.24 Jumper Functions and Default Positions

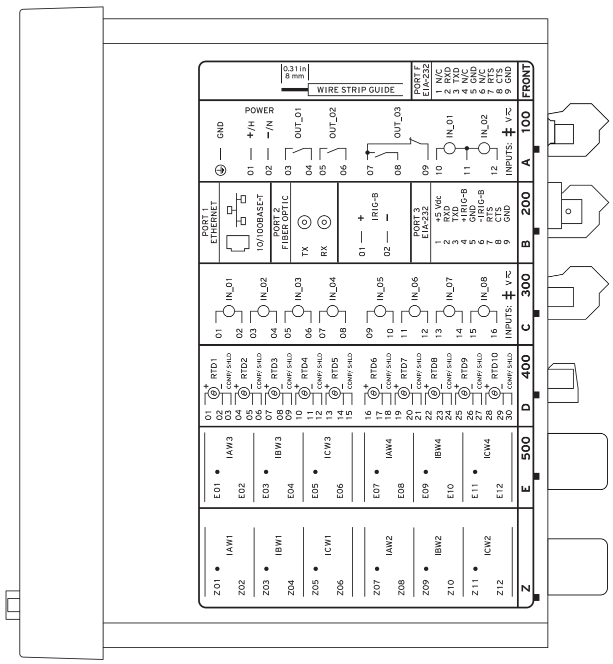
Pins	Jumper Default Position	Description
A	Not bypassed (requires password)	Password bypass
B	On (breaker control enabled)	Enable breaker control[a,b]
C	Not bypassed (not forced SELBOOT)	Forced SELBOOT

[a] Enable/disable serial port, front panel, and Fast Operate commands for the breaker control. This jumper position affects the breaker control using the OPEN or CLOSE commands and output contact control using the PULSE command via the serial port, the front-panel menu-driven user interface, or the communications protocols. The jumper position does not affect the operation of the local bits, the remote bits, or the front-panel programmable pushbuttons.
[b] Devices shipped prior to December 3, 2019 did not have the breaker control jumper installed by default.

Relay Connections

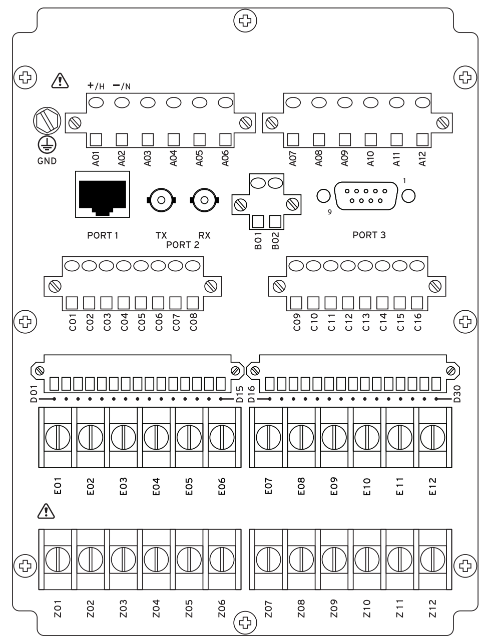
Side-Panel and Rear-Panel Diagrams

The physical layout of the connectors on the rear-panel and side-panel diagrams of three sample configurations of the SEL-787 are shown in *Figure 2.8*, *Figure 2.9*, *Figure 2.10*, *Figure 2.11*, and *Figure 2.12*.



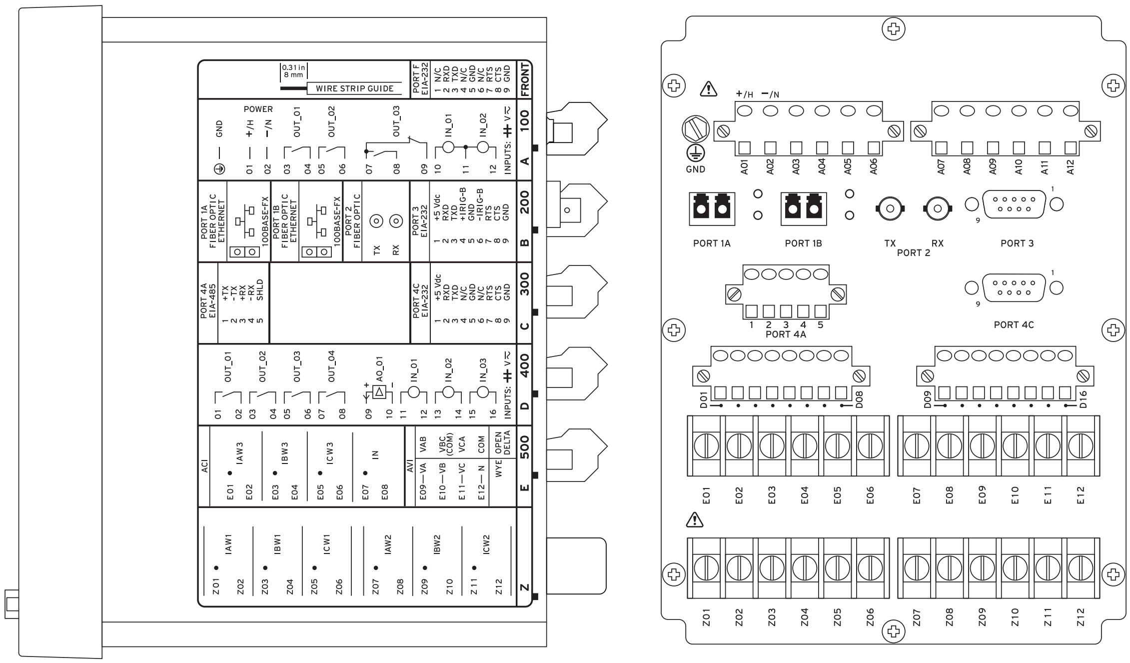
‡ SEE DOCUMENTATION FOR INPUT VOLTAGE RATING

(a) Side-Panel Layout



(b) Rear-Panel Layout

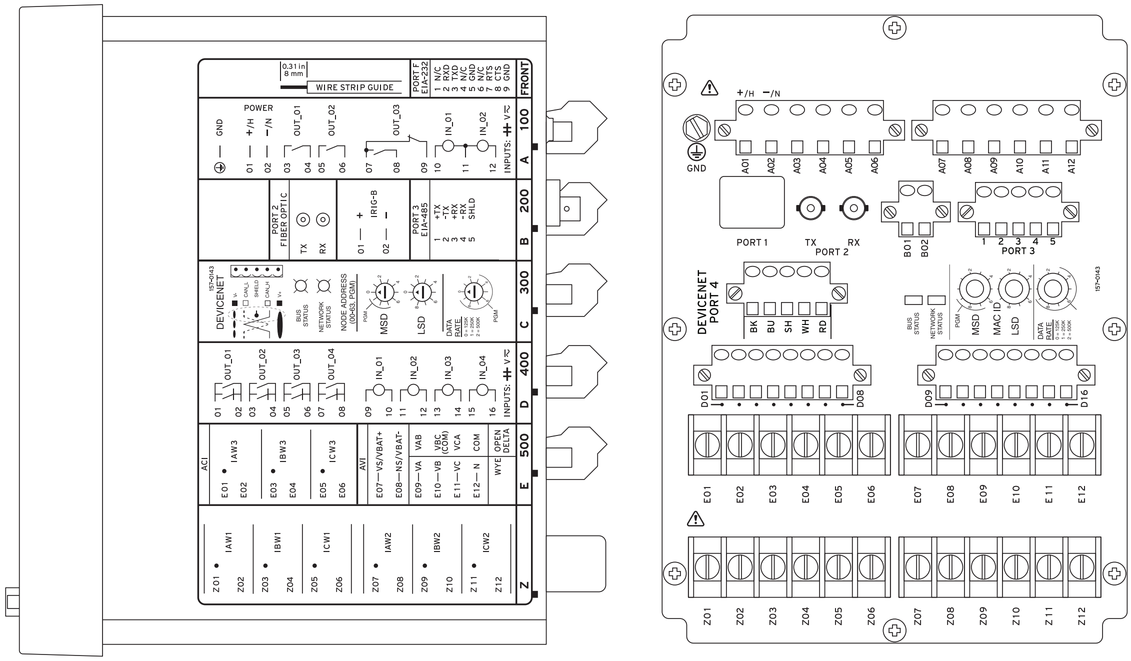
Figure 2.8 SEL-787-4X With Single Copper Ethernet, 8 DI, RTD, 6 ACI, and 6 ACI Option (Relay MOT 07874XE1A3A9XA5850210)



‡ SEE DOCUMENTATION FOR INPUT VOLTAGE RATING

(a) Side-Panel Layout (b) Rear-Panel Layout

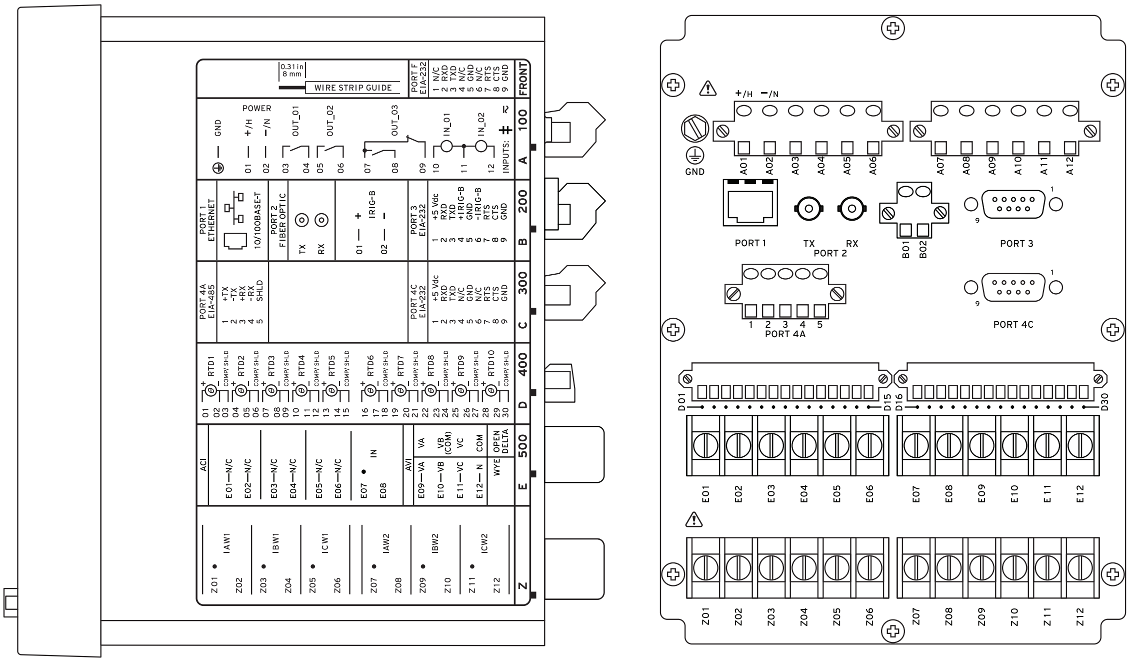
Figure 2.9 SEL-787-3E With Dual-Fiber Ethernet, EIA-232/485 Communications, 3 DI/4 DO/1 AO, 4 ACI/3 AVI, and 6 ACI Option (Relay MOT 07873EE1AA0BA72810870)



‡ SEE DOCUMENTATION FOR INPUT VOLTAGE RATING

(a) Side-Panel Layout (b) Rear-Panel Layout

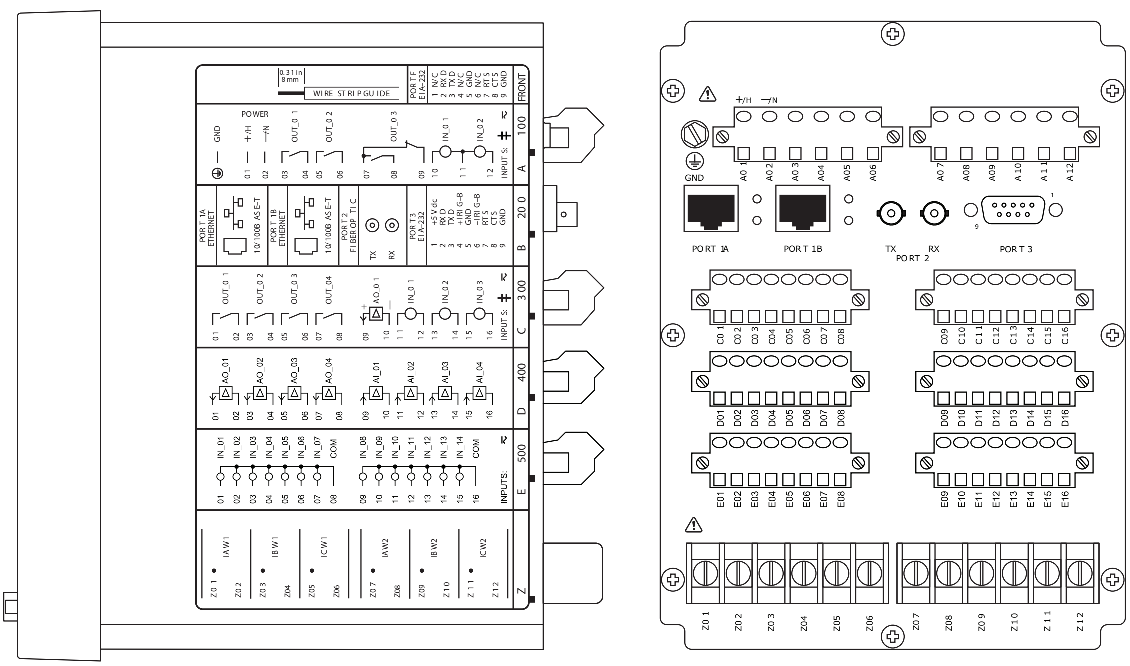
Figure 2.10 SEL-787-3S With DeviceNet, Hybrid 4 DI/4 DO, 3 ACI/4 AVI, and 6 ACI Option (Relay MOT 07873SE1AA31A75850000)



‡ SEE DOCUMENTATION FOR INPUT VOLTAGE RATING

(a) Side-Panel Layout (b) Rear-Panel Layout

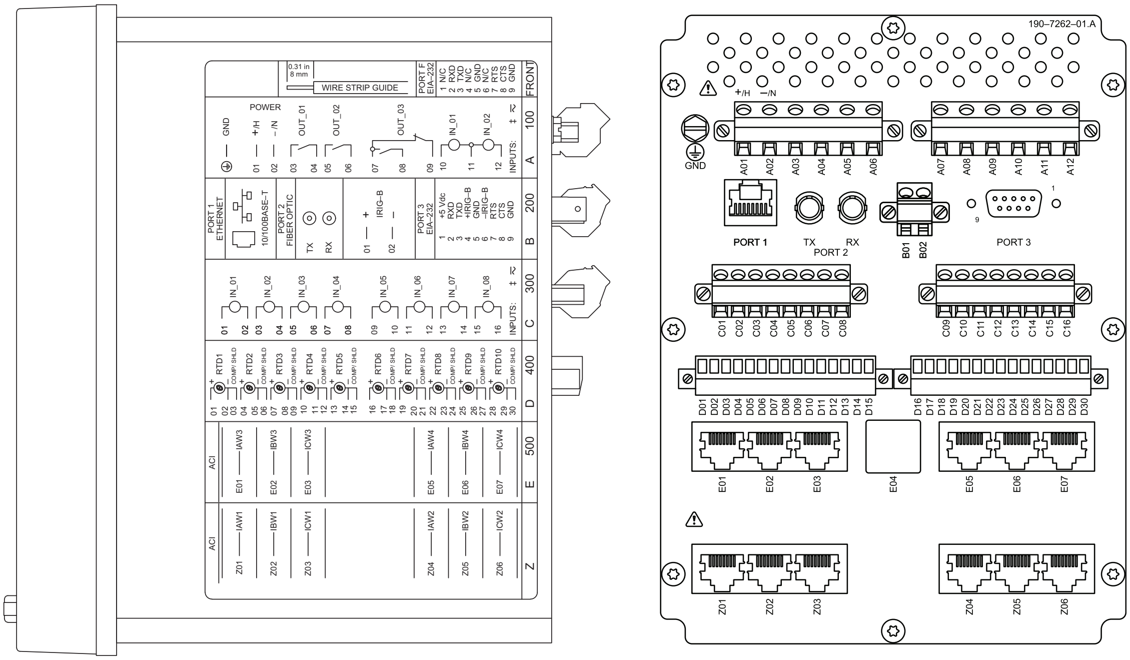
Figure 2.11 SEL-787-2E With Single Ethernet, EIA-232/485 Communications, RTD, 1 ACI, 3 AVI, and 6 ACI Option (Relay MOT 07872ES1AA09X78810271)



‡ SEE DOCUMENTATION FOR INPUT VOLTAGE RATING

(a) Side-Panel Layout (b) Rear-Panel Layout

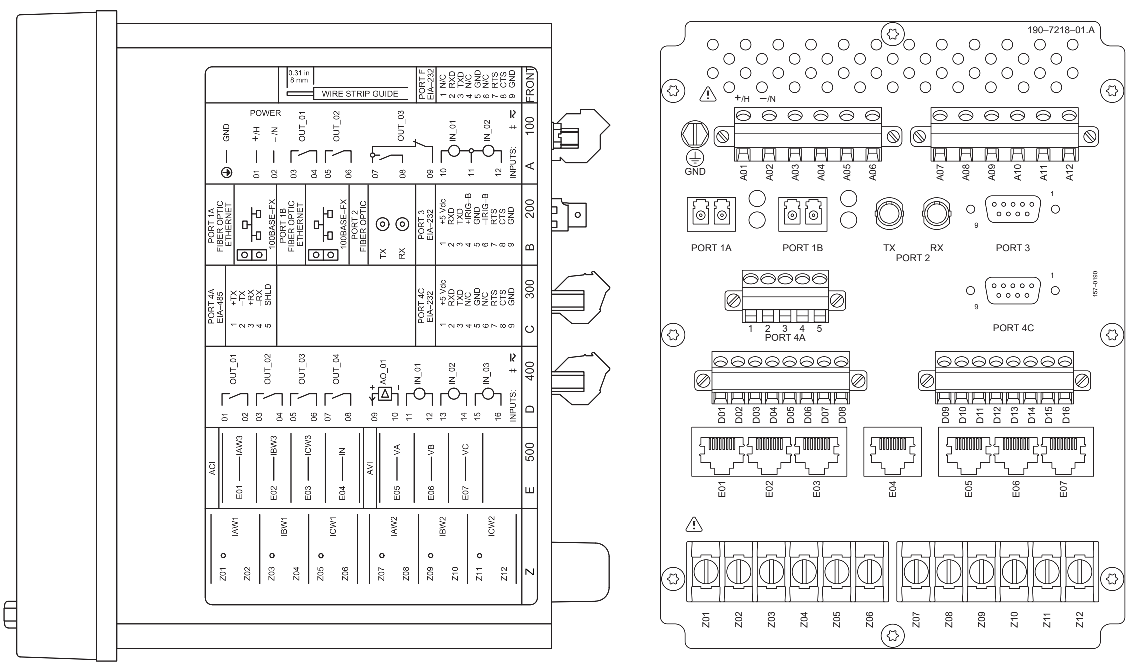
Figure 2.12 SEL-787-2X With Dual-Copper Ethernet, 3 DI/4 DO/1 AO, 4 AI/4 AO, 14 DI, 6 ACI LEA, and 6 ACI Option (Relay MOT 07872XE1ABA6X4A85A670)



‡ SEE DOCUMENTATION FOR INPUT VOLTAGE RATING

(a) Side-Panel Layout (b) Rear-Panel Layout

Figure 2.13 SEL-787-4X With Single Copper Ethernet, 8 DI, RTD, 6 ACI LEA, and 6 ACI LEA Option (Relay MOT 07874XE1A3A9XL0L00210)



‡ SEE DOCUMENTATION FOR INPUT VOLTAGE RATING

(a) Side-Panel Layout (b) Rear-Panel Layout

Figure 2.14 SEL-787-3E With Dual-Fiber Ethernet, EIA-232/485 Communications, 3 DI/4 DO/1 AO, 4 ACI/3 AVI LEA, and 6 ACI Option (Relay MOT 07873EE1AA0BAL2810870)

Power Connections

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

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

The **POWER** terminals on the rear panel (**A01 (+/H)** and **A02 (—/N)**) must connect to 110–240 Vac, 110–250 Vdc or 24–48 Vdc (see *Power Supply on page 1.12* for complete power input specifications). The **POWER** terminals are isolated from chassis ground. Use 14 AWG (2.1 mm^2) to 16 AWG (1.3 mm^2) size wire to connect to the **POWER** terminals.

The SEL-787 comes with an orange Euro connector on the Slot A card for the 24–48 Vdc low-voltage power supply option. *Figure 2.15* shows the orange Euro connector with the 24–48 Vdc power supply rating.

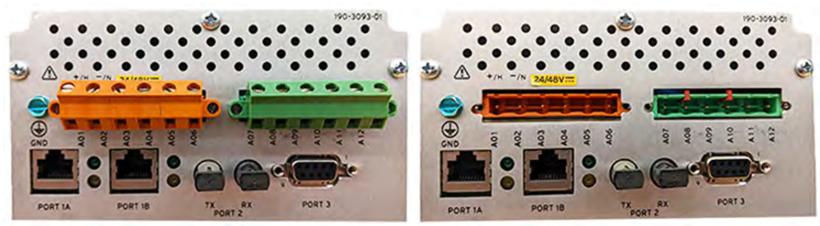


Figure 2.15 Slot A Euro Connector

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-787; this device should interrupt both the hot (+/H) and neutral (-/N) power leads. The maximum rating for the power disconnect circuit breaker or optional overcurrent device (fuse) should be 20 A, 300 V.

Operational power is internally fused by a power supply fuse. See *Field Serviceability on page 2.43* for details. Be sure to use fuses that comply with IEC 60127-2.

Serial Ports

Because all ports (**F**, **2**, **3**, and **4**) are independent, you can communicate to any combination simultaneously. Although serial **PORT 4** on the optional communications card consists of an EIA-485 (**4A**) and an EIA-232 (**4C**) port, only one port is available at a time. Use the **PORT 4** communications interface COMMINF setting to select between EIA-485 and EIA-232.

The serial port EIA-485 plug-in connector accepts wire size 26 AWG through 14 AWG. Strip the wires 8 mm (0.31 in) and install with a small slotted-tip screwdriver. All EIA-232 ports accept 9-pin D-subminiature male connectors.

For connecting devices at distances over 100 ft, where metallic cable is not appropriate, SEL offers fiber-optic transceivers or the SEL-2812 compatible ST fiber-optic port. 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.

IRIG-B Time-Code Input

The SEL-787 accepts a demodulated IRIG-B time signal to synchronize the internal clock with an external source. Three options for IRIG-B signal input are given, but only one should be used at a time. You can use IRIG-B (**B01** and **B02**) inputs, an SEL communications processor via EIA-232 serial **PORT 3**, or fiber-optic serial **PORT 2**. The available communications processors are the SEL-2032, SEL-2030, SEL-2020, and the SEL-2100 Logic Processor. You can also use the SEL-3530 Real-Time Automation Controller (RTAC) to provide IRIG-B input.

The models with fiber-optic Ethernet and dual copper Ethernet do not have the terminals **B01** and **B02** for IRIG-B, but have IRIG-B input via EIA-232 **PORT 3**. The third option for IRIG-B is via fiber-optic Serial **PORT 2**. Use an

SEL-2812MT Transceiver to connect to the SEL-2030 or SEL-2032 and bring the IRIG-B signal with the EIA-232 input. Use a fiber-optic cable pair with ST connectors (C805, C807, or C808) to connect to **PORT 2** on the SEL-787. Refer to *Section 7: Communications* for IRIG-B connection examples and for details about using an SEL-2401/2407/2488 as a time source.

Ethernet Port

The SEL-787 can be ordered with optional single/dual 10/100BASE-T or 100BASE-FX Ethernet port. Connect to **PORT 1** of the device using a standard RJ45 connector for the copper port and an LC connector for the fiber-optic port.

Fiber-Optic Serial Port

The optional fiber-optic serial port is compatible with the SEL-2812 (with IRIG-B) or the SEL-2814 Fiber-Optic Transceivers or the SEL-2600 RTD Module.

I/O Connections

When the relay is ordered with the 24 Vdc/Vac or 48 Vdc/Vac input voltage option, the digital inputs come with the orange Euro connector on the slot. *Figure 2.16* shows the orange Euro connector for the 3 DI/4 DO/1 AO digital inputs option on Slot C.

Figure 2.16 Slot C Euro Connector

I/O Diagram

A more functional representation of two of the control (I/O) connections are shown in *Figure 2.17* and *Figure 2.18*.

NOTE: All digital input and digital output (including high-current , high-speed hybrid) connections are polarity neutral.

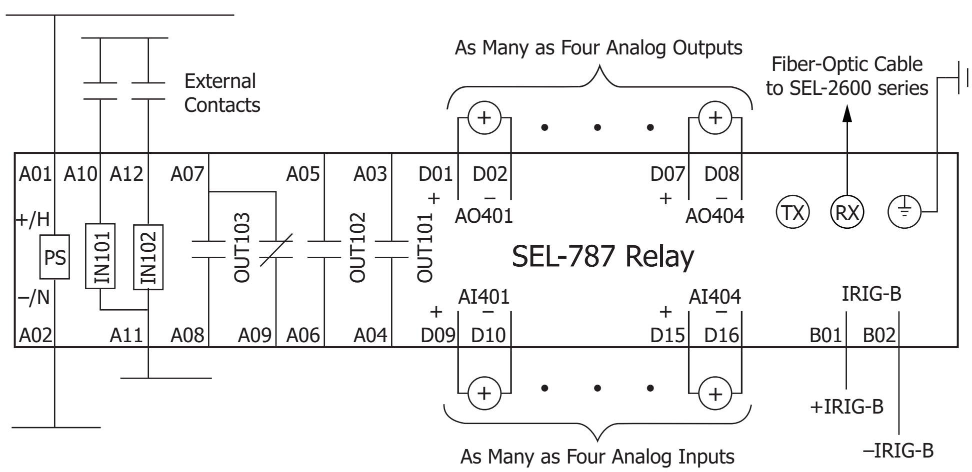
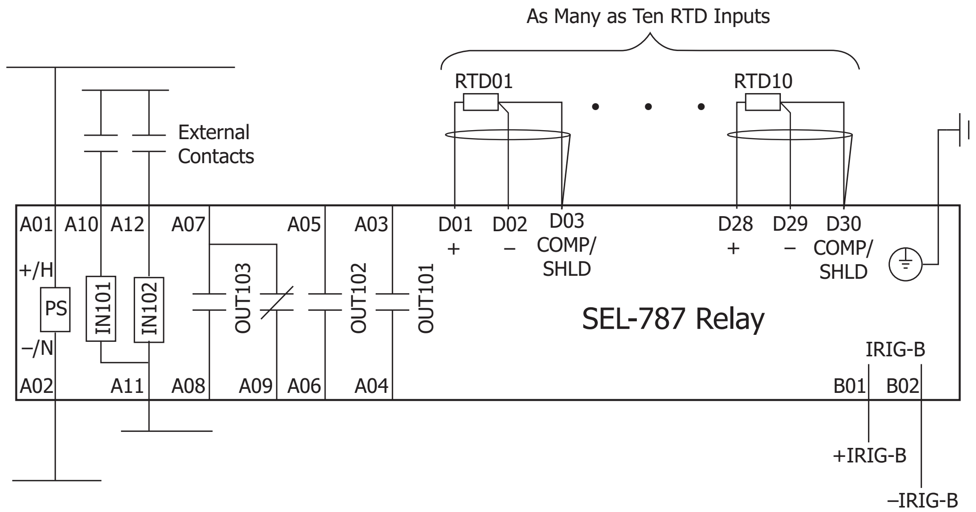


Figure 2.17 Control I/O Connections—4 AI/4 AO Option in Slot D and Fiber-Optic Port in Slot B

NOTE: All RTD comp/shield terminals are internally connected to the relay chassis and ground.



Notes:

- The chassis ground connector located on the rear-panel card in Slot A must always be connected to the local ground mat.
- Power supply rating (110–240 Vac, 110–250 Vdc or 24–48 Vdc) depends on the relay part number.
- Optoisolated Inputs IN101 and IN102 are standard and located on the card in Slot A.
- All optoisolated inputs are single-rated: 24, 48, 110, 125, 220, or 250 Vac/Vdc. Standard Inputs IN101/102 may have a different rating than the optional IN401/402/403/404 (not shown).
- Output Contacts OUT101, OUT102, and OUT103 are standard and located on the card in Slot A.
- The analog (transducer) outputs shown are located on the optional I/O expansion card in Slot D.
- The fiber-optic serial port is located on the card in Slot B. A Simplex 62.5/200 µm fiber-optic cable is required to connect the SEL-787 with an SEL-2600 RTD Module. This fiber-optic cable should be 1000 meters or shorter.

Figure 2.18 Control I/O Connections—Internal RTD Option

RTD Wiring

Table 2.25 shows the maximum cable lengths for the RTD connections that satisfy the 25-ohm limit required for connecting to SEL devices.

NOTE: RTD inputs are not internally protected from electrical surges. External protection is recommended if surge protection is necessary.

Table 2.25 Typical Maximum RTD Lead Length

RTD Lead AWG	Maximum Length
28	116 m
26	184 m
24	290 m
22	455 m
20	730 m
18	1155 m
16	1848 m

Refer to application guide *AG2017-09: Applying Various Types of RTDs with SEL Devices*. This application guide specifies the correct connection of two-wire, three-wire, and four-wire RTDs to three-terminal SEL measurement devices.

RTD wiring recommendations:

1. Use shielded, twisted-pair cables for RTD wiring.
2. Connect the RTD_CAL wire to the RTD CAL/SHIELD Terminal on the SEL device. This will eliminate any wiring resistance error.
3. Make sure the RTD mounting ear screws are snug and secure.

Use relay wire termination kits—see *Application Note AN2014-08*—and avoid fitting multiple wires into a single terminal, the bird-caging effect of stranded wires, and bulky wire bundles.

Analog Output Wiring

NOTE: Connection of dc voltage to the analog output terminals could result in damage to the relay.

Connect the two terminals of the analog output as shown in *Figure 2.19*. Also connect the analog output cable shield to ground at the relay chassis ground, programmable logic controller (PLC), or meter location. Do not connect the shield to ground at both locations.

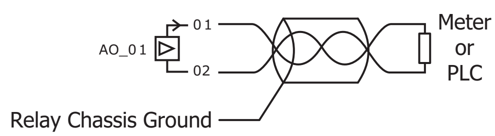


Figure 2.19 Analog Output Wiring Example

AC/DC Control Connection Diagrams

This section describes fail-safe versus nonfail-safe tripping, describes voltage connections, and provides the ac and dc wiring diagrams.

Fail-Safe/Nonfail-Safe Tripping

NOTE: Fast hybrid contacts are designed for fast closing (50 µs) only. Fail-safe mode operating time (time to open the contacts) for fast-hybrid contacts is <8 ms (the same time as for a normal output contact).

Figure 2.20 shows the output **OUT103** relay coil and Form C contact. When the relay coil is de-energized, the contact between **A07** and **A08** is open while the contact between **A07** and **A09** is closed.

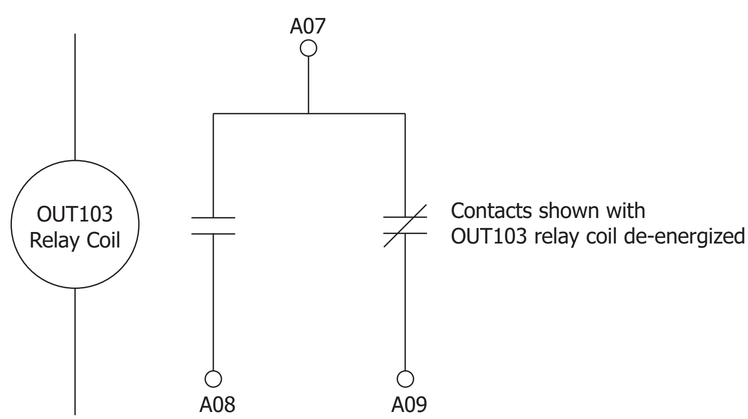


Figure 2.20 Output OUT103 Relay Output Contact Configuration

The SEL-787 provides fail-safe and nonfail-safe trip modes (setting selectable) for all output contacts. The following actions occur in fail-safe mode:

- ➤ The relay coil is energized continuously if the SEL-787 is powered and operational.
- ➤ When the SEL-787 generates a trip signal, the relay coil is de-energized.
- ➤ The relay coil is also de-energized if the SEL-787 power supply voltage is removed or if the SEL-787 fails (self-test status is FAIL).

Figure 2.21 shows fail-safe and nonfail-safe wiring methods to control breakers.

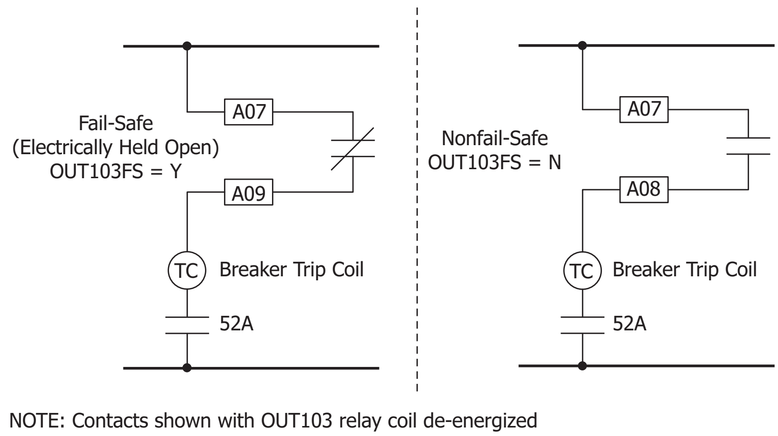


Figure 2.21 Breaker Trip Coil Connection With OUT103FS := Y and OUT103FS := N

High-Speed, High-Current Interrupting Tripping Outputs

High-speed outputs are optimized for the direct tripping of power circuit breakers. High-speed outputs operate in less than 50 µs, work with dc trip coil circuits, are polarity insensitive and capable of making 30 A, and can interrupt 10 A with an 8 ms dropout time. High-speed outputs are implemented as hybrid circuits, each of which consists of the parallel combination of a high-current, solid-state switch and an electromechanical bypass relay. Avoid using high-speed outputs to drive highly sensitive, high-resistance electronic inputs (e.g., <2 mA electronic circuits) unless such inputs are connected in parallel with a low-resistance load (e.g., a breaker trip coil).

Avoid connecting multiple high-speed outputs in parallel when driving highly sensitive electronic inputs. Keep wiring short, and use fiber-based MIRRORED BITS communications to bridge longer distances.

Voltage Connections

NOTE: Current limiting fuses in direct-connected voltage applications are recommended to limit short circuit arc-flash incident energy.

With the voltage inputs option, the ac voltages may be directly connected, wye-wye VT connected, open-delta VT connected, or a single-phase VT can be used. *Figure 2.22* and *Figure 2.23 (a–c)* show the methods of connecting single-phase and three-phase voltages. *Figure 2.23 (c)* shows open-delta VT connections with Phase B (E10) grounded. You can choose to ground Phase A or Phase C instead of Phase B, but the jumper between terminals E10 and E12 must remain as is.

Figure 2.23 (d) shows typical methods for connecting three-phase LEA sensor voltages, which support only wye-wye connections. Note that the LEA cable is part of the LEA sensor. This connection is applicable to the SEL-787 with the LEA VT option (MOT ...xL1x...). Refer to *Under- and Overvoltage*

Functions on page 4.66 and *LEA Ratio and Angle Correction Factors (Global Settings) on page 4.13* for the LEA settings and ratio correction factor calculations. Refer to *Section 4: Protection and Logic Functions* for more details.

Figure 2.23 (e–f) shows typical methods for connecting three-phase voltages using the SEL-3790 voltage divider module. For specifications, installation, and application details of SEL-3790, refer to the *SEL-3790 Low-Voltage Divider Module Instruction Manual*, available at selinc.com.

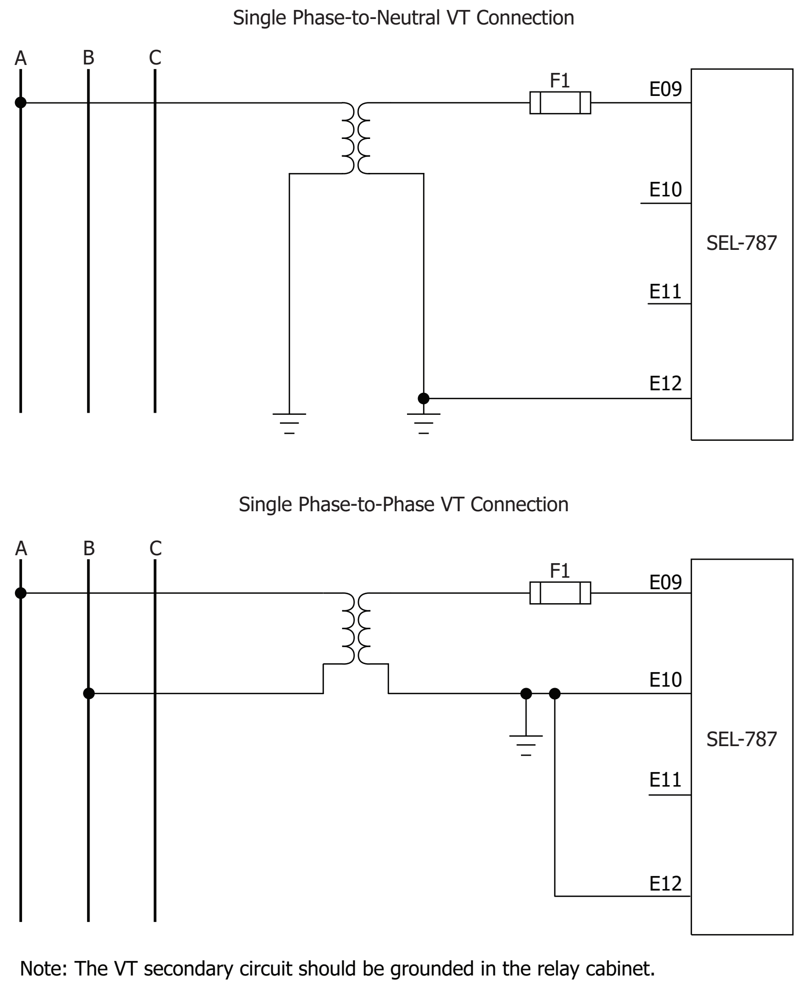
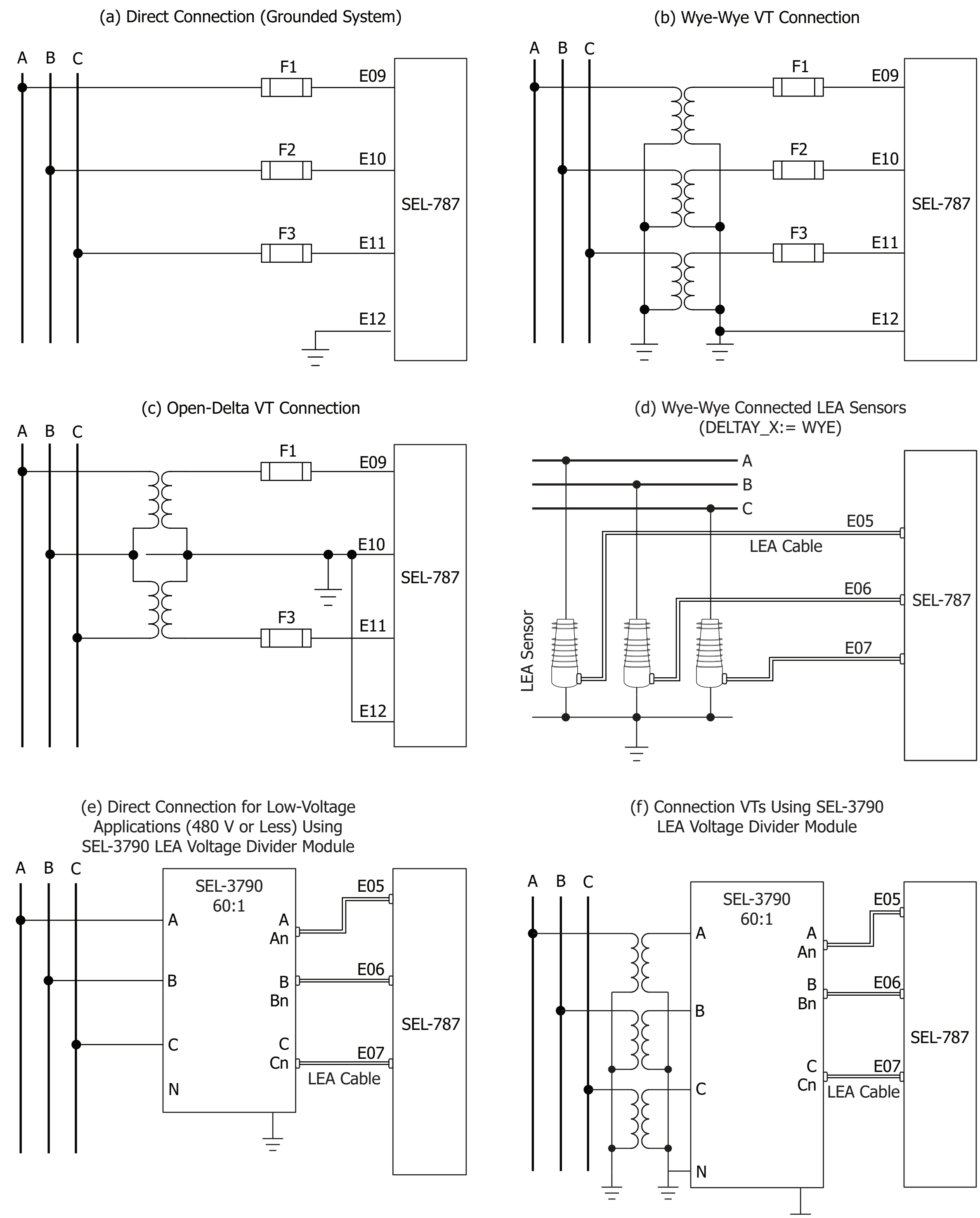


Figure 2.22 Single Phase Voltage Connections



Note: The VT secondary circuit should be grounded in the relay cabinet.

Figure 2.23 Voltage Connections

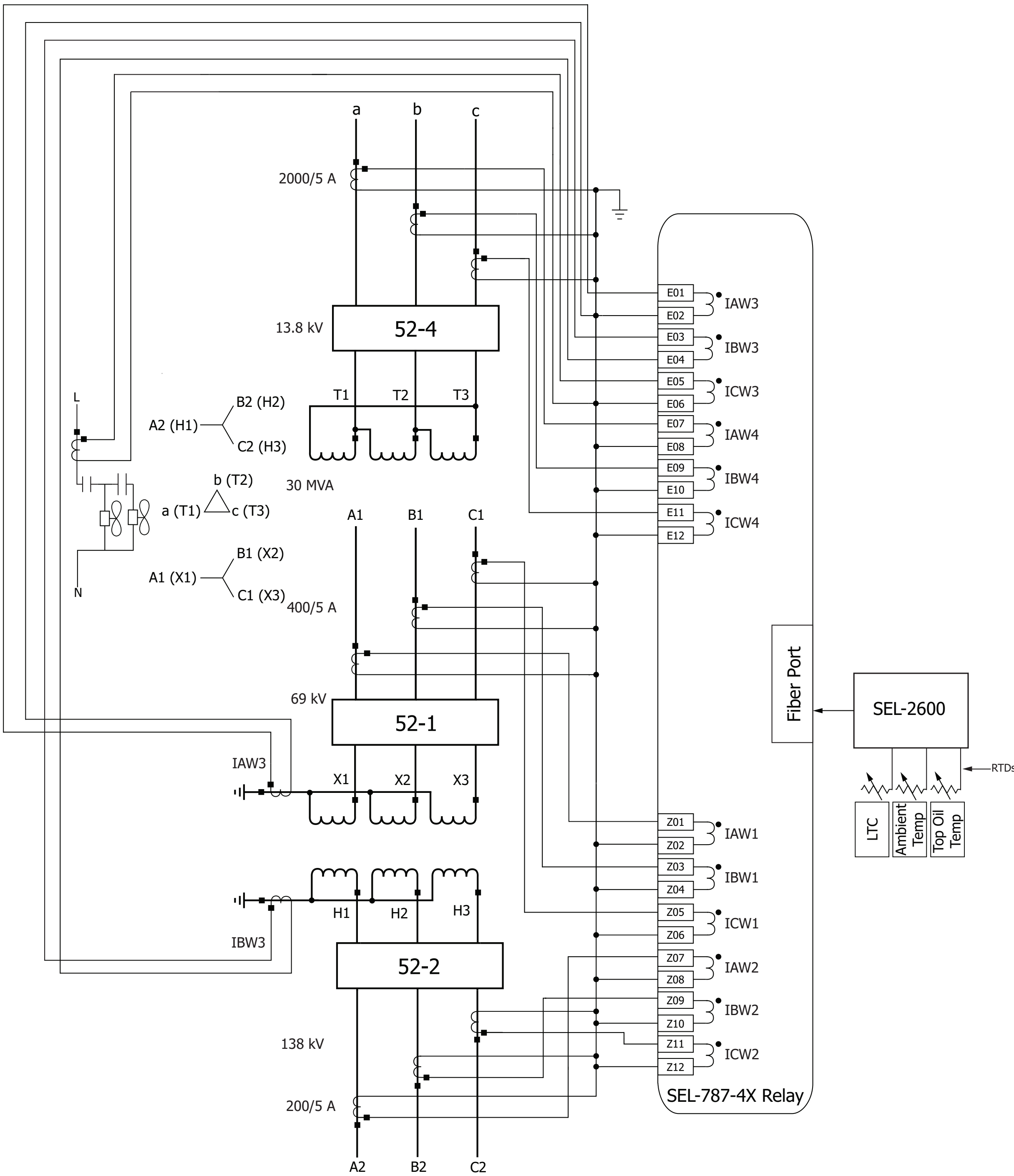
Applications

Figure 2.24, *Figure 2.25*, and *Figure 2.26* show connection diagrams for different applications involving the SEL-787-4X, SEL-787-3S, and SEL-787-3E models, respectively. Refer to *Section 4: Protection and Logic Functions* for more details.

Figure 2.24 shows the application of an SEL-787-4X Relay for protection of a three-winding transformer. Windings 1, 2, and 4 on the relay can be configured for differential protection by setting E87W1 := Y, E87W2 := Y, and E87W4 := Y, respectively. The 50/51 elements associated with each winding can be applied towards overcurrent protection. By setting E87W3 := REF, REF3APOL := 1, and REF3BPOL := 2, Phase A and B of Winding 3 can be configured for REF protection for Windings 1 and 2, respectively. Phase C of Winding 3, along with the RTD thermal elements, can be configured to provide fan bank control and protection. Use additional RTD thermal elements to monitor load tap changer (LTC) tank temperatures and SELOGIC programming to indicate temperature differential alarms between transformer and LTC tank temperatures.

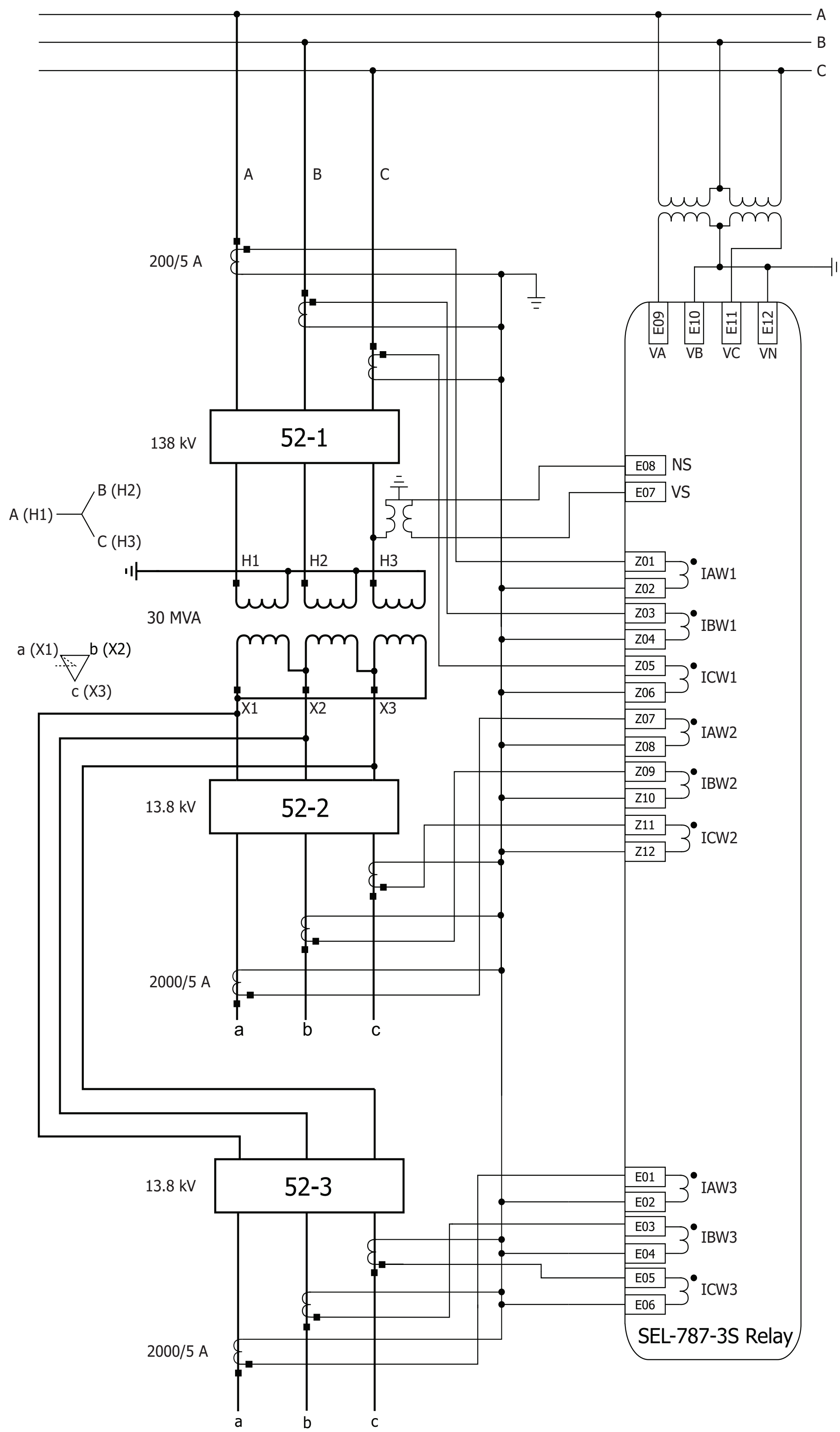
Figure 2.25 shows an SEL-787-3S Relay protecting a two-winding transformer with three terminals. Windings 1, 2, and 3 on the relay can be configured for differential protection by setting E87W1 := Y, E87W2 := Y, and E87W3 := Y, respectively. The 50/51 elements associated with each winding can be applied towards overcurrent protection. The voltage inputs provide the relay with 15.0 to 70.0 Hz frequency tracking, over- and undervoltage elements, frequency elements, power elements, and volts-per-hertz protection of the transformer. Voltage channel VS is shown connected for use in synchronism-check elements, voltage elements, and voltage metering.

Figure 2.26 shows an SEL-787-3E Relay protecting an autotransformer with three terminals. Windings 1, 2, and 3 on the relay can be configured for differential protection by setting E87W1 := Y, E87W2 := Y, and E87W3 := Y, respectively. The 50/51 elements associated with each winding can be applied towards overcurrent protection. Channel IN on the relay can be configured for REF protection by setting REF1POL := 123. The three-phase voltage inputs can be used for V/Hz, over- and undervoltage, over- and underfrequency, and directional power protection.



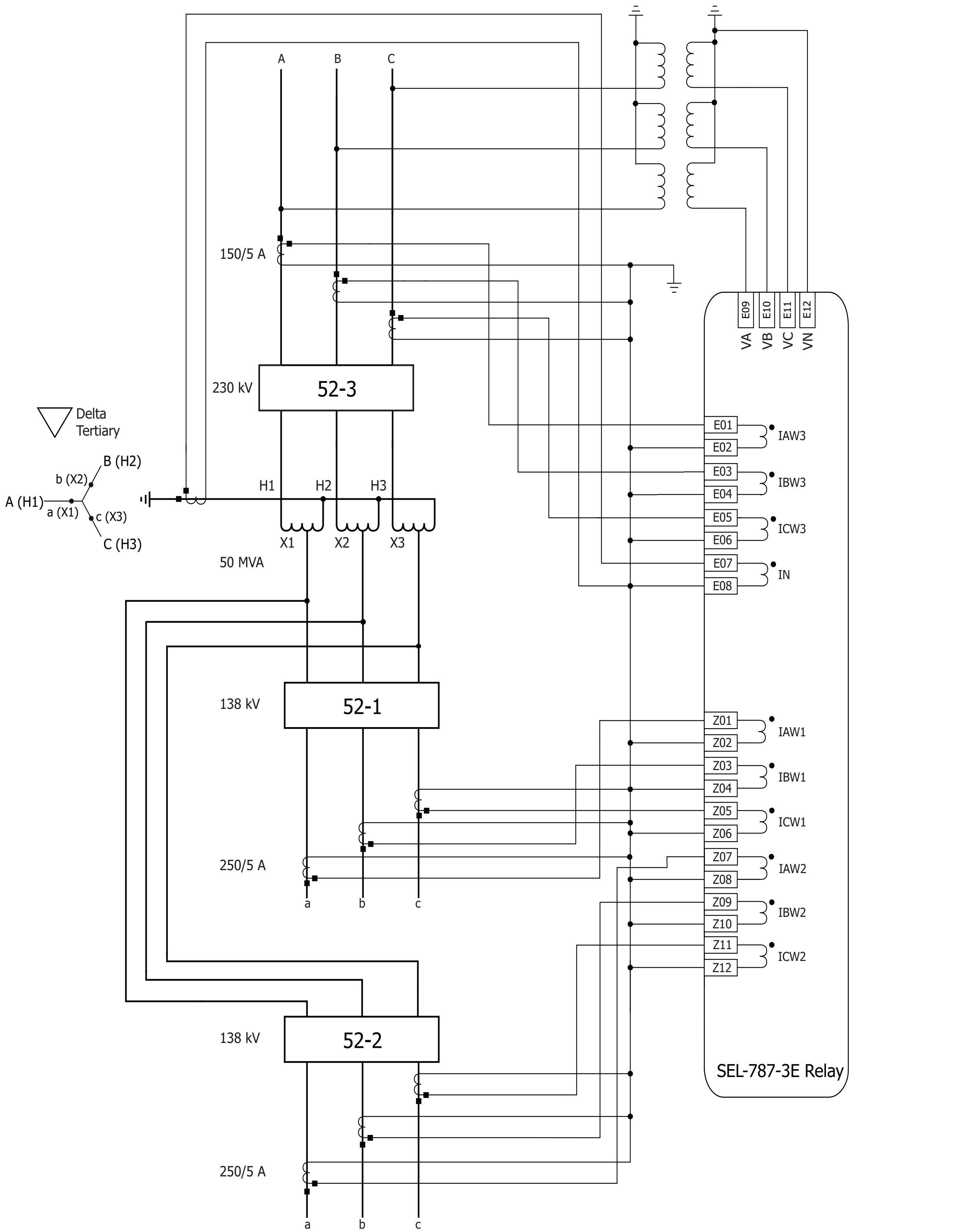
Note: The CT secondary circuit should be grounded in the relay

Figure 2.24 Application Example of an SEL-787-4X Providing 3-Winding Transformer Differential Protection, REF Protection, Overcurrent Protection, and Fan Bank Control With LTC Monitoring



Note: The CT secondary circuit should be grounded in the relay cabinet.

Figure 2.25 Application Example of an SEL-787-3S Providing 3-Winding Transformer Differential Protection, Overcurrent Protection, Voltage Protection, and Synchronism Check



Note: The CT secondary circuit should be grounded in the relay cabinet.

Figure 2.26 Application Example of an SEL-787-3E Providing Auto-Transformer Differential Protection, REF Protection, Overcurrent Protection, and Voltage-Based Protection

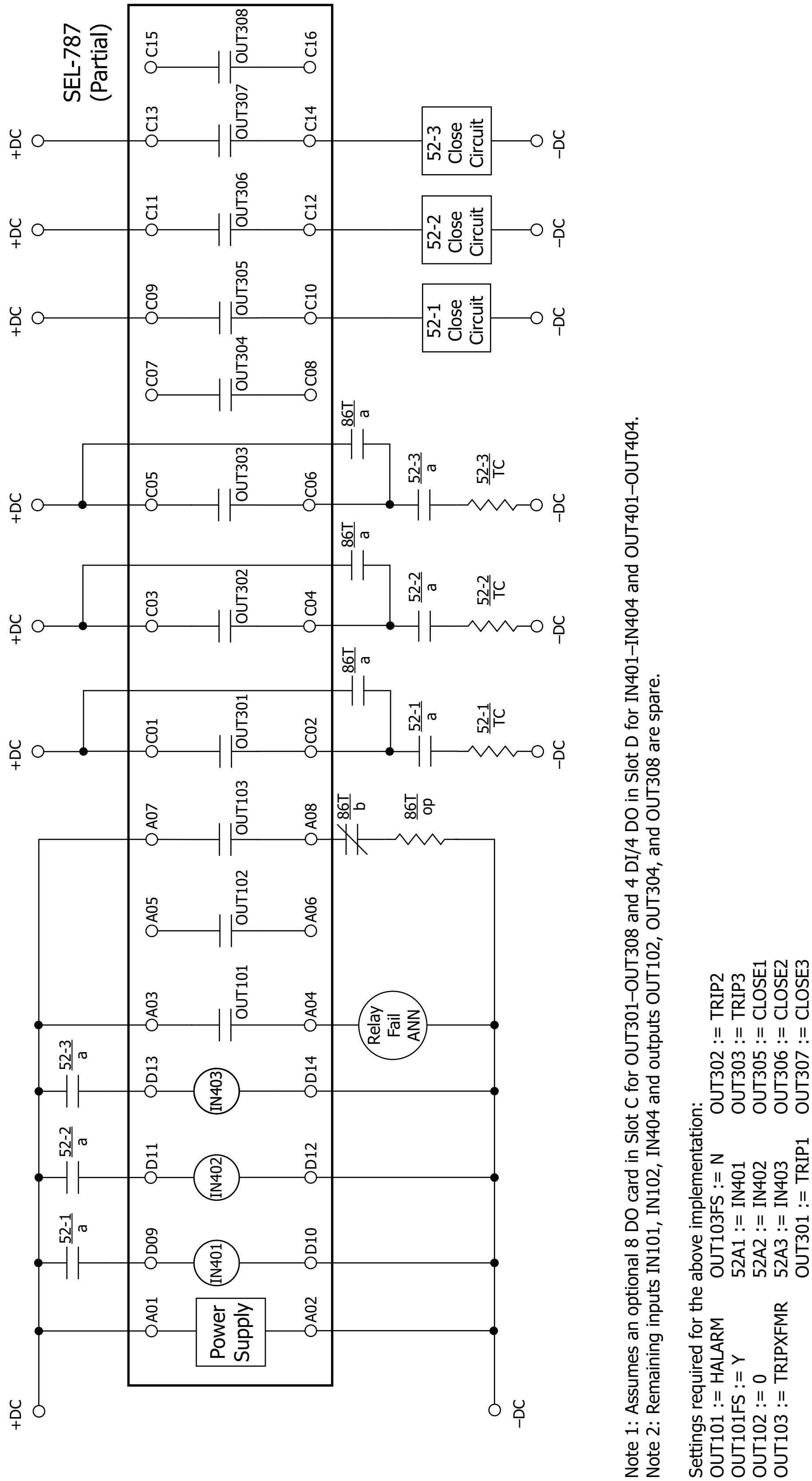


Figure 2.27 Example of DC Connections for the Three Terminal Applications

Field Serviceability

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

The SEL-787 firmware can be upgraded in the field; refer to *Appendix B: Firmware Upgrade Instructions* for firmware upgrade instructions. You can detect when a self-test failure has occurred by configuring an output contact to create a diagnostic alarm as explained in *Section 4: Protection and Logic Functions*. By using the metering functions, you may know if the analog front-end (not monitored by relay self-test) is functional. Refer to *Section 11: Testing and Troubleshooting* for detailed testing and troubleshooting information.

The only two components replaceable in the field are the power supply fuse and the real-time clock battery. A lithium battery powers the clock (date and time) if the external power source is lost or removed. The battery is a 3 V lithium coin cell, Rayovac BR2330A or equivalent. At room temperature (25°C), the battery will operate nominally for 10 years at rated load. When the relay is powered from an external source, the battery experiences a low self-discharge rate. Thus, battery life may extend well beyond 10 years. The battery cannot be recharged.

Fuse Replacement

⚠DANGER
Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.

To replace the power supply fuse, perform the following steps:

Step 1. De-energize the relay.

Step 2. Remove the four rear-panel screws and the relay rear panel.

Step 3. Remove the Slot **A** printed circuit board.

Step 4. Locate the fuse on the board.

Step 5. Remove the fuse from the fuse holder.

Step 6. Replace the fuse with a BUSS S505 3.15A (ceramic), Schurter T3.15AH250V, or equivalent.

Step 7. Insert the printed circuit board into Slot **A**.

Step 8. Replace the relay rear panel and energize the relay.

Real-Time Clock Battery Replacement

⚠CAUTION
There is danger of explosion if the battery is incorrectly replaced. Replace only with Rayovac no. BR2330A 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.

To replace the real-time clock battery, perform the following steps:

Step 1. De-energize the relay.

Step 2. Remove the four rear-panel screws and the relay rear panel.

Step 3. Remove the Slot **B** printed circuit board.

Step 4. Locate the battery clip (holder) on the board.

Step 5. Carefully remove the battery from beneath the clip.

Properly dispose of the old battery.

Step 6. Install the new battery with the positive (**+**) side facing up.

Step 7. Insert the printed circuit board into Slot **B**.

Step 8. Replace the relay rear panel and energize the relay.

Step 9. Set the relay date and time.

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Section 3
PC Interface

Overview

NOTE: We have tested the web server for correct operation and formatting with the following browsers: Internet Explorer 8, Firefox 14, and Chrome 5.

There are a wide variety of browsers available. While most browsers have the same functionality, we cannot guarantee the correct operation and formatting for all of them.

The SEL-787 Transformer Protection Relay can communicate with your computer in three different ways.

- ➤ The web server requires a web browser (Microsoft Internet Explorer, Mozilla FireFox, Google Chrome, etc.) and an Ethernet cable. The relay must have the Ethernet port option. Refer to *Web Server* for functional details and capabilities.
- ➤ The SEL software solution requires downloading ACSELERATOR QuickSet SEL-5030 Software (via Compass) to your computer. Communication to the relay is accomplished through a serial or Ethernet port. Refer to *QuickSet Software on page 3.11* for functional details and capabilities.
- ➤ The ASCII command line requires PC-based terminal emulation software (HyperTerminal, Tera Term, etc.), a serial or Ethernet port, and a serial or Ethernet cable to connect to the relay. Refer to *Section 7: Communications* for ASCII commands and supported functions.

Web Server

Connection and Login to Web Server

The web server provides a GUI for the relay without loading any software on your PC. The GUI is contained in the relay firmware. To connect to the web server of the SEL-787, the relay and your PC must be connected to the same Ethernet network. The network can be of any size, from a company-wide network to a direct-connect from your PC to the relay. The connection from the relay is through the Ethernet port of the relay (Port 1). To start communicating with the relay, you must enter a valid IP address (SET P 1 IPADDR) and valid default router (SET P 1 DEFRTR) via a relay serial port. Be sure to obtain the IP address and default router from your IT resource to avoid network conflicts (e.g., duplicate IP addresses).

The SEL-787 comes pre-loaded with settings that enable you to communicate with the relay over a simple network. The network consists of connecting the SEL-787 (via Port 1) directly to the Ethernet port of your computer. Connect to Ethernet Port 1 of the relay using a standard RJ45 connector for the copper port and an LC connector for the fiber-optic port. This connection requires that the computer not be connected to any other network (see *Figure 3.1*).

NOTE: For relays with a fiber-optic Ethernet port, use a commercially available 100BASE-FX to 100BASE-TX media converter to interface with a PC RJ45 port. Use an SEL-C808 62.5/125 µm Multimode Fiber-Optic Cable to connect to Port 1 of the relay.

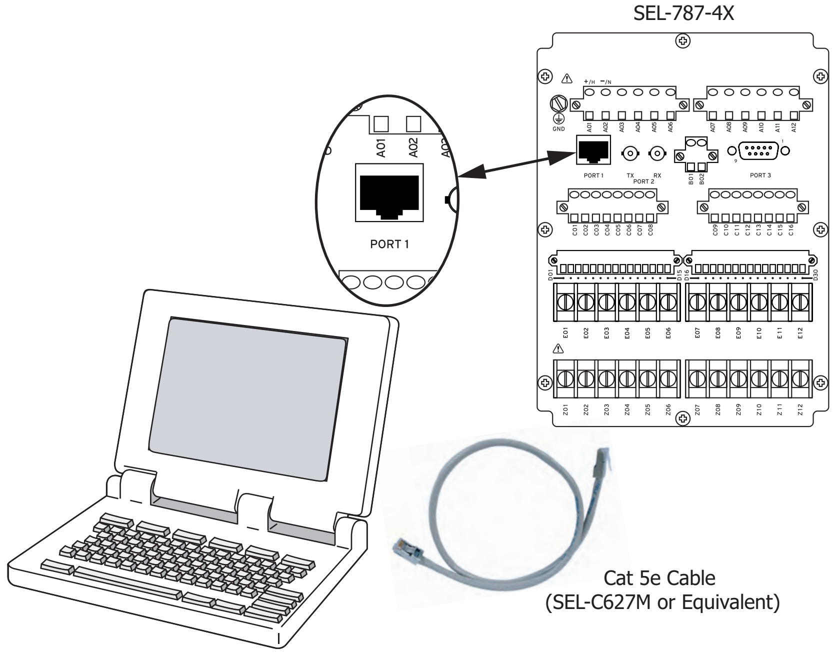

Figure 3.1 Direct Connection of an SEL-787 to a Computer

The default IP address is 192.168.1.2 and the default router is 192.168.1.1. Once the network is configured, as shown in *Figure 3.1*, you can connect to the web server in the relay by entering 192.168.1.2 in the address bar of your web browser (see *Figure 3.2*).

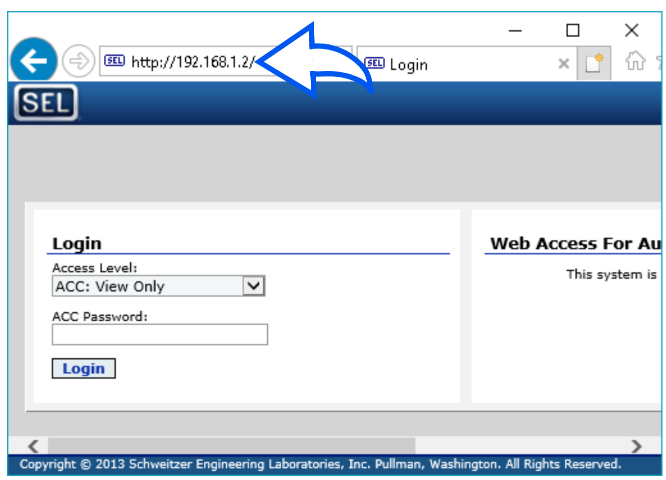

Figure 3.2 Login Page of Web Server for an SEL-787

The Login page of the web server allows you to access either Access Level 1 (ACC) or Access Level 2 (2AC). The menu item you select under Access Level determines the access level at which you enter the web server (see *Figure 3.3*). For factory-default passwords, refer to *Table 7.39*.

Meter, Reports, Communications, Relay Status, and Settings (show only) require Access Level 1 or 2. System requires Access Level 2.

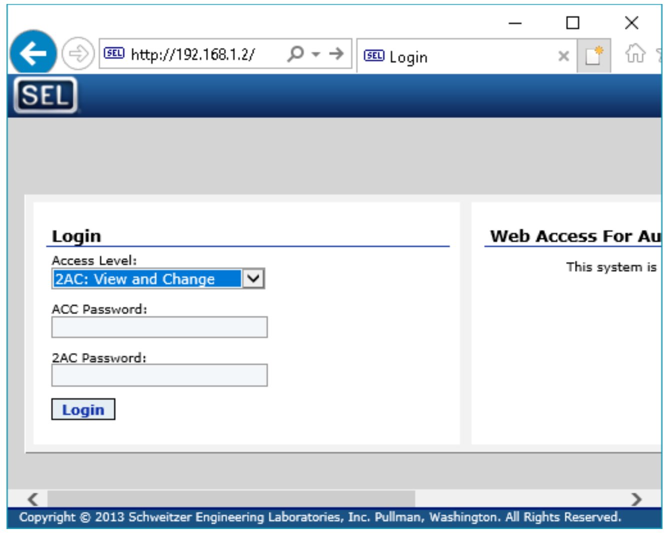

Figure 3.3 Select Access Level 2 From the Web Server Login

Meter

NOTE: All metering reports automatically update. To disable the updates, select the **Disable Page Refresh** button at the bottom of the display window.

The web server offers a convenient method for displaying all the metering reports stored in the relay. Located on the navigation pane, the Meter menu lists each of the available metering reports. When you select a metering report from the Meter menu, the corresponding report is displayed (see *Figure 3.4*).

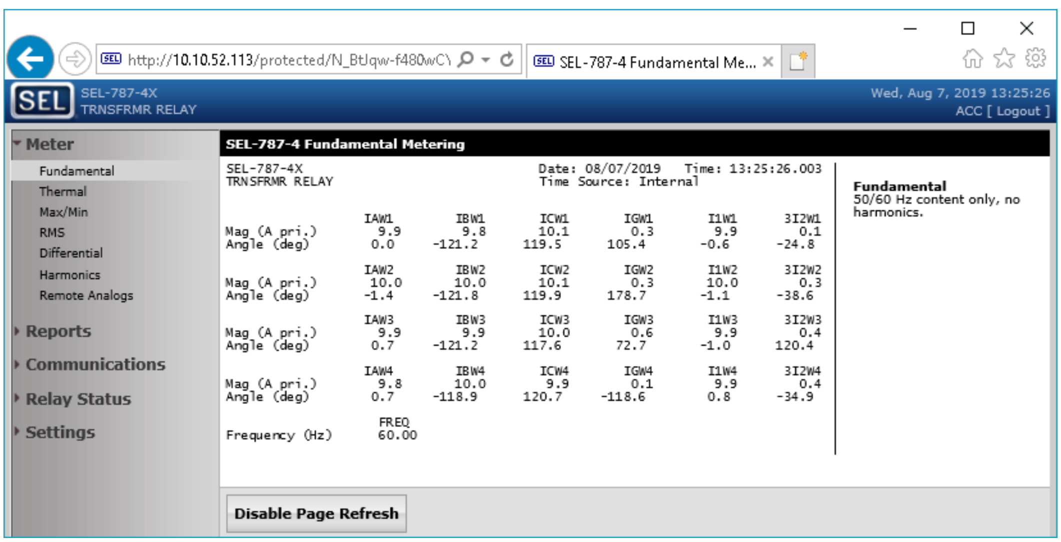

Figure 3.4 Fundamental Meter Report Webpage

Reports

The SEL-787 collects and stores a variety of data and statistics from the power system. These data are stored and reported through a series of reports. Located on the navigation pane, the Report menu lists each of the reports stored in the relay (Event Reports, Sequential Events Recorder, Load Profile, and Breaker Monitor). When you select a report from the Reports menu, its corresponding report is displayed.

Event Reports

Event reports stored in the SEL-787 can be exported in three different formats (binary COMTRADE, raw CEV, or filtered CEV). When you select **Event Reports**, a list of all the event reports presently stored in the relay is shown (see *Figure 3.5*).

After selecting the event format to be used, select the event report to export by clicking on the event needed. When prompted, you can open or save the event.

In addition to retrieving events, the Event Reports page allows you to clear all the events stored in the relay or to trigger events. Clear Event Report History erases the event from the nonvolatile memory of the relay. Trigger Event Report commands the relay to do an event capture of the present voltages and currents detected by the relay (see *Figure 3.5*).

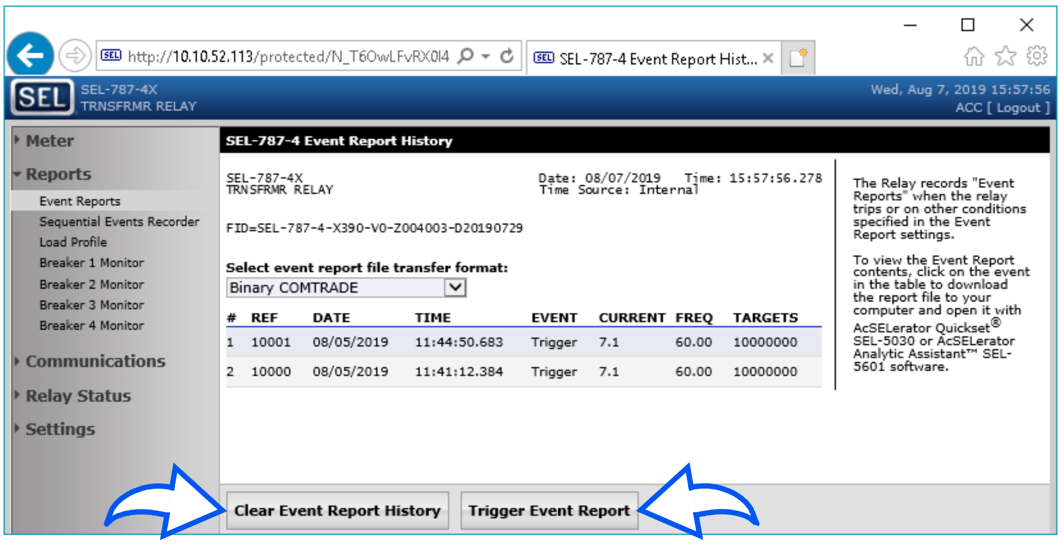

Figure 3.5 Event Report Webpage

Sequential Events Recorder

In addition to event reports, the SEL-787 collects and stores time-stamped data for assertion and deassertion of the Relay Word bits. These data are captured in the Sequential Events Recorder (SER) and can be exported through the web server.

When you select **Sequential Events Recorder**, a list of all the SER records presently stored in the relay displays (see *Figure 3.6*). The SER report stored in the SEL-787 can be downloaded or cleared by clicking the appropriate button at the bottom of the webpage.

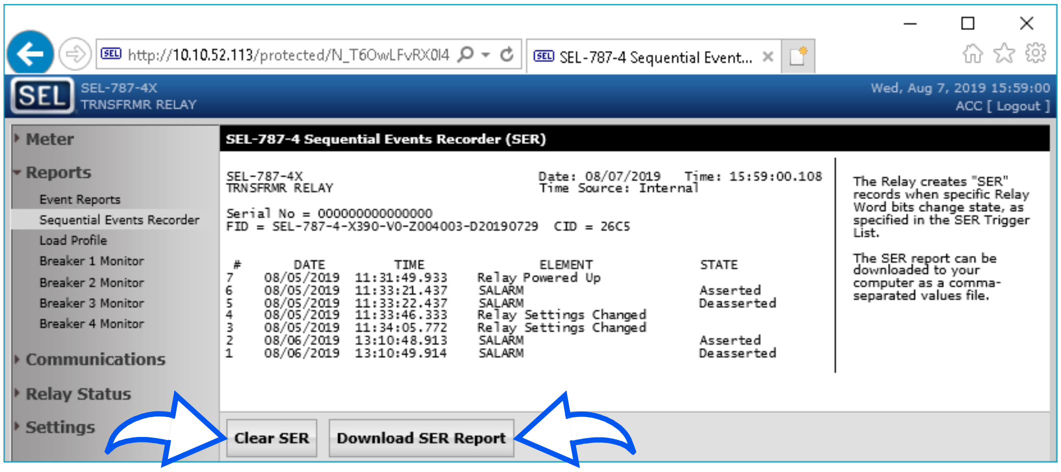

Figure 3.6 Sequential Events Recorder Report Webpage

Load Profile

The SEL-787 collects and stores time-stamped data of the analog quantities. These data are reported in the load profile report. When you select **Load Profile**, a list of all the load profile records presently stored in the relay displays (see *Figure 3.7*). You can export or clear the load profile report stored in the SEL-787 by using the two buttons at the bottom of the display window.

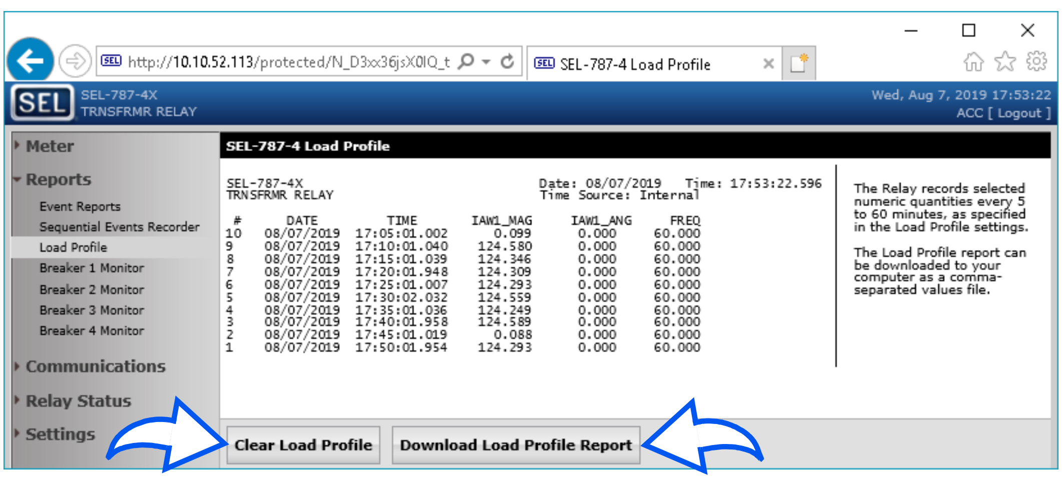

Figure 3.7 Load Profile Webpage

Breaker Monitor Report

The breaker monitor in the SEL-787 helps in scheduling circuit breaker maintenance (see *Breaker Monitor*). When you select **Breaker *n* Monitor** (where *n* = 1, 2, or 3), the corresponding breaker monitor report stored in the relay displays (see *Figure 3.8*). The breaker monitor reports stored in the SEL-787 can be downloaded with the Download Breaker Monitor Report button.

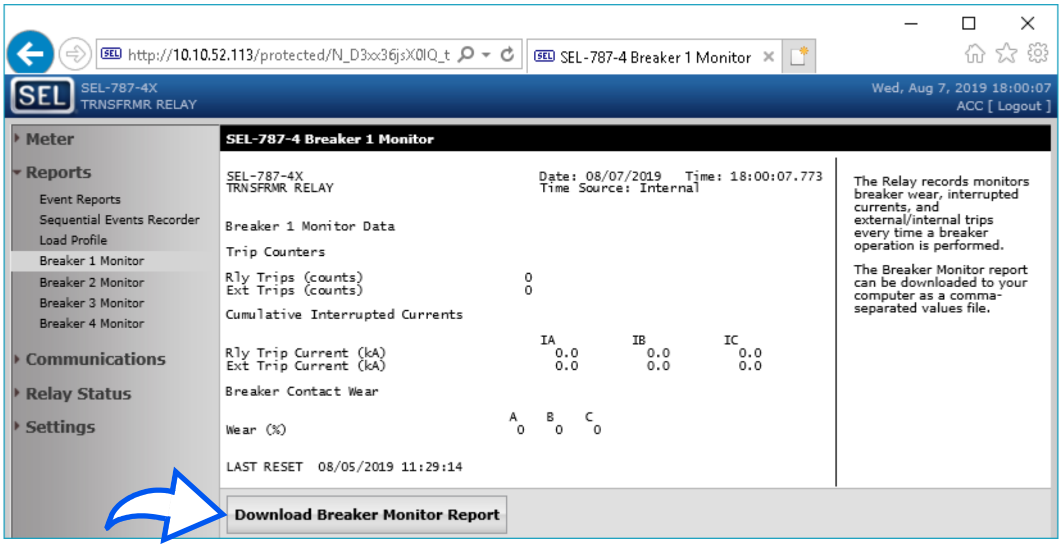

Figure 3.8 Breaker 1 Monitor Report Webpage

Communications

You can view the Ethernet port configuration details, including the MAC address of the relay, by clicking **Communications** > **Ethernet** (see *Figure 3.9*). Click **Clear Ethernet Statistics** to clear PACKETS, BYTES, and ERRORS data. Refer to *Section 7: Communications* for additional details on the Ethernet command.

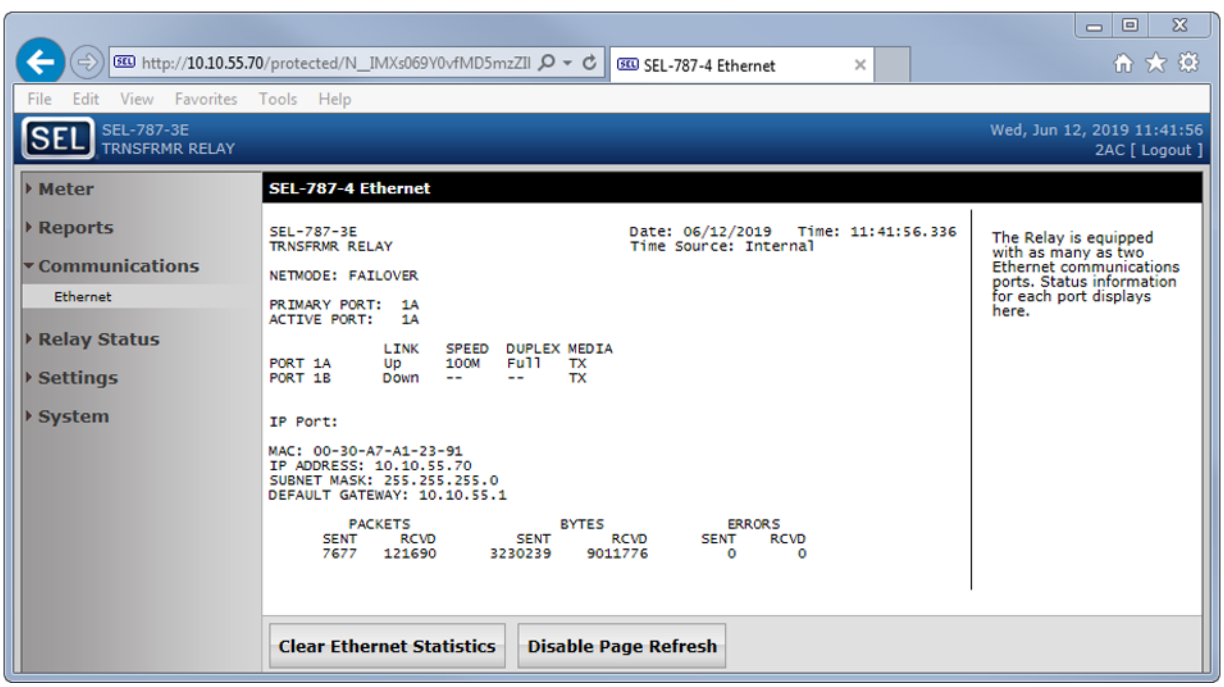

Figure 3.9 MAC Address

Relay Status

The Relay Status menu lists each of the status report pages available through the web server (Self-Tests, Relay Word Bits, and SELOGIC Counters). When you select a status report from the Relay Status menu, the corresponding status report displays.

Self-Tests

The SEL-787 has continual diagnostics that verify the status of the relay hardware. The results of these diagnostics can be viewed by selecting **Relay Status** > **Self-Tests** in the navigation pane. When you select **Relay Status** > **Self-Tests**, the status of the relay, including the serial number, part number, and self-tests results, are displayed (see *Figure 3.10*).

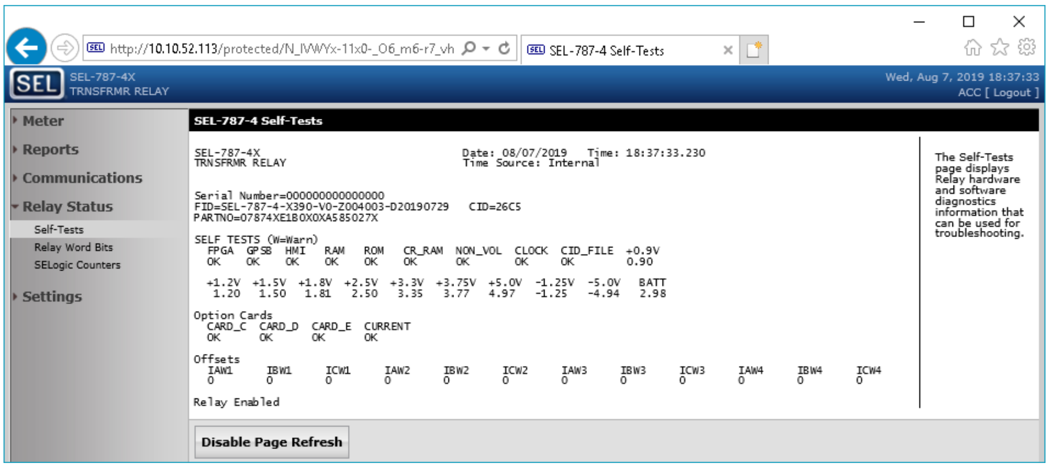

Figure 3.10 Self-Tests Webpage

Relay Word Bits

The web server can display the present state of all the Relay Word bits in the relay. Select **Relay Word Bits** to display the state of all the Relay Word bits (see *Figure 3.11*). Relay Word bits shown in yellow are asserted. This webpage is updated automatically; you can disable the automatic updates by clicking **Disable Page Refresh**. Scroll up or down to view the remaining Relay Word bits not visible on the screen.

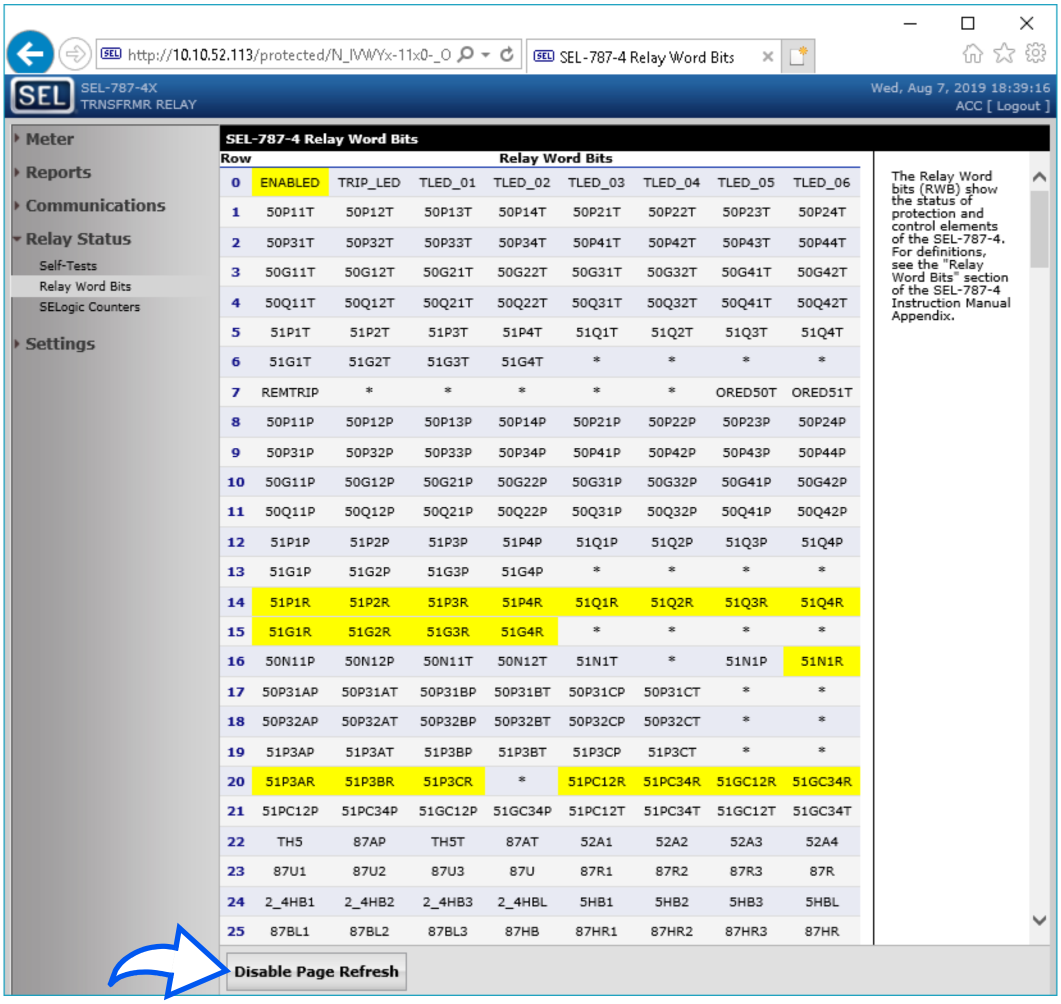

Figure 3.11 Relay Word Bits Webpage

SELOGIC Counters

When you select **Relay Status** > **SELogic Counters**, the count of each of the enabled SELOGIC counters displays (see *Figure 3.12*). A counter is only displayed when it is enabled.

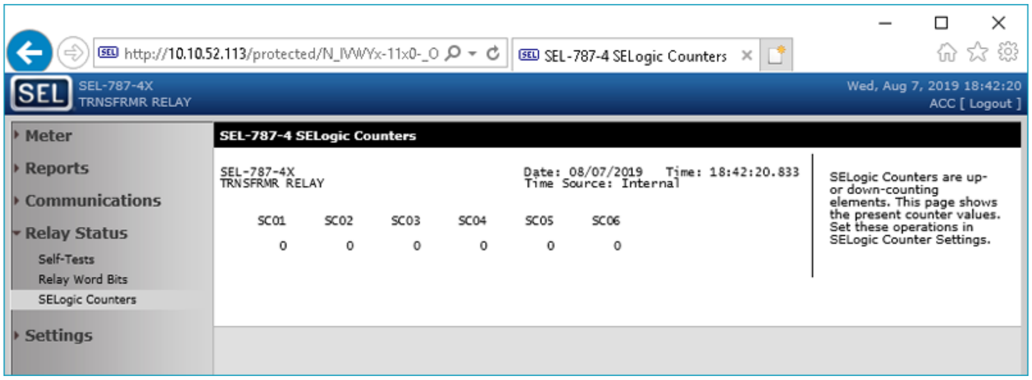

Figure 3.12 SELOGIC Counters Webpage

Settings

Select **Settings** on the navigation pane to view a list of all the available settings classes in the SEL-787. Select a class of settings to view each of the settings in that class (Group, Logic, Global, Report, etc.). *Figure 3.13* shows the Group 1 settings class of Settings.

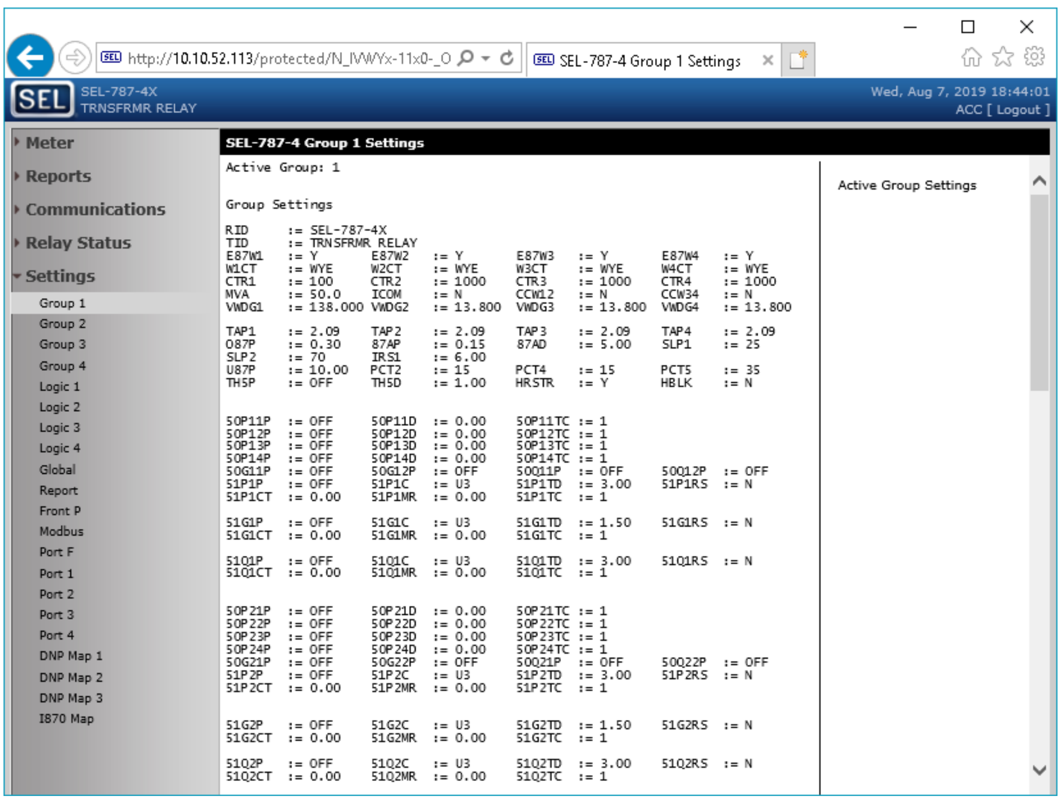

Figure 3.13 Group 1 Settings Webpage

System

File Management

The web server offers a convenient method for upgrading the relay firmware (Access Level 2). Select **System** > **File Management** (on the navigation pane) to upgrade your relay firmware (see *Figure 3.14*).

When preparing to upgrade the relay firmware, you must first download the new relay firmware. The firmware is designated with a .zds extension. Click **Browse** to navigate to and select the firmware you want to send to the relay, and click **Upgrade Firmware** to start the upgrade process (see *Figure 3.14*). See *Appendix B: Firmware Upgrade Instructions* for the complete firmware upgrade procedure.

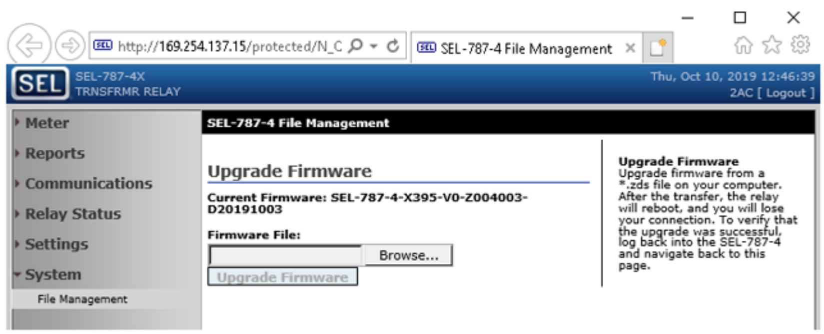

Figure 3.14 Upgrade Relay Firmware From the File Management Webpage

Language Support

The web server reports can be displayed in English or Spanish by setting the Ethernet Port 1 setting LANG to either ENGLISH or SPANISH.

QuickSet Software

This section describes how to get started with the SEL-787 and QuickSet. SEL provides many PC software solutions (applications) to support the SEL-787 Relay and other SEL devices. *Table 3.1* lists SEL-787 software solutions.

Table 3.1 SEL Software Solutions

Part Number	Product Name	Description
SEL-5030	ACSELERATOR QuickSet SEL-5030 Software	See *Table 3.2*
SEL-5032	ACSELERATOR Architect SEL-5032 Software	Configures IEC 61850 communications
SEL-5036	ACSELERATOR Bay Screen Builder SEL-5036 Software	Designs and manages bay screens in conjunction with SEL-5030 for the SEL-787 with the color touchscreen display
SEL-5040	ACSELERATOR Report Server SEL-5040 Software	Automatically retrieves, files, and summarizes reports
SEL-5601-2	SEL-5601-2 SYNCHROWAVE Event Software	Plots COMTRADE and SEL ASCII format event report oscillography; performs custom calculations on analog, digital, and complex quantities; and analyzes the Impedance Plane for distance element (mho) operation, the Alpha Plane for differential element (78L) operation, and the Bewley Lattice for traveling-wave data
SEL-5702	SEL-5702 Synchrowave Operations Software	Supports a variety of power system operations and analytics applications with high-resolution time-series data, real-time analytics, and GIS location information to improve operator situational awareness
SEL-5703	SEL-5703 Synchrowave Monitoring Software	Provides power system situational awareness by translating data into visual information; displays and analyzes time-synchronized synchrophasor data and relay event reports
SEL-5801	SEL-5801 Cable Selector	Selects the proper SEL cables for your application
SEL-5806	SEL-5806 Curve Designer Software	Designs user-defined, volts/Hz inverse-time characteristic curve to match any transformer characteristic (refer to *Section 4: Protection and Logic Functions*)

QuickSet is a powerful setting, event analysis, and measurement tool that aids in setting, applying, and using the SEL-787. *Table 3.2* shows the suite of QuickSet applications provided for the SEL-787.

Table 3.2 QuickSet Applications (Sheet 1 of 2)

Application	Description
Rules-Based Settings Editor	Provides online or offline device settings that include interdependency checks. Use this feature to create and manage settings for multiple devices in a database.
HMI	Provides a summary view of device operation. Use this feature to simplify commissioning testing.
Design Templates[a]	Allows you to customize relay settings to particular applications and to store those settings in design templates. You can lock settings to match your standards or lock and hide settings that are not used.
Event Analysis	Provides oscillography and other event analysis tools.
Bay Control	Allows you to design new bay screens and edit existing bay screens by launching the Bay Screen Builder software for SEL-787 Relays with the color touchscreen display.
Settings Database Management	QuickSet uses a database to manage the settings of multiple devices.

Table 3.2 QuickSet Applications (Sheet 2 of 2)

Application	Description
Terminal	Provides a direct connection to the SEL device. Use this feature to ensure proper communications and to directly interface with the device.
Help	Provides general QuickSet and device-specific QuickSet context.

[a] Available only in licensed versions of QuickSet.

Setup

Follow the steps outlined in *Section 2: Installation* to prepare the SEL-787 for use. Perform the following steps to initiate communications:

Step 1. Connect the appropriate communications cable between the SEL-787 and your PC.

Step 2. Apply power to the SEL-787.

Step 3. Start QuickSet.

Communications

QuickSet uses relay communications **Port 1** through **Port 4**, or **Port F** (front panel) to communicate with the SEL-787. Perform the following steps to configure QuickSet to communicate with the relay.

Step 1. Select **Communications** from the QuickSet main menu bar, as shown in *Figure 3.15*.

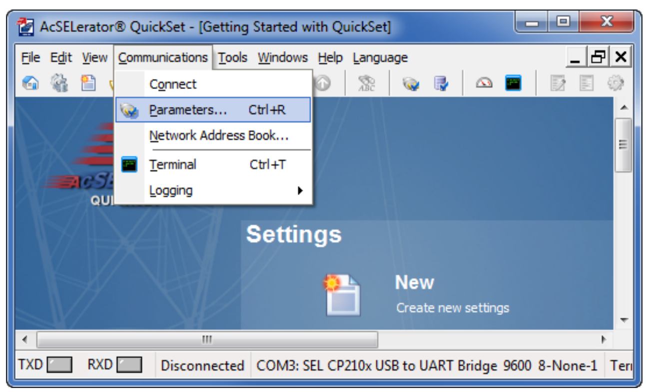

Figure 3.15 Communications Parameter Menu Selection

Step 2. Select the **Parameters** submenu to display the screen shown in *Figure 3.16*.

Step 3. Configure the PC port to match the relay communications settings.

Step 4. Configure QuickSet to match the SEL-787 default settings by entering the Access Level 1 and Access Level 2 passwords in the respective text boxes.

Step 5. For network communications, select **Network** from the Active Connection Type drop-down menu and enter the network parameters as shown in *Figure 3.17*.

For the SEL-787, always select FTP as the file transfer option.

Step 6. Exit the menu by clicking **OK** when finished.

NOTE: Factory-default passwords for Access Level 1 and 2 are OTTER and TAIL, respectively.

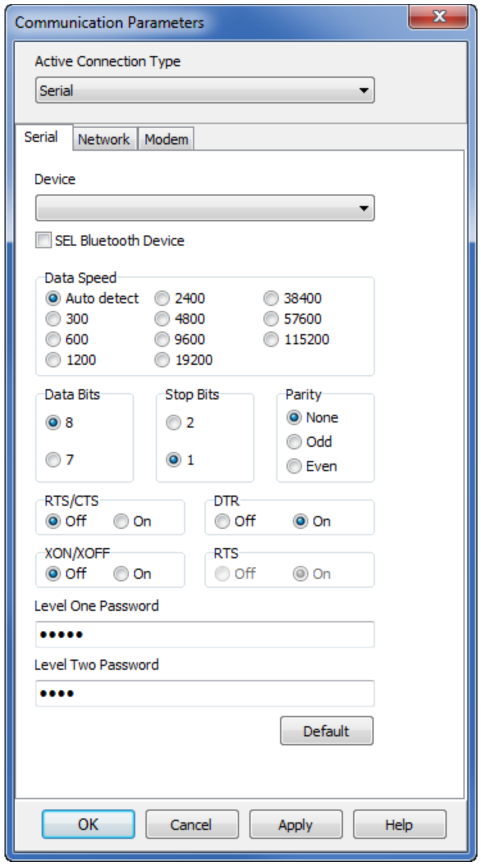

Figure 3.16 Serial Port Communication Parameters Dialog Box

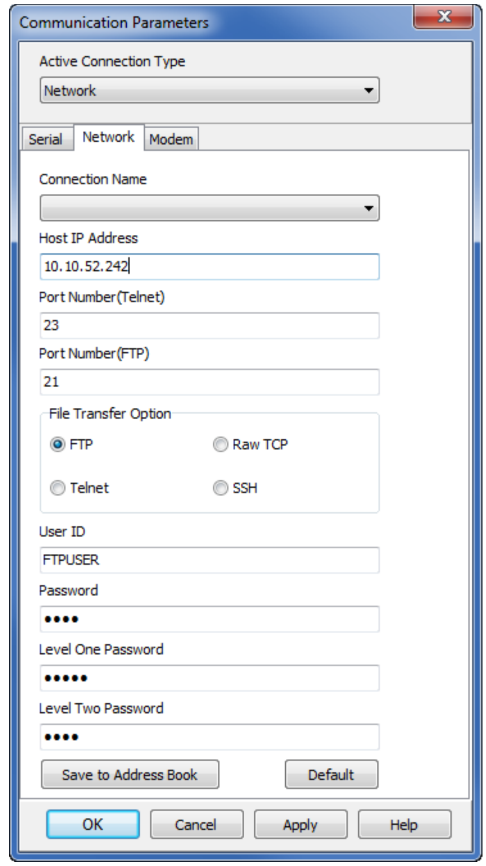

Figure 3.17 Network Communication Parameters Dialog Box

Terminal

Terminal Window

Select **Communications > Terminal** on the main menu bar (see *Figure 3.18*) to open the terminal window.

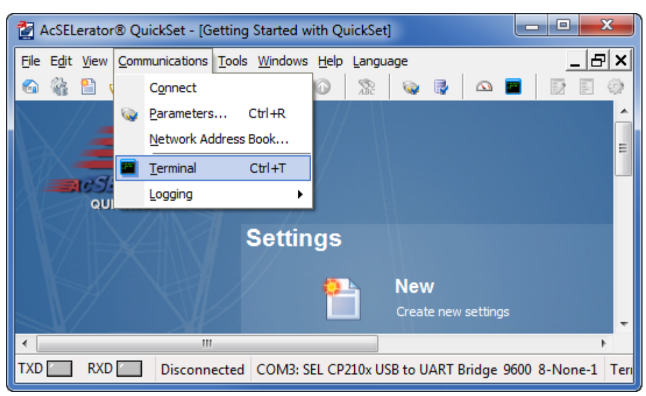

Figure 3.18 Communications Terminal Menu Selection

The terminal window is an ASCII interface with the relay. This is a basic terminal emulator. Many third-party terminal emulation programs are available with file transfer encoding schemes. Open the terminal window by either clicking **Communications > Terminal** or pressing **<Ctrl+T>**. Verify proper communications with the relay by opening a terminal window, pressing **<Enter>** a few times, and verifying that a prompt is received. If a prompt is not received, verify proper setup.

Terminal Logging

To create a file that contains all terminal communications with the relay, select **Communications > Logging > Terminal Logging**, and specify a file at the prompt. QuickSet records communications events and errors in this file. Click **Communications > Logging > Connection Log** to view the log. Clear the log by selecting **Communications > Logging > Clear Connection Log**.

Driver and Part Number

After clicking **Communications > Terminal**, access the relay at Access Level 1. Issue the **ID** command to receive an identification report, as shown in *Figure 3.19*.

NOTE: The SEL display package and customer display package versions are only displayed in the touchscreen display model.

```
=>ID <Enter>

"FID=SEL-787-4-X348-V0-Z003002-D20180412","091E"
"BFID=BOOTLDR-R501-V0-Z000000-D20140224","0947"
"CID=DD6C","027E"
"DEVID=SEL-787-3S","0483"
"DEVCODE=79","0317"
"PARTNO=07872EE1B0X0X7981A87X","0777"
"CONFIG=112112010","041C"
"SEL DISPLAY PACKAGE=1.0.40787.3460","0895"
"CUSTOMER DISPLAY PACKAGE=1.576351499","09A1"
"iedName=","0360"
"type=","026F"
"configVersion=","0609"
"LIB61850ID=3DB89FD6","04FF"
=>
```

Figure 3.19 Device Response to the ID Command

Locate and record the Z-number (Z003002) in the FID string. The first portion of the Z-number (Z003…) determines the settings driver version when you are creating or editing relay settings files in QuickSet. The use of the driver version is discussed in more detail in *Settings Editor on page 3.18*. Compare the part number (PARTNO=07873SXXXXXXXXXXXXXX) with the Model Option Table (MOT) to ensure the correct relay configuration. The SEL display package version can be found in *Table A.5*. The customer display (CDP) version has a unique ID code based on the total number of seconds from
1/1/2000 to the time stamp when the CDP was created and downloaded to the relay via QuickSet.

Settings Database Management and Driver

QuickSet uses a database to save the relay settings. QuickSet contains sets of all settings files for each relay specified in the database manager. Choose appropriate backup storage methods and a secure location for storing the database files.

Database Manager

Select **File > Database Manager** on the main menu bar to create new databases and manage records within existing databases.

Settings Database

Step 1. Open the database manager to access the database. Click **File > Database Manager**. A dialog box appears.

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

Step 2. Enter a description for the database in the Database Description text box.

Step 3. Enter special operating characteristics that describe the relay settings in the Settings Description text box. These can include the protection scheme settings and communications settings.

Step 4. Highlight a relay or settings file listed in Settings and click the **Copy** button to create a new set of settings.

QuickSet prompts for a new name. Be sure to enter a new description in Settings Description.

Copy/Move Settings Between Databases

Copy creates an identical device or settings file that appears in both databases. Move removes the device or settings file from one database and places the device or settings file in another database. To copy/move settings between settings databases, perform the following steps.

Step 1. Select the **Copy/Move Settings Between Settings Databases** tab to create multiple databases with the database manager; these databases are useful for grouping similar protection schemes or geographic areas.

Step 2. Click the **Settings Database B** [...] button to open a relay database.

Step 3. Type a filename and click **Open**.

a. Highlight a device or settings file in Settings Database A.

b. Click **Copy** or **Move**, and click the **>** button to create a new device or settings file in Settings Database B.

Step 4. Reverse this process to move or copy a device or settings file from Settings Database B to Settings Database A.

Create a New Database, Copy an Existing Database

To create a new database:

Step 1. Click **File > Database Manager**, and click **New**. QuickSet prompts you for a file name.

Step 2. Type the new database name (and select a new location if the new location differs from the existing one), and click **Save**. QuickSet displays the message `Settings [path and filename] was successfully created`.

Step 3. Click **OK**.

To copy an existing database of devices to a new database:

Step 1. Click **File > Database Manager**, and select the **Copy/Move Settings Between Settings Databases** tab.

QuickSet opens the last active database and assigns it as Settings Database A.

Step 2. Click the **Settings Database B** button; QuickSet prompts you for a file location.

Step 3. Type a new database name and click **Open**. Click **Yes**; the program creates a new empty database. Load devices or settings files into the new database as in *Copy/Move Settings Between Databases on page 3.15*.

Settings

QuickSet has the capability of creating settings for one or more SEL-787 Relays. Store existing relay settings downloaded from SEL-787 Relays with QuickSet. Create a library of relay settings, then modify and upload these settings from the settings library to an SEL-787. QuickSet makes setting the relay easy and efficient. However, you do not have to use QuickSet to configure the SEL-787; you can use an ASCII terminal or a computer running terminal emulation software. QuickSet provides the advantages of rules-based settings checks, SELOGIC control equation Expression Builder, operator control and metering HMI, event analysis, and help.

The QuickSet settings editor shows the relay settings in easy-to-understand categories. Settings are grouped logically, and relay elements that are not used in the selected protection scheme are not accessible. For example, if there is only one analog card installed in the relay, you can access settings for this one card only. Settings for the other slots are dimmed (grayed) in the QuickSet menu. QuickSet shows all of the settings categories in the settings tree view. The settings tree view remains constant whether settings categories are enabled or disabled.

Settings Menu

QuickSet uses a database to store and manage SEL relay settings. Each unique relay has its own settings records. Use the **File** menu to **Open** an existing record, create and open a **New** record, or **Read** relay settings from a connected SEL-787 and then create and open a new record. Click **Tools** > **Settings** > **Convert** to convert and open an existing record in the settings editor.

Table 3.3 File/Tools Menus

Menus	Description
<<, >>	Use these navigation menu buttons to move from one category to the next
New	Open a new record
Open	Open an existing record
Read	Read device settings and then create and open a new record
Convert	Convert and open an existing record

File > New

To make SEL-787 settings with the settings editor, click **File** > **New** on the main menu bar and select the SEL-787 and the latest driver version (00*X*) on the Settings Editor Selection screen, as shown in *Figure 3.20*.

QuickSet makes the new settings file using the driver that you specify in the Settings Editor Selection screen. QuickSet uses the Z-number in the FID-string to create a particular settings file.

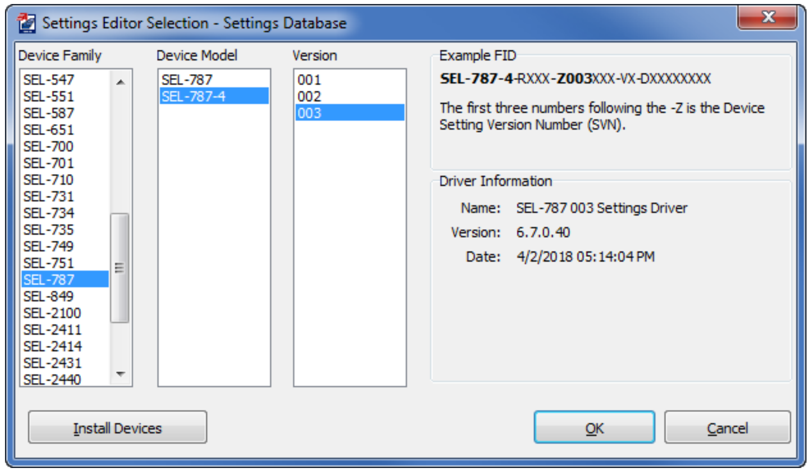

Figure 3.20 Driver Selection

After the relay model and settings driver selection, QuickSet presents the Device Part Number dialog box. Use this dialog box to configure the settings editor to produce settings for a relay with options determined by the part number, as shown in *Figure 3.21*. Click **OK** when finished.

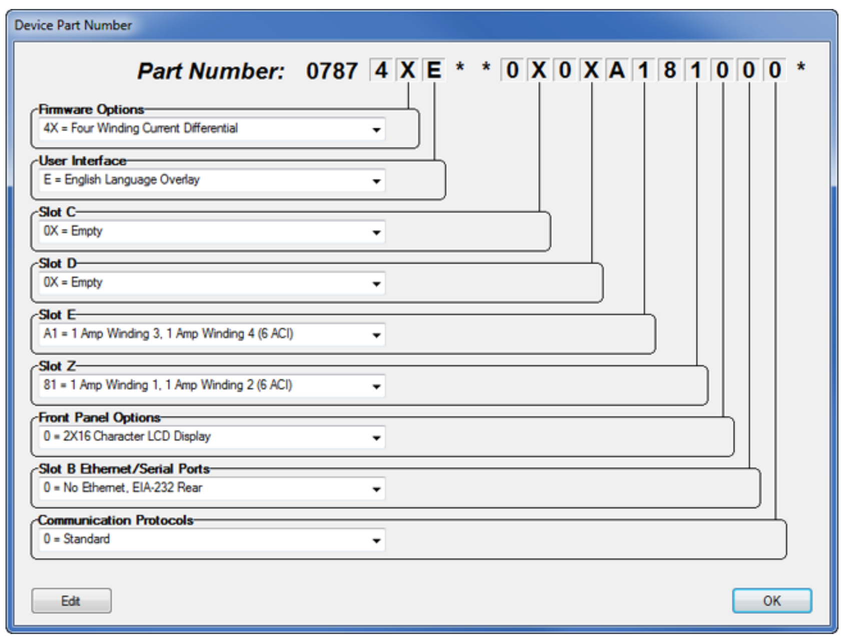

Figure 3.21 Update Part Number

Figure 3.22 shows the Settings Editor screen. Check the driver version number in the title bar of the Settings Editor screen. Compare the QuickSet settings driver number and the first portion of the Z-number in the FID string (select **Tools > HMI > HMI > Status**). These numbers must match. QuickSet uses this first portion of the Z-number to determine the correct settings editor to display.

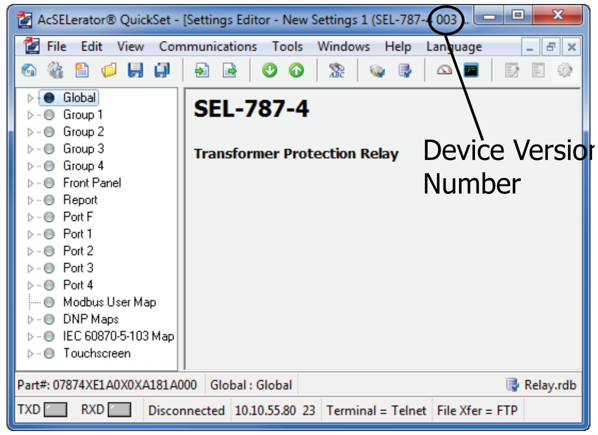

Figure 3.22 New Settings Editor Screen

File > Open

The **Open** menu item opens an existing device from the active database folder. QuickSet prompts for a device to load into the settings editor.

File > Read

When the **Read** menu item is selected, QuickSet uses serial protocols to read the device settings from the connected device. As QuickSet reads the device, a Transfer Status dialog box appears.

Tools > Settings > Convert

Use the **Convert** menu item (**Tools** > **Settings**) to convert from one settings version to another. Typically, this utility is used to upgrade an existing settings file to a newer version because devices are using a newer version number. QuickSet provides a Convert Settings report that shows missed, changed, and invalid settings created as a result of the conversion. Review this report to determine whether changes are necessary.

Settings Editor

Use the settings editor to enter settings. The settings editor includes the settings driver version (the first three digits of the Z-number) in the Settings Editor title bar.

Enter Settings

NOTE: Setting changes made during the edit session are not read by the relay unless they are transferred to the relay with the **Send** menu item.

Step 1. Click the ▷ drop-downs and the buttons in the settings tree view to expand and select the settings you want to change.

Step 2. Use **Tab** to navigate through the settings, or click a settings text box.

Step 3. To restore the previous value for a setting, right-click on the setting text box and select **Previous Value**.

Step 4. To restore the factory-default setting value, right-click on the setting text box and select **Default Value**.

Step 5. If you enter a setting that is out of range or has an error, QuickSet shows the error at the bottom of the settings editor. Double-click the error listing to go to the setting and enter a valid input.

Expression Builder

NOTE: Be sure to enable the functions you need (**Logic Settings > SELogic Enable**) before using Expression Builder.

SELOGIC control equations are a powerful means for customizing device performance. QuickSet simplifies this process with Expression Builder, a rules-based editor for programming SELOGIC control equations. Expression Builder organizes device elements, analog quantities, and SELOGIC control equation variables.

Access Expression Builder. Use the ellipsis button [...] that follows the settings text boxes in the settings editor to create an expression, as shown in *Figure 3.23*.

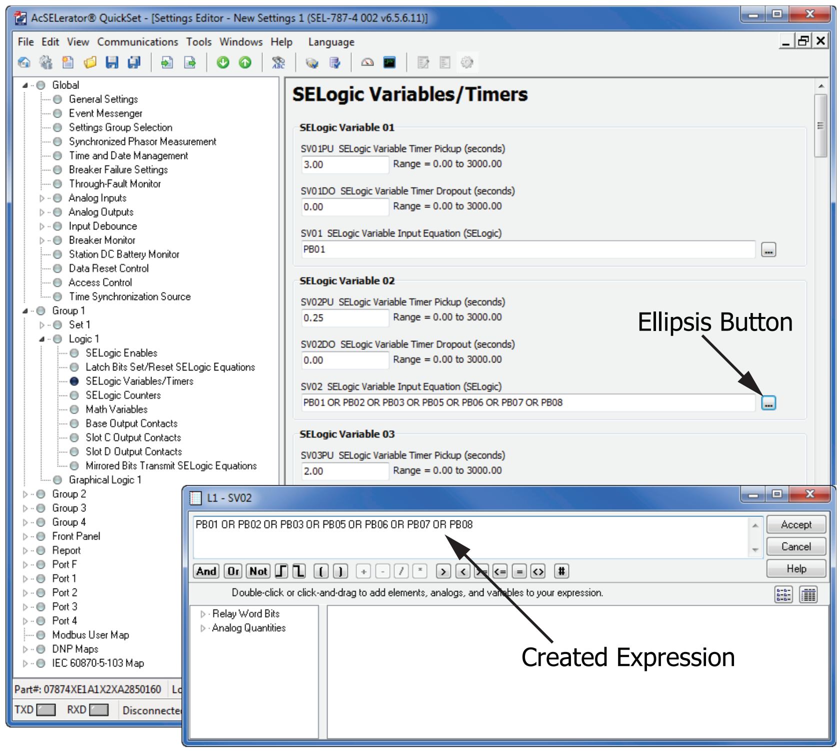

Figure 3.23 Expression Created With Expression Builder

Using Expression Builder. The expression builder screen is organized into three main parts: the expression builder text box, the left side column (which contains broad categories of device elements, analog quantities, counters, timers, latches, and logic variables), and the right side column (which displays category operands for use in the expression). Directly underneath the expression builder text box is a row of operators that you can include in your expression. The operators include basic logic, rising- and falling-edge triggers, expression compares, and comments.

Touchscreen Settings and Bay Screen Builder

The touchscreen settings are available when the touchscreen display option is selected as part of the front-panel options. This option provides you with the ability to design bay screen one-line diagrams with the help of Bay Screen Builder SEL-5036 Software. For more information, refer to *Bay Screens Design Using QuickSet and Bay Screen Builder on page 9.10*.

File > Save

Select **File** > **Save** once settings are entered into QuickSet to ensure that the settings are not lost.

File > Send

To transfer the edits made in the QuickSet edit session, you must send the settings to the relay by clicking **File** > **Send**. In the dialog box that opens, select the settings section(s) that you want to transfer to the relay by checking the appropriate box and click **OK**.

Edit > Part Number

Use the **Part Number** menu item to change the part number.

Text Files

Select **Tools > Settings > Import** or **Tools > Settings > Export** on the main menu bar to import or export settings from or to a text file. Use this feature to create a small file that can be easily stored or sent electronically.

Event Analysis

QuickSet has integrated analysis tools that help you retrieve information about relay operations quickly and easily. Use the event information that the SEL-787 stores to evaluate the performance of a system (select **Tools > Events > Get Event Files**). *Figure 3.24* shows the event retrieval screen.

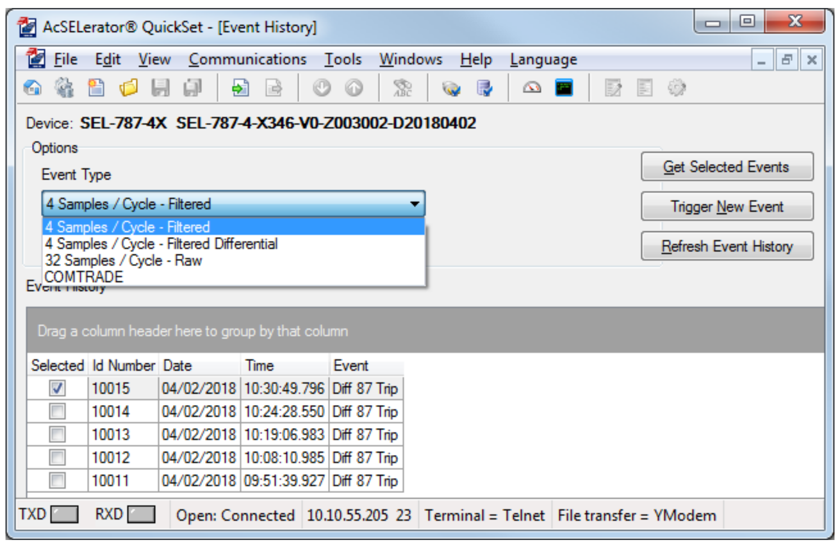

Figure 3.24 Retrieve Events Screen

You can retrieve event files stored in the relay and transfer these files to a computer. For information on the types of event files and data capture, see *Section 10: Analyzing Events*. To download event files from the device, click **Tools** > **Events** > **Get Event Files**. The Event History dialog box appears, as shown in *Figure 3.24*.

View Event History

The SEL-787 can capture two types of events (4 samples/cycle filtered and 32 samples/cycle raw). These events can be captured in either the compressed ASCII (.cev) or COMTRADE format. QuickSet allows you to download the .cev events. Use the Event Type drop-down shown in *Figure 3.24* to select the event type. For information on how to download COMTRADE events from the relay, see *Section 10: Analyzing Events*, *Retrieving COMTRADE Event Files*.

Get Event

Highlight the event you want to view (see *Figure 3.24*), select an event type from the Event Type list (4 samples filtered, 4 samples filtered differential, 32 samples raw, or COMTRADE), and click **Get Selected Event**. QuickSet then queries where to save the file on your computer, as shown in *Figure 3.25*.

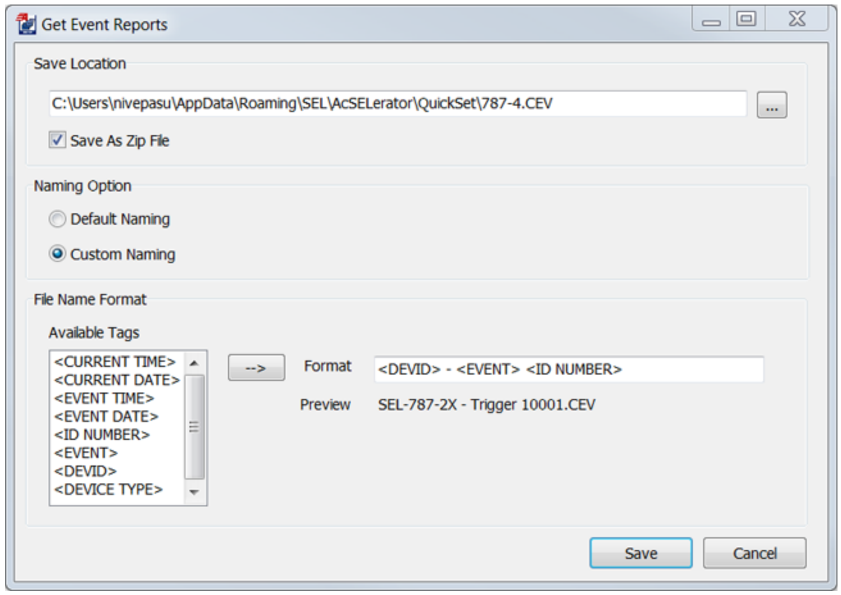

Figure 3.25 Save the Retrieved Event

When saving an event report, select a save location and a file name for your report. Select either **Default Naming** or **Custom Naming**. Default naming has predefined tags and organization, which appears in the Format text box when default naming is selected. You can use custom naming to create file names specific to your application by selecting and organizing your own tags (listed in Available Tags).

View Event Files

Click **Tools > Events** to view an event with SYNCHROWAVE Event. You can view multiple events by clicking on **Load Event** > **Add New Event** in the SYNCHROWAVE Event software.

Meter and Control

Click on **Tools > HMI > HMI** to display a screen similar to the one shown in *Figure 3.26*. The HMI tree view shows all the functions available in the HMI. Unlike the self-configuration of the device settings tree, the HMI tree remains the same regardless of the type of cards installed. For example, if no analog input card is installed, the analog input function is still available, but the relay responds as follows:

```
No Analog Input Card Present.
```

Device Overview

The Device Overview screen provides an overview of the device. The contact I/O portion of the screen displays the status of the two inputs and three outputs of the main board. You cannot change these assignments.

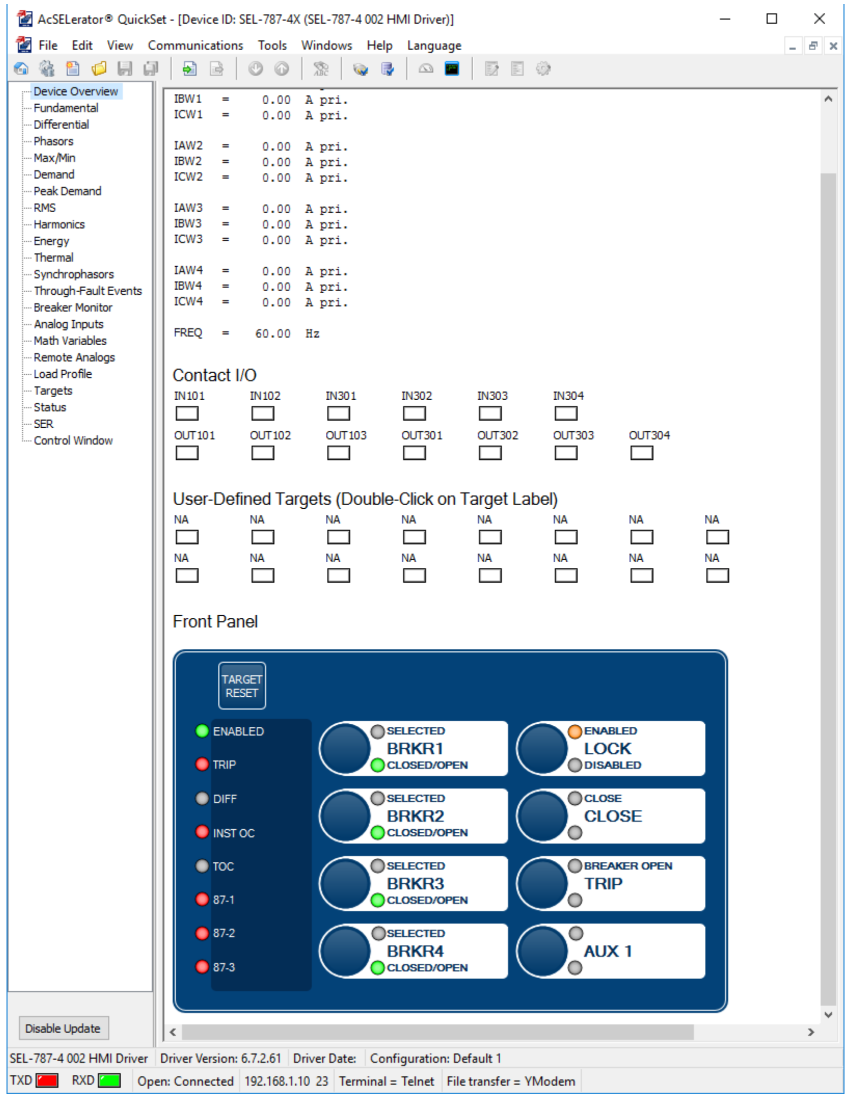

Figure 3.26 Device Overview Screen

You can assign any Relay Word bit to the 16 user-defined target LEDs. To change the present assignment, double-click on the text above the square you want to change. After double-clicking on the text, a box with available Relay Word bits appears in the lower left corner of the screen. Select the appropriate Relay Word bit, and click **Update** to assign the Relay Word bit to the LED. To change the color of the LED, click in the square and make your selection from the color palette.

The front-panel LED representation shown in QuickSet (see *Figure 3.27*) displays the status of the 16 front-panel LEDs. Use the front-panel settings to change the front-panel LED assignments. The Fundamental, Min/Max, Energy, etc., screens display the corresponding values.

Click on **Targets** in the tree view to see the status of all the Relay Word bits. When a Relay Word bit has a value of 1 (e.g., RB02 = 1), the Relay Word bit is asserted. When a Relay Word bit has a value of 0 (e.g., RB02 = 0), the Relay Word bit is deasserted.

The Status and SER screens display the same information as the ASCII **STA** and **SER** commands.

Figure 3.27 shows the control screen. From here, you can reset metering data; clear the event history, SER, MIRRORED BITS report, or LDP; trigger events; or view generator operating statistics. You can also reset the targets, synchronize with IRIG, or set the time and date.

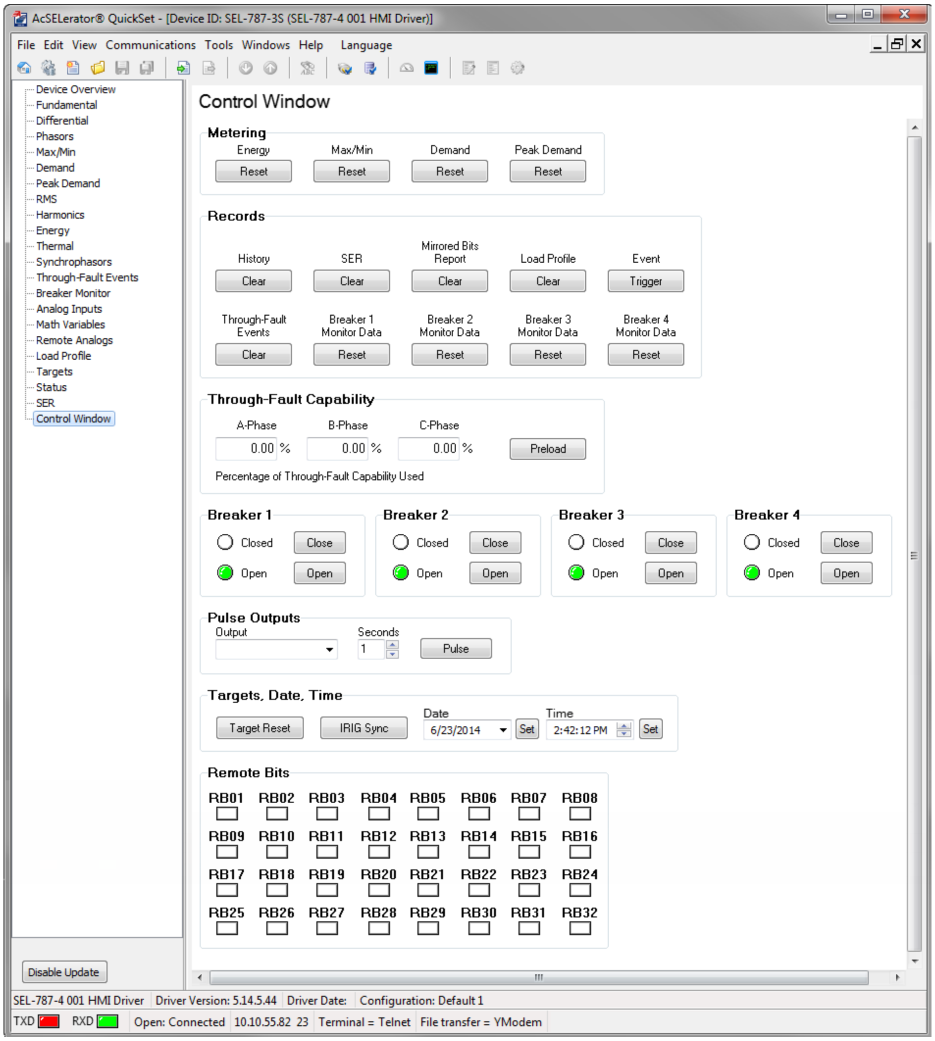

Figure 3.27 Control Screen

To control the remote bits, click on the appropriate square (RB01–RB32), then select the operation from the Remote Bits prompt, as shown in *Figure 3.28*.

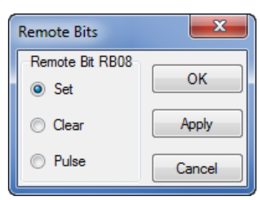

Figure 3.28 Remote Bit Operation Selection

Language Support

NOTE: If the SEL-787 is connected to any SEL communications processors (SEL-203x or RTAC), the corresponding LANG port setting must be set to ENGLISH.

QuickSet has multi-language support. Click **Language** to choose from English, Spanish, French, or Chinese, as seen in *Figure 3.29*. Selecting any of these choices converts the menu items in QuickSet to the selected language.

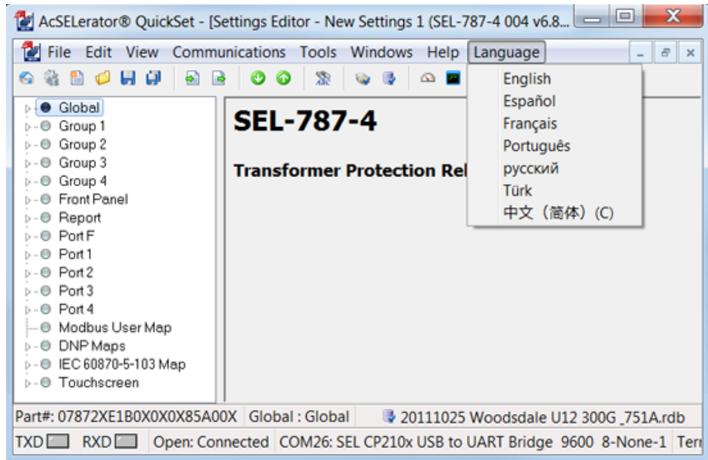

Figure 3.29 Language Support Options

Additionally, if Spanish or English is selected from the Language menu, the relay settings displayed by QuickSet are converted into the corresponding language, as shown in *Figure 3.30*.

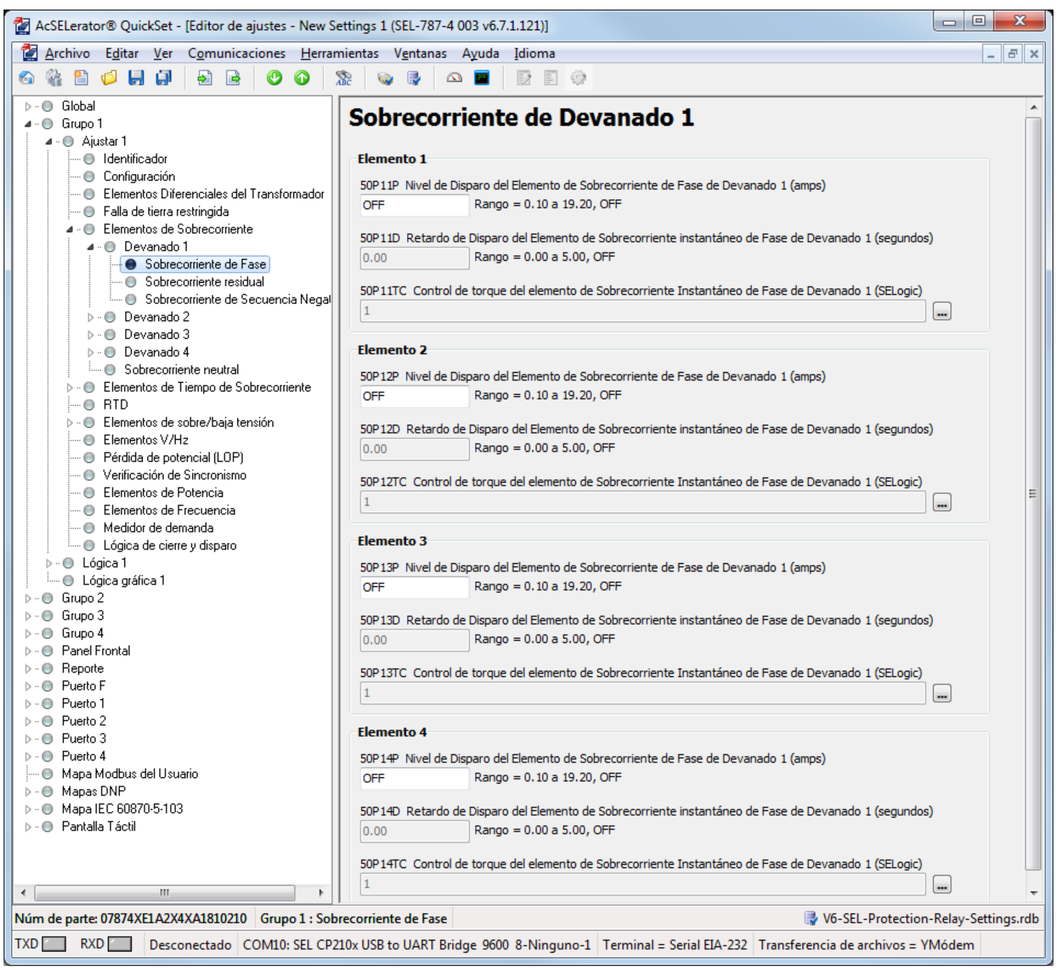

Figure 3.30 Spanish Settings QuickSet Display

NOTE: Once the HMI screen is displayed in QuickSet, the LANG setting does not affect the displayed HMI. To change the language of the HMI, the HMI must be closed, and the LANG setting must be changed, and the HMI reopened.

Each communications port (serial or Ethernet) on the SEL-787 can be independently set to display either English or Spanish. Changing the port setting LANG to SPANISH or ENGLISH results in the QuickSet HMI and all of its available functions to display in the corresponding language. For example, if the Control Window is selected in the HMI while the setting LANG := SPANISH, QuickSet displays the Control Window (Ventana de Control) in *Figure 3.31*.

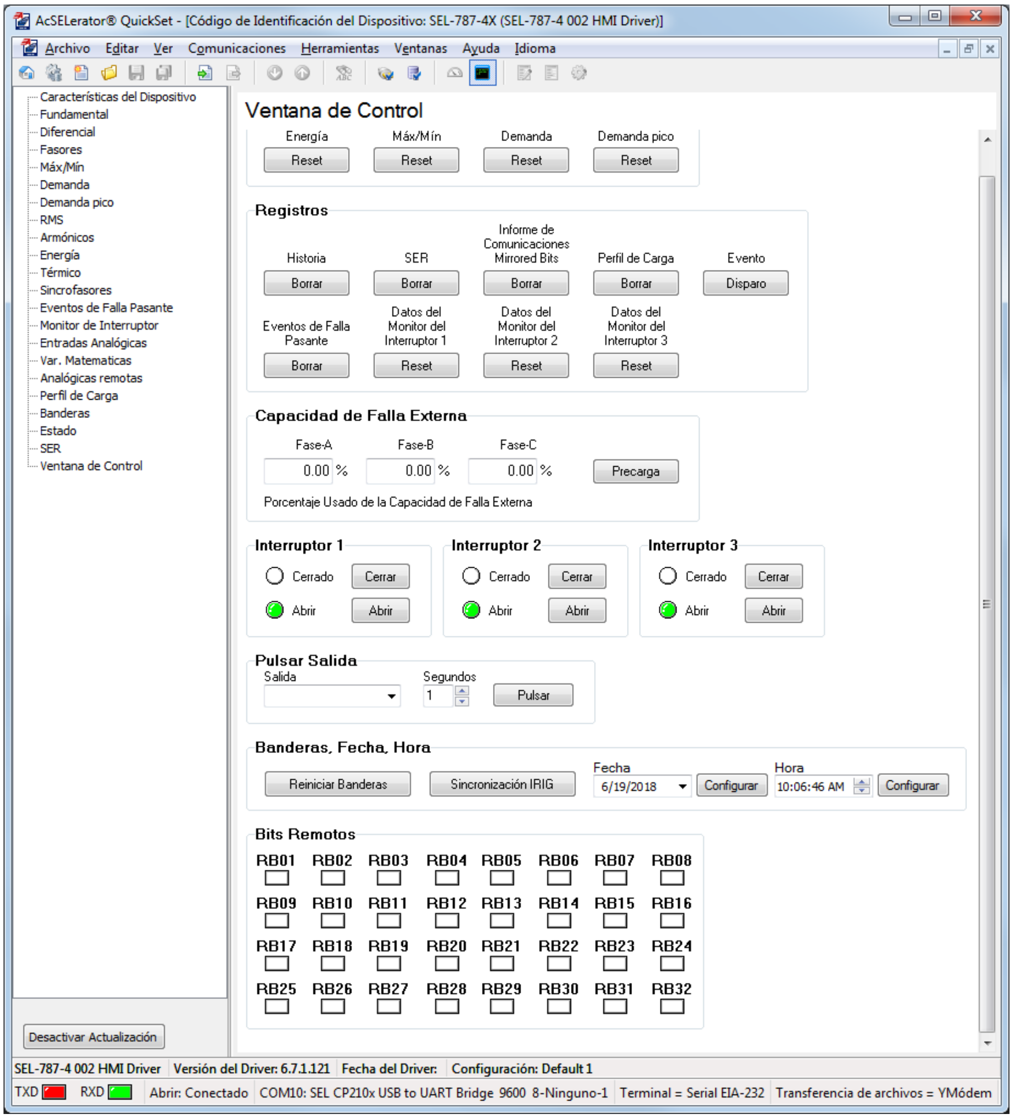

Figure 3.31 Spanish Control Window (Ventana de Control) Display

QuickSet Help

Various forms of QuickSet help are available, as shown in *Table 3.4*. Press **<F1>** to open a context-sensitive help file with the appropriate topic as the default.

Table 3.4 QuickSet Help

Help	Description
General QuickSet	Select **Help** from the main menu bar.
SEL-787 Settings	Select **Settings Help** from the **Help** menu bar while the settings editor is open.

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Section 4

Protection and Logic Functions

Overview

NOTE: Each SEL-787 is shipped with default factory settings. Calculate the settings for your application to ensure secure and dependable protection. Document and enter the settings (see Section 6: Settings).

This section describes the SEL-787 Transformer Protection Relay settings, including the protection elements and basic functions, control I/O logic, as well as the settings that control the communications ports and front-panel displays.

This section includes the following subsections:

Application Data. Lists information that you need to know about the protected equipment before calculating the relay settings.

Group Settings (SET Command).

ID Settings and Configuration Settings. Lists the ID settings and the settings that configure the relay inputs to accurately measure and interpret the ac current and voltage input signals.

VNOM Range Check. Identifies the VNOM range for DELTA and WYE-connected PT configurations.

Differential Element. Lists the settings to configure the differential element. Provides a description of the element operating characteristics, logic, setting calculations, and application guidelines.

Negative-Sequence Differential Element. Lists the settings to configure the differential element. Provides a description of the element operating characteristics, logic, and settings calculations.

Restricted Earth Fault Element. Lists the settings to configure the REF element. Provides a description of the element operating characteristics, logic, and settings calculations.

Overcurrent Elements. Lists the settings and logic associated with overcurrent elements.

Time-Overcurrent Elements. Lists the settings, logic, and time-overcurrent curves associated with the elements.

RTD-Based Protection. Lists settings associated with the RTD inputs. You can skip this subsection if your application does not include RTD inputs.

Under- and Overvoltage Functions. Lists settings associated with the optional ac voltage-based protection elements. You can skip this subsection if your relay is not equipped with optional voltage inputs.

Inverse-Time Undervoltage Protection. Lists the settings, logic, and inverse-time undervoltage curves associated with the elements.

Inverse-Time Overvoltage Protection. Lists the settings, logic, and inverse-time overvoltage curves associated with the elements.

Synchronism-Check Elements. Lists the settings and logic associated with the synchronism-check elements.

Volts Per Hertz Elements. Describes the settings, logic, and volts/hertz inverse-time characteristics associated with the element.

Power Elements. Lists the settings associated with the power elements.

Frequency Elements. Describes the settings and logic associated with the frequency elements.

Loss-of-Potential (LOP) Protection. Lists the logic and settings associated with the LOP element.

Demand Metering. Lists settings associated with demand metering.

Trip/Close Logic. Lists trip and close logic.

Logic Settings (SET L Command). Lists settings associated with latches, timers, and output contacts.

Global Settings (SET G Command). Lists settings that allow you to configure the relay to your power system, date format, analog inputs/outputs, and logic equations of global nature.

General Settings. Lists the global system settings such as phase rotation, nominal frequency, date format, etc.

Event Messenger Points. Describes the configuration of event messenger points.

Multiple Settings Groups. Lists the settings for active settings group selection and describes the configuration of active settings group selection via SELOGIC control equations.

Synchrophasor Measurement. Describes Phase Measurement Unit (PMU) settings for C37.118 Protocol.

Time and Date Management Settings. Lists settings for time and date management, describes the configuration of the settings, and lists the supported protocols.

Breaker Failure Setting. Lists the settings and describes the logic for the flexible breaker failure function.

Through-Fault Monitoring. Lists the settings and describes the through-fault monitoring function that you can use for scheduling transformer maintenance.

Analog Inputs. Describes analog input functionality, lists the settings, and provides an example.

Analog Outputs. Describes analog output functionality, lists the settings, and provides an example.

Station DC Battery Monitor. Describes the station dc battery monitor function and lists the settings.

Breaker Monitor. Lists the settings and describes the breaker monitor function that you can use for scheduling circuit breaker maintenance.

Digital Input Debounce. Provides the settings for digital input dc debounce or ac debounce mode of operation.

Data Reset. Lists the data reset SELOGIC control equation settings for resetting targets, energy metering, max/min metering, demand metering, and peak demand metering.

Access Control. Describes the SELOGIC control equation setting you would use for disabling settings changes from the relay front panel.

Time-Synchronization Source. Describes the setting you would use for choosing IRIG1 or IRIG2 as the time-synchronization source.

Disconnect Control Settings. Describes the settings and logic associated with the disconnects.

Local/Remote Control. Describes the local/remote function for controlling breakers and disconnects.

Port Settings (SET P Command). Lists settings that configure the relay front and rear ports.

Front-Panel Settings (SET F Command). Lists settings for the front-panel display, pushbuttons, and LED control.

Report Settings (SET R Command). Lists settings for the sequential event reports, event reports, and load profile reports.

DNP Map Settings (SET D Command). Shows DNP user map register settings.

Modbus Map Settings (SET M Command). Shows Modbus user map register settings.

EtherNet/IP Assembly Map Settings (SET E Command). Shows EtherNet/IP assembly map settings.

Touchscreen Settings. The touchscreen settings apply to relays that support the color touchscreen display. (The settings are supported in ACSELERATOR QuickSet SEL-5030 Software only.)

When you calculate the protection element settings, proceed through the subsections listed earlier. Skip the RTD, voltage-based, and frequency protection subsections if they do not apply to your specific relay model or installation.

See *Section 6: Settings* for the list of all settings (*SEL-787-2, -3, -4 Settings Sheets*) and various methods of accessing them. All current and voltage settings in the SEL-787 are in secondary.

NOTE: The DeviceNet port parameters can only be set at the rear of the relay on the DeviceNet card (see Figure I.1).

You can enter the settings by using the front-panel SET RELAY function (see *Section 8: Front-Panel Operations*), the serial ports (see *Section 7: Communications*), the DeviceNet port (see *Appendix I: DeviceNet Communications*), or the Ethernet port (see *Section 7: Communications*).

Application Data

NOTE: The terms winding and terminal are used interchangeably in this manual.

It is faster and easier for you to calculate settings for the SEL-787 if you collect the following information before you begin:

- Power transformer data: MVA rating, winding configurations and voltages, impedance, etc.
- Highest expected load current
- Current transformer primary and secondary ratings and connections
- System phase rotation and nominal frequency
- Voltage transformer ratios and connections, if used

- Type and location of resistance temperature detectors (RTDs), if used
- Expected fault current magnitudes for ground and three-phase faults

Group Settings (SET Command)

ID Settings

All models of the SEL-787 have the identifier settings described in *Table 4.1*.

Table 4.1 Identifier Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
UNIT ID LINE 1	16 characters	RID := SEL-787-*XX*[a]
UNIT ID LINE 2	16 characters	TID := TRNSFRMR RELAY

[a] XX can be 21, 2E, 2X, 3S, 3E, or 4X based on the MOT.

The SEL-787 prints the relay and terminal identifier strings at the top of the responses to serial port commands to identify messages from individual relays.

Enter as many as 16 characters, including letters A–Z (not case sensitive), numbers 0–9, periods (.), dashes (-), and spaces. Suggested identifiers include the location or number of the protected transformer.

Configuration Settings

Table 4.2 Configurations and Ratings (Phase CTs, Power Transformer) (Sheet 1 of 3)

Setting Prompt	Setting Range	Setting Name := Factory Default
WDG1 DIFF ENABLE	Y, N	E87W1 := Y
WDG2 DIFF ENABLE	Y, N	E87W2 := Y
WDG3 DIFF ENABLE	Y, N, REF	E87W3 := Y
WDG4 DIFF ENABLE	Y, N	E87W4 := Y
WDG1 CT CONN	DELTA, WYE	W1CT := WYE
WDG2 CT CONN	DELTA, WYE	W2CT := WYE
WDG3 CT CONN	DELTA, WYE	W3CT := WYE
WDG4 CT CONN	DELTA, WYE	W4CT := WYE
WDG1 PHASE CTR	1–50000/INOM1[a]	CTR1 := 100
CURR SENSOR TYPE	RCOIL, LPCT	CS_TYP1 := RCOIL
RATED PRI CURR	1–6000 A primary	IPR1 := 100
RATED SENS VOLT	10.0–1000.0 mV @ FNOM[b]	USR1 := 180.0
NOMINAL CURRENT	1 A[a]	INOM1 := 1
RATED FEEDER CUR	1–10000 A primary	FDR_CR1 := 100
PHASE ILEA SCALE	1.00–10000.00[d]	ILEA_S1 := 100.00
WDG2 PHASE CTR	1–50000/INOM2[a]	CTR2 := 1000
CURR SENSOR TYPE	RCOIL, LPCT	CS_TYP2 := RCOIL

Table 4.2 Configurations and Ratings (Phase CTs, Power Transformer) (Sheet 2 of 3)

Setting Prompt	Setting Range	Setting Name := Factory Default
RATED PRI CURR	1–6000 A primary	IPR2 := 100
RATED SENS VOLT	10.0–1000.0 mV @ FNOM[c]	USR2 := 180.0
NOMINAL CURRENT	1 A[a]	INOM2 := 1
RATED FEEDER CUR	1–10000 A primary	FDR_CR2 := 1000
PHASE ILEA SCALE	1.00–10000.00[d]	ILEA_S2 := 1000.00
WDG3 PHASE CTR	1–50000/INOM3[a,b]	CTR3 := 1000
CURR SENSOR TYPE	RCOIL, LPCT	CS_TYP3 := RCOIL
RATED PRI CURR	1–6000 A primary	IPR3 := 100
RATED SENS VOLT	10.0–1000.0 mV @ FNOM[c]	USR3 := 180.0
NOMINAL CURRENT	1 A[a]	INOM3 := 1
RATED FEEDER CUR	1–10000 A primary	FDR_CR3 := 1000
PHASE ILEA SCALE	1.00–10000.00[d]	ILEA_S3 := 1000.00
WDG3 A PHASE CTR	1–50000/INOM3[a,b]	CTR3A := 1000
CURR SENSOR TYPE	RCOIL, LPCT	CS_TYP3A := RCOIL
RATED PRI CURR	1–6000 A primary	IPR3A := 100
RATED SENS VOLT	10.0–1000.0 mV @ FNOM[c]	USR3A := 180.0
RATED FEEDER CUR	1–10000 A primary	FDR_CR3A := 1000
PHASE ILEA SCALE	1.00–10000.00[d]	ILEA_S3A := 1000.00
WDG3 B PHASE CTR	1–50000/INOM3[a,b]	CTR3B := 1000
CURR SENSOR TYPE	RCOIL, LPCT	CS_TYP3B := RCOIL
RATED PRI CURR	1–6000 A primary	IPR3B := 100
RATED SENS VOLT	10.0–1000.0 mV @ FNOM[c]	USR3B := 180.0
RATED FEEDER CUR	1–10000 A primary	FDR_CR3B := 1000
PHASE ILEA SCALE	1.00–10000.00[d]	ILEA_S3B := 1000.00
WDG3 C PHASE CTR	1–50000/INOM3[a,b]	CTR3C := 1000
CURR SENSOR TYPE	RCOIL, LPCT	CS_TYP3C := RCOIL
RATED PRI CURR	1–10000 A primary	IPR3C := 100
RATED SENS VOLT	10.0–1000.0 mV @ FNOM[c]	USR3C := 180.0
RATED FEEDER CUR	1–10000 A primary	FDR_CR3C := 1000
PHASE ILEA SCALE	1.00–10000.00[d]	ILEA_S3C := 1000.00
WDG4 PHASE CTR	1–50000/INOM4[a]	CTR4 := 1000
CURR SENSOR TYPE	RCOIL, LPCT	CS_TYP4 := RCOIL
RATED PRI CURR	1–6000 A primary	IPR4 := 100
RATED SENS VOLT	10.0–1000.0 mV @ FNOM[c]	USR4 := 180.0
NOMINAL CURRENT	1 A[a]	INOM4 := 1
RATED FEEDER CUR	1–10000 A primary	FDR_CR4 := 1000
PHASE ILEA SCALE	1.00–10000.00[d]	ILEA_S4 := 1000.00

Table 4.2 Configurations and Ratings (Phase CTs, Power Transformer) (Sheet 3 of 3)

Setting Prompt	Setting Range	Setting Name := Factory Default
BASE XFMR CAP	OFF, 0.2–5000.0 MVA	MVA := 50
DEFINE CT COMP	Y, N	ICOM := N
WDG1 CT COMP	0–12	W1CTC := 12
WDG2 CT COMP	0–12	W2CTC := 12
WDG3 CT COMP	0–12	W3CTC := 12
WDG4 CT COMP	0–12	W4CTC := 12
COMB CURR W1 W2	Y, N	CCW12 := N
COMB CURR W2 W3	Y, N	CCW23 := N
COMB CURR W3 W4	Y, N	CCW34 := N
WDG1 L-L VOLTS	0.200–1000.000 kV	VWDG1 := 138.000
WDG2 L-L VOLTS	0.200–1000.000 kV	VWDG2 := 13.800
WDG3 L-L VOLTS	0.200–1000.000 kV	VWDG3 := 13.800
WDG4 L-L VOLTS	0.200–1000.000 kV	VWDG4 := 13.800

[a] INOMn (n = 1, 2, 3, or 4) is part number dependent for convention CT inputs (1 A or 5 A). INOMn is a setting that is forced to 1 A for LEA current sensor inputs.
[b] When E87W3 := REF, the settings CTR3A, CTR3B, and CTR3C are available and setting CTR3 is hidden. When E87W3 := Y or N, CTR3 is available and CTR3A, CTR3B, and CTR3C are hidden.
[c] The setting range is 10.0–1000.0 mV and default USRn := 22.5 mV for CS_TYPn := LPCT (n = 1, 2, 3A, 3B, 3C, 4).
[d] Autocalculated and used to scale the primary currents to an equivalent secondary current used for the pickup thresholds.

The configuration settings for the SEL-787 are identified in *Table 4.2*. Based on the Model Option Table, the SEL-787 allows as many as four sets of three-phase current inputs. The E87W*n* (*n* = 1, 2, 3, or 4) setting specifies which of the terminals the relay is to include in the differential calculation. Set E87W*n* to Y or N depending on the application. You may not need all of the terminals to be included in the differential protection. The terminals not included in the differential element are still available for other protection such as standalone overcurrent protection. To enable the differential element, you need to set E87W*n* := Y for at least two windings.

The winding CT connection settings (W*n*CT, *n* = 1, 2, 3, or 4) are used to appropriately configure protection (differential, overcurrent, etc.) and power metering functions.

The CT ratio settings (CTR*n*, *n* = 1, 2, 3, or 4) configure the relay to accurately scale measured values and report the primary quantities. Calculate the phase CT ratios by dividing the primary rating by the secondary rating. You can configure Terminal 3 for restricted earth fault (REF) protection by setting E87W3 := REF. Under this configuration, the relay allows you to use the CT ratio of Terminal 3 on a per-phase basis (CTR3A, CTR3B, and CTR3C).

EXAMPLE 4.1 Phase CT Ratio Setting Calculations

Consider an application where the Winding 1 CT rating is 600:5 A.

Set CTR1 := 600/5 := 120.

The CS_TYP*n*, IPR*n*, USR*n*, FDR_CR*n*, ILEA_S*n* (*n* = 1, 2, 3, 3A, 3B, 3C, 4, N1), and INOM*m* (*m* = 1, 2, 3, 4, N1) settings are applicable to the relay with LEA current inputs. Set the current sensor type to RCOIL or LPCT using the CS_TYP*n* setting. Obtain the rated primary current (IPR*n*) and rated sensor voltage (USR*n*) from the LEA sensor. For RCOIL, use the IPR*n* and USR*n* values that correspond to the system nominal frequency (FNOM). Set the rated feeder current (FDR_CR*n*) setting to the load current in the feeder or the nominal primary current of a conventional CT that would otherwise be used. The ILEA_S*n* setting is autocalculated by the relay and is not available for setting. ILEA_S*n* is derived as the ratio of feeder current to nominal current, ILEA_S*n* := FDR_CR*n*/INOM*n*. Similarly to the LEA phase current inputs, the CS_TYPN1, IPRN1, USRN, INOMN1, FDR_CURN1, and ILEA_SN1 settings are applicable to the relay with neutral LEA current inputs. These settings are shown in *Table 4.3*. Refer to *LEA Current Inputs* for additional details.

Use the base transformer rating for the MVA setting.

The ICOM setting defines whether the input currents need any correction, either to accommodate phase shifts in the transformer or CTs or to remove zero-sequence components from the secondary currents. If this setting is Y, the relay permits the user, in the next group of settings, to define the amount of shift needed to properly align the secondary currents for the differential calculation.

The amount of compensation to each set of terminal currents is defined by settings W*n*CTC (*n* = 1, 2, 3, or 4) for respective Terminals 1, 2, 3, or 4. These settings properly account for phase shifts in transformer winding connections and also in CT connections. For example, this correction is needed if both wye and delta power transformer windings are present, but all of the CTs are connected in wye. The effect of the compensation is to create phase shift and removal of zero-sequence current components.

The combined winding overcurrent and power elements are available when the settings CCW12, CCW23, and CCW34 are set to Y. The relay allows you to combine currents on Terminals 1 and 2 by setting CCW12 := Y, Terminals 2 and 3 by setting CCW23 := Y, and Terminals 3 and 4 by setting CCW34 := Y. CCW12 and CCW34 can be enabled together. CCW23 cannot be enabled simultaneously with CCW12 or CCW34. For the relay to combine the currents at Terminals 1 and 2, the following criteria must be met.

- ➤ Nominal rating of both the relay current inputs must be equal (INOM1 = INOM2)
- ➤ Both CTs must be connected in WYE; DELTA connection is not supported (W1CT = W2CT = WYE)
- ➤ Both CT ratios (or LEA scales in the case of the LEA card) must be equal (CTR1 = CTR2 or ILEA_S1 = ILEA_S2)
- ➤ Nominal line-to-line terminal voltage ratings must be equal (VWDG1 = VWDG2)

The previous set of criteria can be extended to the CCW23 and CCW34 setting for Terminals 2 and 3 and Terminals 3 and 4.

Set VWDG*n* (*n* = 1, 2, 3, or 4) equal to corresponding terminal nominal line-to-line voltage. If the transformer differential zone includes a load tap-changer, assume that it is in the neutral position. The setting units are kilovolts.

Table 4.3 shows additional configuration settings for relay models with optional voltage and/or neutral CT inputs.

Table 4.3 Configurations and Ratings (Optional Neutral CT, Phase PT)

Setting Prompt	Setting Range	Setting Name := Factory Default
NEUT 1 CT RATIO	1–50000/INOMN1[a]	CTRN1 := 120
CURR SENSOR TYPE	RCOIL, LPCT	CS_TYPN1 := RCOIL
RATED PRI CURR	1–6000 A primary	IPRN1 := 100
RATED SENS VOLT	10.0–1000.0 mV @ FNOM[b]	USRN := 180.0
NOMINAL CURRENT	1 A[a]	INOMN1 := 1
RATED FEEDER CUR	1–10000 A primary	FDR_CRN1 := 100
NEUT ILEA SCALE	1.00–10000.00[c]	ILEA_SN1 := 100.00
PHASE PT RATIO	1.00–10000.00	PTR := 120
PHASE LPVT RATIO	37.50–500000.00	LEA_R := 4500
PHASE LPVT SCALE	1.00–13333.33[d]	LEA_SC := 120
SYNCV PT RATIO	1.00–10000.00	PTRS := 180
SYNCV LPVT RATIO	37.50–500000.00	LEA_S_R := 180
SYNCV LPVT SCALE	1.00–13333.33[d]	LEA_S_SC := 4.80
NOMINAL VOLTAGE	0.20–1000.00 kV	VNOM := 13.8
PT CONNECTION	DELTA, WYE	DELTA_Y := DELTA
VOLT-CURR WDG	1, 2, 3[e] or 1, 2, 3, 12[f] or 1, 2, 3, 23[g] or 1, 2[h]	VIWDG := 2
COMP ANGLE	0–360°	COMPANG := 0
SINGLE V INPUT	Y, N	SINGLEV := N

[a] INOMN1 is part number dependent for conventional CT inputs (1 A or 5 A). INOMN1 is a setting that is forced to 1 A for LEA current sensor inputs.
[b] The setting range is 10.0–1000.0 mV and default USRN1 := 22.5 mV for CS_TYPN1 := LPCT.
[c] Autocalculated and used to scale the primary currents to an equivalent secondary current used for the pickup thresholds.
[d] Autocalculated.
[e] This setting range is applicable when the setting CCW12 := N.
[f] This setting range is applicable when the setting CCW12 := Y.
[g] This setting range is applicable when the setting CCW23 := Y.
[h] This setting range is applicable to the SEL-787-2E model and the SEL-787-3E or SEL-787-3S model when E87W3 = REF.

Neutral CT ratio setting is used to convert the current input to primary, similar to the phase CT ratio settings.

The remaining settings shown in *Table 4.3* configure the optional relay voltage inputs to correctly measure and scale the voltage signals. Set the phase PT ratio (PTR) setting equal to the VT ratio (see *Example 4.2* for sample calculations). The synchronism-check voltage input VS is an optional single phase-to-neutral or phase-to-phase voltage input. Set the synchronism-check voltage input PT ratio (PTRS) setting equal to the VT ratio of the VS input. The PTRS setting is available only if the VS_VBAT setting is set to VS under the Global settings.

EXAMPLE 4.2 Phase VT Ratio Setting Calculations

Consider a 13.8 kV transformer application where 14400:120 V rated voltage transformers (connected in open delta) are used.

Set PTR := 14400/120 := 120, VNOM := 13.8, and DELTA_Y := DELTA.

Set the phase LEA ratio (LEA_R) setting equal to the marked LEA sensor ratio. Set the synchronism-check voltage input LEA ratio (LEA_S_R) setting equal to the marked LEA sensor ratio of the VS input.

EXAMPLE 4.3 Phase VT Ratio Setting Calculations

Consider a 13.8 kV feeder application where a 2500:1 ratio LEA sensor (connected in wye) is used.

Set LEA_R := 2500/1 := 2500.

VNOM is the rated transformer line-to-line voltage in kV at the protected winding determined by setting VIWDG. Consider the transformer tap when calculating this setting. For example, a 345 kV transformer set on the 327.75 kV TAP would have VNOM := 327.75. VNOM is used by the *Volts Per Hertz Elements* and the *Loss-of-Potential (LOP) Protection*.

When phase-to-phase potentials are connected to the relay, set DELTA_Y to DELTA. When phase-to-neutral potentials are connected to the relay, set DELTA_Y to WYE.

Use the VIWDG setting to tell the relay which winding current to use when calculating power for the meter report. For example, set VIWDG := 2 when the voltage inputs to the relay are derived from Winding 2 side. Set VIWDG := 12 when the voltage inputs to the relay are common to Windings 1 and 2 and CCW12 := Y.

The COMPANG setting adjusts the power metering to account for angular differences that may be present resulting from delta connected CTs. Set the COMPANG equal to the angle by which the current input lags the corresponding phase voltage input (e.g., IA and VA inputs) at unity power factor.

In applications where only a single voltage is available, set SINGLEV equal to Y. As shown in *Figure 2.22*, the single voltage must be connected to the A-phase input, but it may be an A-N or an A-B voltage. Be sure to set DELTA_Y equal to WYE for an A-N input or DELTA_Y equal to DELTA for an A-B input voltage. When you set SINGLEV equal to Y, the relay performance changes in the following ways:

- **Power and Voltage Elements**. When you use one voltage, the relay assumes that the system voltages are balanced in both magnitude and phase angle. Power, power factor, and positive-sequence impedance are calculated assuming balanced voltages.
- **Metering.** When you use one voltage, the relay displays magnitude and phase angle for the measured PT. The relay displays zero for the magnitudes of the unmeasured voltages. Balanced voltages are assumed for power, power factor, VG, V1, and 3V2 metering.
- **Event Reports.** When you use one voltage, the event report shows the measured magnitudes of the connected voltage. The unmeasured voltage magnitudes are reported as zero.

DELTA_Y	SINGLEV	Event Report Voltages
DELTA	Y	VAB, VBC, VCA = 0.0
WYE	Y	VA, VB, VC = 0.0

Relays that are not equipped with phase voltage inputs hide these settings and disable voltage-based protection and metering functions.

Low-Energy Analog (LEA) Sensor Inputs

LEA sensors for measurement of primary voltages and currents are gaining popularity because of their excellent linearity and dynamic range characteristics, reduced size, reduced weight, and enhanced personnel safety. Typically, Rogowski coils and low-power CTs (LPCT) are used for current measurements, and low-power VTs (LPVT) are used for voltage measurements. The SEL-787 offers different card options for receiving signals from these sensors. Refer to the SEL-787 Model Option Table, available at selinc.com, for all the variants.

LEA Current Inputs

The SEL-787 can be ordered with either a conventional card or an LEA input card. The LEA input card complies with the LEA specifications defined in the IEC 61869-13 standard. The card is compatible with low-power instrument transformers that comply with IEC 61869-10 and IEC 61869-11 standards and supports sensors having outputs compliant with the IEEE C37.92 standard.

The current channels of an LEA input card support two types of sensors: LPCTs and Rogowski coils. LPCTs are conventional CTs equipped with an internal shunt resistor that generates an output voltage proportional to the primary current. A Rogowski coil produces an output voltage proportional to the rate of change of the primary current. When operating in the Rogowski coil mode, the SEL-787 uses an internal hardware integrator to produce a signal proportional to the primary current.

Considerations for Selecting Rogowski Coil/LPCT

Rogowski coils and LPCT sensors support an exceptionally wide dynamic range that may be 20 or more times wider than the conventional CT; in practice, this means that a single 100 A sensor may be able to protect circuits with loads going as high as 2,000 A. Voltage output produced by such a sensor may easily exceed 100 V during the fault. To accommodate the wide range of applications made possible by the low-energy sensors, the SEL-787 adjusts its current-channel gain, allowing the relay to support Rogowski coil sensors with output between 4–128 V full scale rms during the fault. The SEL-787 is designed to measure as much as 30 times the nominal feeder current without clipping. The choice of Rogowski coil and feeder current should be made such that calculated clipping voltage is within 4–128 Vrms range for Rogowski coils and 1–8 Vrms for LPCTs. Refer to *Example 4.4* for calculation of clipping voltages for the Rogowski coils and *Example 4.5* for calculation of the clipping voltages for the LPCT-based sensors.

EXAMPLE 4.4 Clipping Voltage Calculation for Rogowski Coil

Assume a Rogowski coil sensor with the following data and relay settings:

FNOM = 60 Hz
CS_TYPn = RCOIL
IPRn = 100 A
USRn = 180 mV at 60 Hz
INOMn = 1 A

FDR_CRn = 800 A
ILEA_Sn = 800/1 = 800, is auto-calculated
Sensor output voltage at 800 A = 180 mV/100 • 800 = 1.44 Vrms
Clipping Voltage = 1.44 Vrms • 30 = 43.2 Vrms

EXAMPLE 4.5 Clipping Voltage Calculation for LPCT

Assume an LPCT sensor with the following data:

CS_TYPn = LPCT
IPRn = 100 A
USRn = 22.5 mV
INOMn = 1 A
FDR_CRn = 800 A
ILEA_S1 = 800/1 = 800, is saved in CTR (auto-calculated)
Sensor output voltage at 800 A = 22.5 mV/100 • 800 = 180 mVrms
Clipping Voltage = 180.0 mV • 30 = 5.4 Vrms

Secondary Current Calculation for LEA Current Inputs

Relays with LEA current inputs calculate a secondary current equivalent to that measured by conventional current input cards. This secondary current is equal to the primary current divided by the scaling factor ILEA_S*n*, which is autocalculated by the relay as ILEA_S*n* = FDR_CR*n*/INOM*n*. Because INOM*n* := 1 A in the LEA relay, this simplifies to ILEA_SC*n* := FDR_CR*n*.

Example 4.6 explains the conversion of an instantaneous overcurrent element pickup setting from a conventional 4 ACI card to an equivalent setting for the LEA input card.

EXAMPLE 4.6 Setting Conversion

Consider an application with a conventional CT card with a 1200/5 = 240 CT ratio and a pickup setting for an instantaneous overcurrent element of 50P11P = 15 A secondary. The equivalent 50P1P setting for an LEA current input card (Rogowski coil or LPCT sensor) can be calculated as shown below.

First convert 50P11P setting to primary amperes, $I_{primary}$ = 15 * 240 = 3600 A primary.

Calculate 50P11P settings in secondary amperes for each of the LEA cards as shown in the table below.

The corresponding 50P11P settings in both conventional and LEA relays will pick up for the same primary current.

Settings/Calculations	Rogowski Coil	LPCT
IPR1	80 A	100 A
USR1	180 mV @ 60 Hz	22.5 mV
FDR_CR1	1500	1000
INOM1	1	1
ILEA_S1	1500 (autocalculated)	1000 (autocalculated)
50P11P = $I_{primary}$/ILEA_S1	3600/1500 = 2.4 A secondary	3600/1000 = 3.6 A secondary

LEA Voltage Inputs

The SEL-787 can be ordered with different secondary ac input voltage configurations—conventional voltage inputs rated for 300 V and LEA voltage inputs rated for 8 V. The LEA voltage inputs are suitable for IEEE C37.92-

compliant high-impedance sensors, such as capacitive voltage dividers and resistive voltage dividers (see *Figure 4.1*).

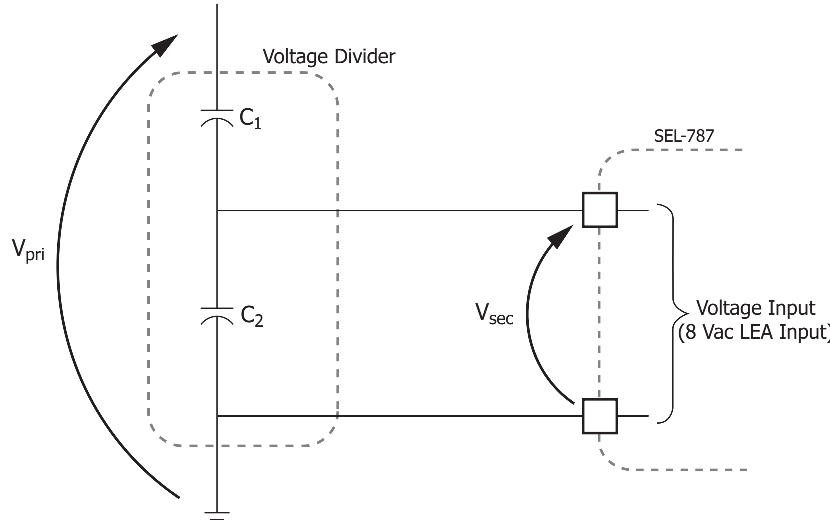


Figure 4.1 Low-Energy Analog Voltage Sensor (Capacitive Voltage Divider)

Derived LEA Scale for 8 Vac LEA Voltage Inputs and Voltage-Related Settings

Irrespective of the voltage input option, conventional (300 Vac) or LEA (8 Vac), all the voltage-related settings are based at 300 V. For example, the 59 element pickup range for conventional voltage inputs is 2.0–300.0 V and this range will remain the same for LEA inputs. To maintain the same 300 V base across different voltage options, such as LEA inputs, the relay scales up the input signal by a factor of 37.5 (300 V/8 V). Likewise, you can scale the voltage-related pickup settings to convert the settings from 8 V to 300 V base. Refer to *Example 4.7*. With LEA voltage inputs, the relay sees 8 Vac on the voltage inputs as 300 Vac secondary (8 • 37.5 = 300 V). Further, to realize accurate primary voltage metering, the relay uses the derived LEA scales, LEA_SC and LEA_S_SC. These scale factors are autocalculated by the relay based on LEA_R and LEA_S_R settings, respectively. The LEA scale is derived as follows:

LEA_SC = LEA_R • (8/300)

where LEA_R is the marked LEA sensor ratio.

The ratio of V_{pri} to V_{sec} of the voltage divider shown in *Figure 4.1* is referred to as true ratio. Ideally, the marked LEA sensor ratio should equal the true ratio. If not, apply the following additional ratio correction factors.

For example, if an LEA sensor has an LEA sensor ratio of 1400:1,

LEA_R = 1400

LEA_SC = 1400 • 8/300 = 37.33

EXAMPLE 4.7 Voltage Setting Conversion to 300 V Base

A voltage divider (10000 ratio) is connected between a 12.47 kV system (7.2 kV line-to-neutral) and the LEA inputs.

7200 V / 10000 = 0.72 V
(actual voltage divider output to the 8 Vac LEA inputs;
8 V base)

0.72 V • (300/8) = 27 V

(the relay thinks it is looking at 27 V on a 300 V base, not 0.72 V on an 8 V base)

27 V is the nominal adjusted secondary voltage—adjusted by the 300/8 factor from an 8 V base to a 300 V base. For this same example, if a 0.8 V output of the 8 Vac LEA (8 V base) is deemed an overvoltage condition, then an overvoltage element pickup setting (e.g., 59P1P) could be set at 59P1P = 0.8 V • (300/8) = 30 V (300 V base).

LEA Ratio and Angle Correction Factors (Global Settings)

In the SEL-787 with LEA inputs, Global settings VARCF, VBRCF, VCRCF, VSRCF, IAW*n*RCF, IBW*n*RCF, ICW*n*RCF, VAPAC, VBPAC, VCPAC, VSPAC, IAW*n*PAC, IBW*n*PAC, and ICW*n*PAC are applied to the respective voltage and current inputs, **VA**, **VB**, **VC**, **VS**, **IAWn**, **IBWn**, and **ICWn**. These normalized secondary voltages and currents are used throughout the SEL-787. Refer to *Table 4.52* through *Table 4.54* under Global Settings for these settings.

Ratio Correction Factors (RCF) for LEA Inputs

The ratio correction factor (RCF) settings minimize the magnitude error by compensating for the irregularities (on a per-phase basis) introduced by LEA sensors. The derivation of the RCF value for a voltage divider for a particular phase is defined as follows:

$$\mathrm{RCF} = \frac{\text{True ratio}}{\text{Marked ratio}} = \frac{V_{pri}/V_{sec}}{\mathrm{LEA\_R}} = \frac{V_{pri}}{V_{sec} \bullet \mathrm{LEA\_R}}$$

Equation 4.1

where:

V_{pri} = Test voltage applied to the primary side of the voltage divider

V_{sec} = Resultant voltage measured on the secondary side of the voltage divider

True ratio = V_{pri} / V_{sec}

Marked ratio = LEA_R = effective nominal LEA sensor ratio of the voltage divider connected between the primary voltage system and the LEA input.

Similarly, the RCF value for current sensors is defined as follows:

$$\mathrm{RCF} = \frac{\text{True ratio}}{\text{Marked ratio}} = \left(\frac{I_{Pri}}{\text{Sensor output voltage}}\right) \Big/ \left(\frac{\mathrm{IPR}}{\mathrm{USR}}\right)$$

Equation 4.2

where:

I_{Pri} = Test primary current passing through the Rogowski coil or low-power CT

Sensor output voltage	=	Resultant voltage generated at the terminals of the sensor
IPR and USR	=	Sensitivity parameters of the sensor used

The marked LEA sensor ratio of the voltage divider or transformation ratio for the Rogowski coil sensor is always provided by the manufacturer and often the per phase RCF values are also provided.

If the voltage divider is perfect, then

V_{pri} / V_{sec} = LEA_R and RCF = 1.000

Therefore, the measured voltage divider performance equals the marked ratio of the voltage divider, as given by the manufacturer. But such perfect conditions are usually not the case.

If the voltage divider is putting out more voltage (V_{sec}) than nominally expected for an applied voltage input (V_{pri}), then

V_{pri} / V_{sec} < LEA_R and RCF < 1.000

An example of an RCF value less than 1.000 is found in *Example 4.8*. In this example, setting VBRCF = 0.883 brings down the too-high voltage on voltage input **VB** (0.82 V is brought down to nominal 0.72 V).

If the voltage divider is putting out less voltage (V_{sec}) than nominally expected for an applied voltage input (V_{pri}), then

V_{pri} / V_{sec} > LEA_R and RCF > 1.000

Similar conclusions can be drawn for Rogowski coil and LPCT current sensors.

EXAMPLE 4.8 Normalizing Voltages With Ratio Correction Factors

A voltage divider is connected to the 8 Vac LEA voltage inputs (see Figure 4.1). The RCF values per phase for the voltage divider are given as follows:

V_{ARCF} = 1.078 (voltage input **VA**)
V_{BRCF} = 0.883 (voltage input **VB**)
V_{CRCF} = 1.112 (voltage input **VC**)

The marked ratio of the voltage divider is given as:

LEA_R = 10000

What are the true ratios of each phase of the voltage divider?

true ratio = V_{pri}/V_{sec}

V_{pri} and V_{sec} are measured in manufacturer tests to derive RCF values as shown in Equation 4.1 and accompanying explanation. From Equation 4.1:

RCF • LEA_R = V_{pri}/V_{sec} = true ratio
1.078 • 10000 = 10780 (true ratio for voltage input **VA**)
0.883 • 10000 = 8830 (true ratio for voltage input **VB**)
1.112 • 10000 = 11120 (true ratio for voltage input **VC**)

Note that these true ratios vary from 8830 to 11120, while the marked ratio of the voltage divider is given as 10000.

Consider *Example 4.8*. Assume the primary voltage (V_{pri}) is the same magnitude for each phase. When this primary voltage is run through the respective true ratios, the secondary voltage outputs vary widely. Presuming a primary voltage of 12.47 kV (7.2kV line-to-neutral), the resultant secondary voltages are as follows:

7200 V / 10780 = 0.67 V (true secondary voltage to voltage input **VA**)

7200 V / 8830 = 0.82 V (true secondary voltage to voltage input **VB**)

7200 V / 11120 = 0.65 V (true secondary voltage to voltage input **VC**)

Note that the true secondary voltages to voltage inputs **VA** and **VC** are running low (below the normalized secondary voltage 0.72 V = 7200 V / 10000), while the voltage to voltage input **VB** is running high (above the normalized secondary voltage 0.72 V). But the RCF values adjust these true secondary voltages to normalized secondary voltage:

0.67 V • 1.078 = 0.72 V (normalized voltage from voltage input **VA**)

0.82 V • 0.883 = 0.72 V (normalized voltage from voltage input **VB**)

0.65 V • 1.112 = 0.72 V (normalized voltage from voltage input **VC**)

Again, the normalized secondary voltage (0.72 V) is the same for all three phases in this example, because the primary voltage is assumed to be the same magnitude for each phase (7200 V). The relay uses these normalized secondary voltages for all the voltage-based protection elements and metering. The true secondary voltages cannot be seen (via the SEL-787) unless the RCF values are set to unity (RCF := 1.000).

Phase Angle Compensation (PAC) for LEA Inputs

Use the VAPAC, VBPAC, VCPAC, and VSPAC voltage phase-angle correction Global settings for the voltage inputs **VA**, **VB**, **VC**, and **VS**, respectively. Use the IAW*n*PAC, IBW*n*PAC and ICW*n*PAC current phase-angle correction Global settings for the current inputs **IAWn**, **IBWn**, and **ICWn**, respectively. These settings compensate for the phase error caused by the LEA sensor and the cable connected to the relay. Use a positive phase-angle correction setting if the resulting phase error is negative and vice versa. For example, if the resulting phase error on the **VA** input is –1.00 degree, then set VAPAC := 1.00 degrees.

VNOM Range Check

The relay performs a range check for the VNOM setting that depends upon the voltage-input delta or wye configuration. Valid nominal voltage is 100–250 V secondary (l-l) when DELTA_Y is DELTA; it is 100–480 V when DELTA_Y is WYE.

Note that the VNOM setting is always in line-to-line primary kV, even when set for a wye configuration. You should be careful to use a solidly grounded wye system for VNOM inputs greater than 250 V (l-l, secondary) to avoid a 1.73 increase in terminal voltages from a line-to-ground fault.

Differential Element

Protect your apparatus with the dual-slope phase percentage-restrained differential element. Percentage differential protection provides more sensitive and secure protection than traditional differential protection; the dual-slope characteristic compensates for steady-state, proportional, and transient differential errors within the zone of protection. Steady-state errors are those that do not vary with loading through the differential zone, such as transformer magnetizing current and unmonitored loads. Proportional errors are those that vary with loading, such as relay measuring error, CT ratio errors, and errors because of tap changing. Transient errors are those that occur temporarily as a result of transients such as CT saturation.

The relay allows you to choose harmonic blocking, harmonic restraint, or both, providing stability during transformer inrush conditions. Even-numbered harmonics (second and fourth) provide security during energization, while fifth-harmonic blocking provides security for overexcitation conditions. Refer to *Table 1.4* for the available windings supported in each of the models. Additionally, the SEL-787 offers a *Negative-Sequence Differential Element* that can detect low-magnitude (e.g., turn-to-turn) faults.

Operating Characteristic

The SEL-787 has three differential elements (87R-1, 87R-2, and 87R-3). These elements employ Operate (IOP) and Restraint (IRT) quantities that the relay calculates from the winding input currents. *Figure 4.2* shows the relay characteristic. You can set the characteristic as either a single-slope, percentage differential characteristic or as a dual-slope, variable-percentage differential characteristic. Tripping occurs if the Operate quantity is greater than the curve value for the particular restraint quantity. A minimum pickup level for the Operate quantity must also be satisfied.

The four settings that define the characteristic are:

O87P = minimum IOP level required for operation

SLP1 = initial slope, beginning at the origin and intersecting O87P at IRT = O87P • 100/SLP1

IRS1 = limit of IRT for SLP1 operation; intersection where SLP2 begins

SLP2 = second slope must be greater than or equal to SLP1

By careful selection of these settings, you can duplicate the characteristics of existing differential relays that have been in use for many years.

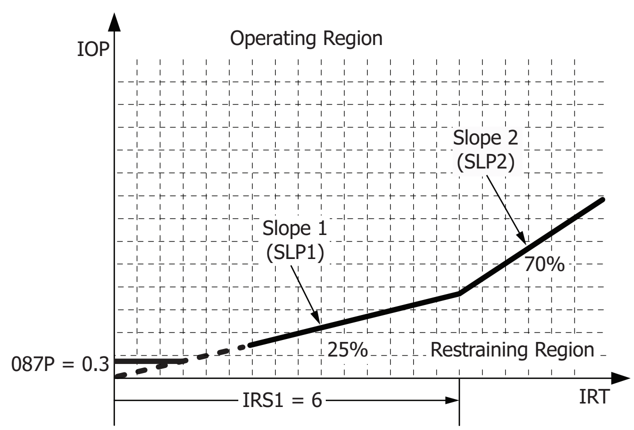


Figure 4.2 Percentage Restraint Differential Characteristic

Figure 4.3, *Figure 4.4*, and *Figure 4.5* illustrate how input currents are acquired and used in the unrestrained and restrained differential elements. Data acquisition, filtering, tap scaling, and transformer and CT connection compensation for Winding 1 are shown in *Figure 4.3*. Four digital filters extract the fundamental, second, fourth, and fifth harmonics out of the input currents.

Using the transformer MVA rating as a common reference point, TAP scaling converts all secondary currents entering the relay from different windings to per unit values, thus changing the ampere values into dimensionless multiples of TAP. Throughout the text, the term "TAP" refers to the per-unit value common to both windings, whereas "TAP*n*" (*n* = 1, 2, 3, and 4) refers to the ampere value of a particular winding(s). This method ensures that, for full-load through-current conditions, all incoming current multiples of tap sum to

1.0 and all outgoing current multiples of tap sum to –1.0, with a reference direction into the transformer windings.

Transformer and CT connection compensation adjusts the sets of three-phase currents for the phase angle and phase interaction effects introduced by the winding connection of the transformer and CTs. Settings W1CTC, W2CTC, W3CTC, and W4CTC determine the mathematical corrections to the three-phase currents for Winding 1, Winding 2, Winding 3, and Winding 4, respectively. CTC1 is shown in *Figure 4.3* as the phase angle and sequence quantity adjustment for Winding 1.

I1W1C1, I2W1C1, and I3W1C1 are the fundamental frequency A-phase, B-phase, and C-phase compensated currents for Winding 1. Similarly, I1W1C2, I2W1C2, and I3W1C2 are the second-harmonic compensated currents for Winding 1. The fourth-harmonic and fifth-harmonic compensated currents use similar names. The I1 compensated currents are used with differential element 87-1, I2 with element 87-2, and I3 with element 87-3.

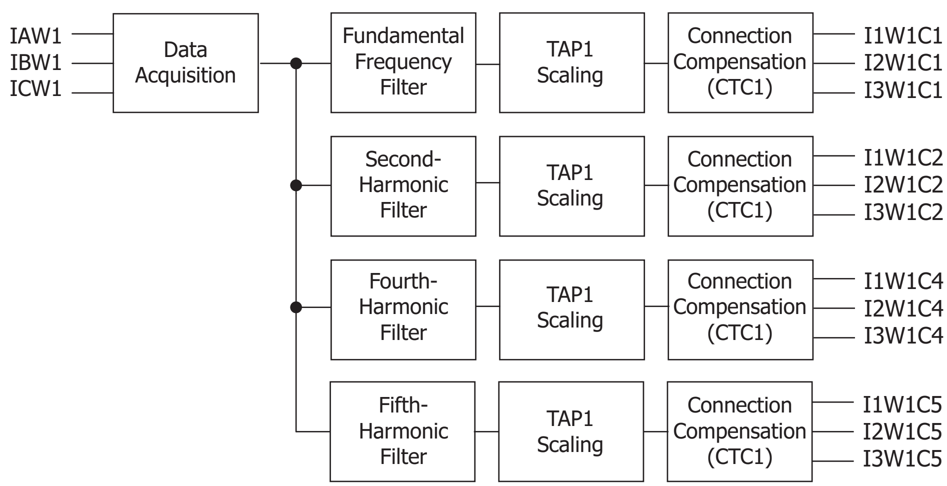


Figure 4.3 Winding 1 Compensated Currents

NOTE: The SEL-787 restraint quantity IRTn calculation differs from the SEL-587 and SEL-387 by a factor of 2.

Figure 4.4 illustrates how the IOP1 (operate), IRT1 (restraint), I1H24 (harmonic restraint), I1H2 (second harmonic), I1H4 (fourth harmonic), and I1H5 (fifth harmonic) quantities are calculated for the 87-1 element. IOP1 is generated by summing the winding currents in a phasor addition. IRT1 is generated by summing the magnitudes of the winding currents in a simple scalar addition. The settings E87W1, E87W2, E87W3, and E87W4 dictate the position of the switch in *Figure 4.4* and, hence, the windings that are part of the differential calculation. Set E87W*n* to Y or N (n = 1, 2, 3, or 4) to include or exclude the winding as part of the differential calculation, respectively. The 87-2 and 87-3 quantities are calculated in a similar manner.

For each restraint element (87R-1, 87R-2, 87R-3), the quantities are summed as phasors and the magnitude becomes the Operate quantity (IOP*n*). For a through-current condition, IOP*n* should calculate to about 1 + (–1) = 0, at rated load. Calculation of the restraint quantity (IRT*n*) occurs through a summation of all current magnitudes. For a through-current condition, this calculates to about (| 1 | + | –1 |) = 2, at rated load.

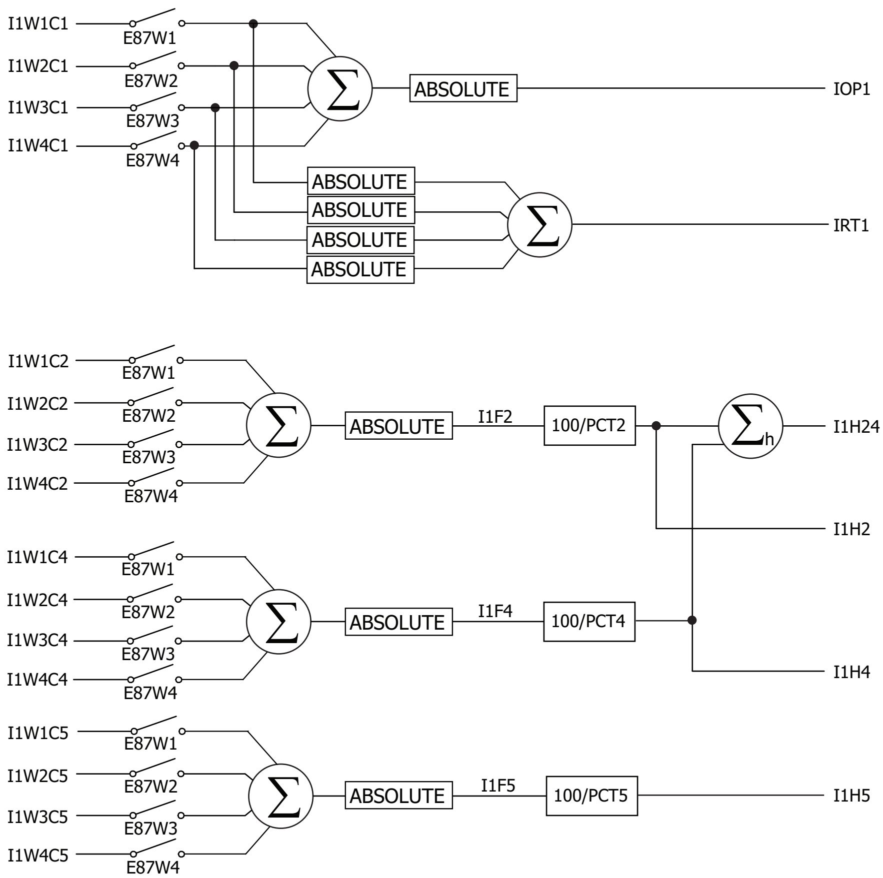


Figure 4.4 Differential Element (87-1) Quantities

Figure 4.5 shows how the differential element quantities are used to generate the unrestrained 87U*n* (87U1, 87U2, 87U3) and restrained 87R*n*/87HR*n* (87R1, 87R2, 87R3, 87HR1, 87HR2, 87HR3) elements.

Unrestrained elements (87U1, 87U2, and 87U3) compare the IOP quantity to a setting value (U87P), typically about 10 times TAP, and trip if this level is exceeded. Elements 87U1, 87U2, and 87U3 are combined to form element 87U, as shown in the lower left corner of *Figure 4.5*. Harmonic blocking or restraint is not performed on the unrestrained elements. Use these elements to protect your transformer bushings and end windings while maintaining security for inrush and through-fault conditions. Operating current elements 87O*n* (87O1, 87O2, 87O3) are not available as Relay Word bits.

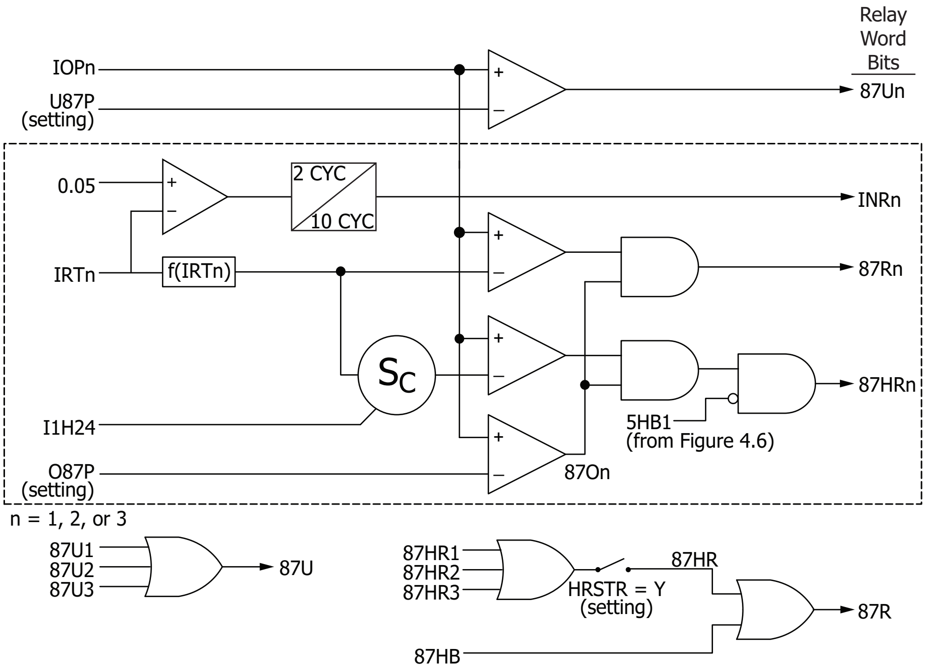


Figure 4.5 Differential Element Decision Logic

Restrained elements (87R1, 87R2, and 87R3) determine whether the IOP quantity is greater than the restraint quantity using the differential characteristic shown in *Figure 4.2*. This characteristic is modified by increasing the restraint current threshold as a function of the second- and fourth-harmonic content in the input currents for the harmonic restraint elements (87HR1, 87HR2, and 87HR3). Set HRSTR := Y to activate the harmonic restraint element 87HR.

In element 87R*n*, for example, the IOP*n* and IRT*n* quantities determine whether the relay trips. The logic enclosed within the dotted line of *Figure 4.5* implements the *Figure 4.2* characteristic. The differential element calculates a threshold as a function of IRT*n.* IOP*n* must exceed this threshold to assert 87R*n*. The function uses the SLP1, SLP2, and IRS1 setting values, along with IRT*n*, to calculate the IOP value. The relay uses SLP2 in place of SLP1 when the Relay Word bit INR*n* is asserted. This features provides a high security mode of operation for 10 cycles when the transformer is energized. The differential element decision logic compares the calculated value, denoted f(IRT*n*), to the actual IOP*n*. If IOP*n* is greater, one input of the AND gate at the right receives a logic 1. Comparison of IOP*n* with the O87P setting determines the second AND input. If IOP*n* is greater than O87P, the bit 87O*n* asserts. The AND gate condition is then satisfied, and Relay Word bit 87R*n* asserts, indicating operation of the restrained differential element, *n*. This does not, as yet, produce a trip. The relay still needs the results of the harmonic blocking decision logic, which is described later.

Harmonic Restraint

Consider the harmonic restraint feature (HRSTR := Y) if your practices require independent harmonic restraint. Blocking features are discussed in more detail later in this section.

For harmonic blocking, the harmonic content of the differential current must exceed the individual (PCT2 or PCT4) threshold values, i.e., the thresholds are treated as independent measurements of each harmonic value. For harmonic restraint, the values of the second- and fourth-harmonic currents are summed, and that value is used in the relay characteristic. Consider, for example, the simple case of Slope 1, i.e., a straight line through the origin. The general equation for a line is:

$$y = m \bullet x + c$$

More specifically, in the SEL-787:

$$IOP = SLP1 \bullet IRT + c$$

Because the line starts at the origin, the value of c is normally zero. The sum of the second- and fourth-harmonic currents now forms the constant c in the equation, raising the relay characteristic proportionally to the harmonic values.

Harmonic Blocking

While the restrained differential elements are making decisions, a parallel blocking decision process occurs regarding the magnitudes of specific harmonics in the IOP quantities.

Figure 4.6 shows how blocking elements, (87BL1, 87BL2, and 87BL3) supervise the restrained differential elements if the second-, fourth-, or fifth-harmonic operating current is above its set threshold. The blocking prevents improper tripping during transformer inrush or allowable overexcitation conditions. The SEL-787 uses common (cross-phase) blocking. Common blocking prevents all restrained elements (87R*n*) from tripping if any blocking element is picked up.

However, an independent blocking is used for the fifth-harmonic current. In this logic, an individual element only disables tripping of that element.

An additional alarm function for fifth harmonic to warn of overexcitation (not shown in *Figure 4.6*) employs a separate threshold (TH5P) and an adjustable timer (TH5D). This threshold and timer may be useful for transformer applications in or near generating stations.

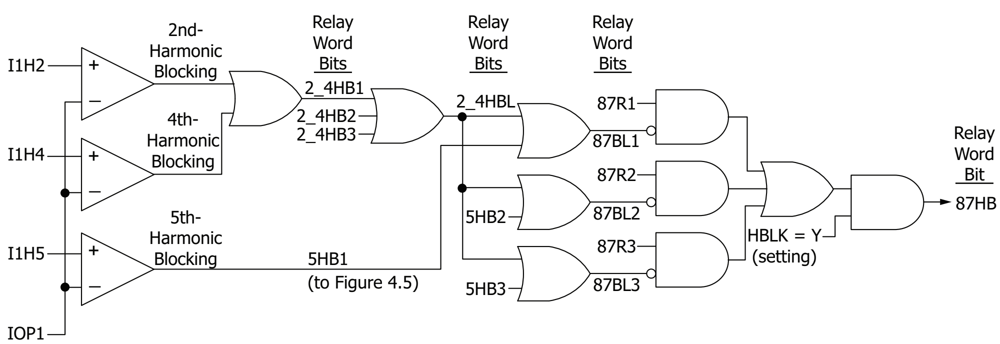


Figure 4.6 Differential Element Harmonic Blocking Logic

Relay Word bits 87R and 87U are high-speed elements that must trip all breakers. The factory default assigns 87R and 87U to trip variable setting TRXFMR. If either bit asserts, this variable asserts bit TRIPXFMR, which drives contact OUT103. OUT103 connects to an 86 lockout device, which trips all breakers via multiple sets of contacts.

Table 4.4 Differential Element Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
WDG1 CURR TAP	0.50–155.00 A[a]	TAP1 := 2.09
WDG2 CURR TAP	0.50–155.00 A[a]	TAP2 := 2.09
WDG3 CURR TAP	0.50–155.00 A[a]	TAP3 := 2.09
WDG4 CURR TAP	0.50–155.00 A[a]	TAP4 := 2.09
OPERATE CURR LVL	0.10–1.00 TAP	O87P := 0.30
DIFF CURR AL LVL	OFF, 0.05–1.00 TAP	87AP := 0.15
DIFF CURR AL DLY	1.0–120.0 sec	87AD := 5.0
RESTRAINT SLOPE1	5%–90%	SLP1 := 25
RESTRAINT SLOPE2	5%–90%	SLP2 := 70
RES SLOPE1 LIMIT	1.0–20.0 TAP	IRS1 := 6.0
UNRES CURR LVL	1.0–20.0 TAP	U87P := 10.0
2ND HARM BLOCK	OFF, 5%–100%	PCT2 := 15
4TH HARM BLOCK	OFF, 5%–100%	PCT4 := 15
5TH HARM BLOCK	OFF, 5%–100%	PCT5 := 35
5TH HARM AL LVL	OFF, 0.02–3.20 TAP	TH5P := OFF
5TH HARM AL DLY	0.0–120.0 sec	TH5D := 1.0
HARMONIC RESTRNT	Y, N	HRSTR := Y
HARMONIC BLOCK	Y, N	HBLK := N
ENABLE 87Q	Y, N	E87Q := N
87Q PICKUP CURR	0.20–1.00 TAP	O87QP := 0.30
87Q RST SLOPE1	5–100%	SLPQ1 := 25
87Q PICKUP DELAY	0.01–99.99 sec	87QD := 0.20
87Q BLOCK	SELOGIC	87QBLK := INR1 OR INR2 OR INR3 OR 87BL1 OR 87BL2 OR 87BL3 OR DRDOPT
EXT FLT DO TIMER	0.05–10.00 sec	HSMDOT := 0.25

[a] Range shown for I_{NOM} = 5 A; Range for I_{NOM} = 1 A is 0.10–31.00 A.

Choose the windings that you want to be part of the differential protection by setting the corresponding winding differential enable setting E87W*n* := Y (*n* = 1, 2, 3, or 4). To enable the differential protection, you need to set E87W*n* := Y for at least two windings.

When a value is entered in the MVA setting (i.e., MVA is not set to “OFF”), the relay uses the MVA, winding voltage, CT ratio, and CT connection settings (see *Table 4.2*) you have entered and automatically calculates the TAP*n* (*n* = 1, 2, 3, or 4) values. You can also directly enter tap values when MVA := OFF. The ratio of maximum ($TAPn/I_{NOMn}$) to the minimum ($TAPn/I_{NOMn}$) must be less than or equal to 32.00, where I_{NOMn} (*n* = 1, 2, 3, or 4) is the nominal rating of the CT, 5 A or 1 A.

Set the operating current level O87P at a minimum for increased sensitivity (typically 0.2 to 0.3 for transformers and around 1.0 for buses), but high enough to avoid operation because of unmonitored loads and transformer excitation current. The value for O87P must be greater than or equal to the maximum of 0.1 • I_{NOMn}/TAP*n*, where *n* = 1, 2, 3, or 4.

The SEL-787 includes a differential current alarm feature. Set the 87AP level above the highest expected differential current under normal operations (typically lower than O87P) setting) and a security delay 87AD. See *Figure 4.7* for the logic diagram of this feature. Assertion of Relay Word bit 87AT indicates a problem in the differential current circuit (e.g., open CT). You must program the 87AT bit to take appropriate action (alarm, display message, SER, etc.) as desired.

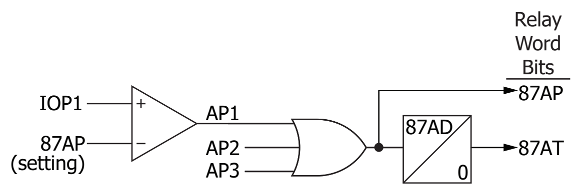


Figure 4.7 Differential Current Alarm Logic Diagram

Use the restraint slope percentage settings to discriminate between internal and external faults. Set SLP1 to accommodate current differences from steady-state and proportional errors such as power transformer tap-changer, CT errors, and relay error. Set SLP2 to accommodate transient error caused by CT saturation.

A two-slope, or variable-percentage differential application, improves sensitivity in the region where CT error is less and increases security in the high-current region where CT error is greater. We must define both slopes, as well as the Slope 1 limit or point IRS1, where SLP1 and SLP2 intersect. If you want a single slope characteristic, set both SLP1 and SLP2 to the desired slope value.

The purpose of the instantaneous unrestrained current element is to react quickly to very heavy current levels that clearly indicate an internal fault. Set the pickup level U87P to 8 to 10 times tap. The unrestrained differential element only responds to the fundamental frequency component of the differential operating current. It is unaffected by the SLP1, SLP2, IRS1, PCT2, or PCT5 settings. Thus, you must set the element pickup level high enough so as not to react to large inrush currents.

Energization of a transformer causes a temporary large flow of magnetizing inrush current into one terminal of a transformer, without the other terminal seeing this current. Thus, it appears as a differential current that could cause improper relay operation. Magnetizing inrush currents contain greater amounts of even-harmonic current than do fault currents. This even-harmonic current can be used to identify the inrush phenomenon and to prevent relay misoperation. The SEL-787 measures the amount of second-harmonic and fourth-harmonic currents flowing in the transformer. You can set the relay to block the percentage restrained differential element if the ratio of the second-harmonic and/or fourth-harmonic current to fundamental current (IF2/IF1, IF4/IF1) is greater than the PCT2 or PCT4 setting, respectively. The differential element automatically goes into high-security mode when the transformer is de-energized and IRN*n* asserts. The relay will stay in this mode for 10 cycles after energization is detected. See *Figure 4.5* and the associated description.

According to industry standards (ANSI/IEEE C37.91, C37.102), overexcitation occurs when the ratio of the voltage to frequency (V/Hz) applied to the transformer terminals exceeds 1.05 per unit at full load or 1.1 per unit at no load. Transformer overexcitation produces odd-order harmonics (primarily fifth harmonic), which can appear as differential current to a transformer differential relay. The SEL-787 measures the amount of fifth-harmonic current flowing in the transformer. You can set the relay to block the percentage restrained differential element if the ratio of fifth-harmonic current to fundamental current (IF5/IF1) is greater than the PCT5 setting. Unit-generator step-up transformers at power plants are the primary users of fifth-harmonic blocking. Transformer voltage and generator frequency may vary somewhat during startup, overexciting the transformers.

Fifth-harmonic alarm level and delay settings (TH5P and TH5D) use the presence of fifth-harmonic differential current to assert a Relay Word bit TH5T. This bit indicates that the rated transformer excitation current is exceeded. You may consider triggering an alarm and/or event report if fifth-harmonic current exceeds the fifth-harmonic threshold that you set.

The SEL-787 includes common harmonic blocking (cross-phase blocking) and harmonic restraint logic; you can select either one or both of them. The combination of both logic functions provides optimum differential element operating speed and security. Use the HRSTR := Y setting to enable the harmonic restraint logic and the HBLK := Y setting to enable the harmonic blocking logic.

Common harmonic blocking provides superior security against tripping on magnetizing inrush during transformer energization, yet allows faster differential element tripping for an energized transformer fault. Differential tripping through the harmonic restraint logic is slightly slower, but provides a dependable tripping function when energizing a faulted transformer that might otherwise have the differential tripping element blocked by common harmonic blocking logic.

Differential Element Settings in SEL-787, SEL-387, and SEL-587

The SEL-787 restraint quantity IRT*n* calculation differs from the SEL-587 and SEL-387 by a factor of 2. To achieve the same characteristics for the differential elements in the SEL-787, SEL-387, and SEL-587, this factor of 2 has to be accounted for. The settings relationships among the three products are as follows.

Convert SEL-387 and SEL-587 Relay Settings to the SEL-787 Relay

$O87P_{787} = O87P_{387/587}$

$SLP1_{787} = 1/2 \bullet SLP1_{387/587}$

$SLP2_{787} = 1/2 \bullet SLP2_{387/587}$

$IRS1_{787} = 2 \bullet IRS1_{387/587}$

$U87P_{787} = U87P_{387/587}$

Convert SEL-787 Relay Settings to the SEL-387 and SEL-587 Relays

$O87P_{387/587} = O87P_{787}$

$SLP1_{387/587} = 2 \bullet SLP1_{787}$

$SLP2_{387/587} = 2 \bullet SLP2_{787}$

$IRS1_{387/587} = 1/2 \bullet IRS1_{787}$

$U87P_{387/587} = U87P_{787}$

Setting Calculation

Connection Compensation Settings

The relay offers connection compensation settings, W*n*CTC (*n* = 1, 2, 3, or 4), to compensate for the phase shift across the transformer. These settings offer a range, 0–12, that represents 3x3 matrices, CTC(0)–CTC(12), permitting compensation from 0 degrees to 360 degrees, in increments of 30 degrees, respectively. The general expression for current compensation is as follows:

$$\begin{bmatrix} \mathrm{I1W}n\mathrm{C} \\ \mathrm{I2W}n\mathrm{C} \\ \mathrm{I3W}n\mathrm{C} \end{bmatrix} = [\mathrm{CTC}(m)] \bullet \begin{bmatrix} \mathrm{IAW}n \\ \mathrm{IBW}n \\ \mathrm{ICW}n \end{bmatrix}$$

where IAW*n*, IBW*n*, and ICW*n* are the three-phase currents entering terminal "*n*" of the relay; I1W*n*C, I2W*n*C, and I3W*n*C are the corresponding phase currents after compensation the relay uses to calculate the operate and restraint quantities; and CTC(*m*) is the three-by-three compensation matrix corresponding to the W*n*CTC setting. The complete list of compensation matrices (*m* = 0–12) and the corresponding correction compensation they result in are shown in *Table 4.5*.

Table 4.5 WnCTC Setting: Corresponding Phase and Direction of Correction (Sheet 1 of 2)

WnCTC Setting[a]	Matrix	Compensation Matrices	Amount and Direction of Correction	
			ABC Phase Rotation	ACB Phase Rotation
0	CTC(0)	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	0°	0°
1	CTC(1)	$\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix}$	30° CCW	30° CW
2	CTC(2)	$\frac{1}{3} \bullet \begin{bmatrix} 1 & -2 & 1 \\ 1 & 1 & -2 \\ -2 & 1 & 1 \end{bmatrix}$	60° CCW	60° CW
3	CTC(3)	$\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 0 & -1 & 1 \\ 1 & 0 & -1 \\ -1 & 1 & 0 \end{bmatrix}$	90° CCW	90° CW
4	CTC(4)	$\frac{1}{3} \bullet \begin{bmatrix} -1 & -1 & 2 \\ 2 & -1 & -1 \\ -1 & 2 & -1 \end{bmatrix}$	120° CCW	120° CW

Table 4.5 WnCTC Setting: Corresponding Phase and Direction of Correction (Sheet 2 of 2)

WnCTC Setting[a]	Matrix	Compensation Matrices	Amount and Direction of Correction	
			ABC Phase Rotation	ACB Phase Rotation
5	CTC(5)	$\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} -1 & 0 & 1 \\ 1 & -1 & 0 \\ 0 & 1 & -1 \end{bmatrix}$	150° CCW	150° CW
6	CTC(6)	$\frac{1}{3} \bullet \begin{bmatrix} -2 & 1 & 1 \\ 1 & -2 & 1 \\ 1 & 1 & -2 \end{bmatrix}$	180° CCW	180° CW
7	CTC(7)	$\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} -1 & 1 & 0 \\ 0 & -1 & 1 \\ 1 & 0 & -1 \end{bmatrix}$	210° CCW	210° CW
8	CTC(8)	$\frac{1}{3} \bullet \begin{bmatrix} -1 & 2 & -1 \\ -1 & -1 & 2 \\ 2 & -1 & -1 \end{bmatrix}$	240° CCW	240° CW
9	CTC(9)	$\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 0 & 1 & -1 \\ -1 & 0 & 1 \\ 1 & -1 & 0 \end{bmatrix}$	270° CCW	270° CW
10	CTC(10)	$\frac{1}{3} \bullet \begin{bmatrix} 1 & 1 & -2 \\ -2 & 1 & 1 \\ 1 & -2 & 1 \end{bmatrix}$	300° CCW	300° CW
11	CTC(11)	$\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix}$	330° CCW	330° CW
12	CTC(12)	$\frac{1}{3} \bullet \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix}$	0° (360°) CCW	0° (360°) CW

[a] n = 1, 2, 3, 4.

Compensation matrix CTC(0) is intended to create no changes at all in the currents and merely multiplies them by an identity matrix. Compensation matrix CTC(12) is similar to CTC(0), in that it produces no phase shift (or, more correctly, 360 degrees of shift) in a balanced set of phasors separated by 120 degrees. However, it removes zero-sequence components from the winding current, as do all of the matrices with non-zero values of *m*.

Use the following guidelines to determine correct compensation settings for each winding.

Step 1. Determine the phase shift as seen by the relay. The following information is required to accurately determine this phase shift.

- ➢ Transformer winding connection diagram (transformer nameplate)
- ➢ Three-line connection diagram showing: (1) system phase-to-transformer bushing connections, (2) current transformer (CT) connections, and (3) CT-to-relay connections

Step 2. Choose one of the relay current inputs as the reference winding.

- ➢ If a delta winding exists and is wired into the relay, choose it as the reference. Select matrix CTC(0) for the compensation of the delta winding in traditional delta/wye power transformer applications. However, select Matrix CTC(1) for the compensation of the delta winding in rare delta/zig-zag power transformer applications. Selecting an odd matrix for the delta winding would result in an odd numbered matrix (preferred) and zero-sequence current removal for the zig-zag winding. For additional detail, refer to SEL Application Guide AG2020-03, "Selecting Compensation Settings for Zig-Zag Power Transformers," available on selinc.com.
- ➢ If a delta winding does not exist, select matrix CTC(11) for the compensation of one of the wye windings.

Step 3. With the winding in *Step 2* as reference, determine the required compensation settings for all other windings. Use odd matrices for compensating wye or zig-zag windings. Avoid the use of even matrices when possible.

Refer to *Appendix O: Protection Application Examples* for more details on application of these guidelines in determining correct compensation settings.

Winding Line-to-Line Voltages

Enter the nominal line-to-line transformer terminal voltages. If a load tap-changer is included in the transformer differential zone, assume that it is in the neutral position. The setting units are kilovolts.

Current TAP

The relay uses a standard equation to set TAP*n*, based on settings entered for the particular winding (*n* denotes the winding number.)

$$\mathrm{TAPn} = \frac{\mathrm{MVA} \bullet 1000}{\sqrt{3} \bullet \mathrm{VWDG} \bullet \mathrm{CTR}n} \bullet \mathrm{C}$$

where:

C = 1 if W*n*CT setting = Y (wye-connected CTs)
C = $\sqrt{3}$ if W*n*CT setting = D (delta-connected CTs)
MVA = base power transformer capacity setting (must be the same for all TAP*n* calculations)
VWDG*n* = winding line-to-line voltage setting, in kV
CTR*n* = current transformer ratio setting

The relay calculates TAP*n* with the following limitations:

- The tap settings are within the range 0.10 • I_{NOMn} and 31.00 • I_{NOMn}.
- The ratio of the highest ($TAPn/I_{NOMn}$) to the lowest ($TAPn/I_{NOMn}$) is less than or equal to 32.00, where n = 1, 2, 3, or 4).

Restrained Element Operating Current Pickup

The O87P setting range is 0.1 to 1.0; we suggest an O87P setting of 0.2 to 0.3. The setting must be at a minimum for increased sensitivity but high enough to avoid operation because of steady-state errors such as unmonitored station service loads, transformer excitation current, and relay measuring error at very low current levels. The setting must also yield an operating current greater than or equal to a maximum of 0.1 • $I_{NOMn}/TAPn$, where n = 1, 2, 3, or 4.

Restraint Slope Percentage

The purpose of the percentage restraint characteristic is to allow the relay to differentiate between differential current from an internal fault versus differential current during normal or external fault conditions. You must select slope characteristic settings that balance security and dependability. To do this, determine what slope ratio is characteristic of normal conditions (slope must be above that for security) and what slope ratio is characteristic of an internal fault (the slope must be below that for dependability). In the SEL-787 Relay, the slope ratio for a bolted internal fault is 100%.

The sources of differential current for external faults fall into three categories:

- Differential current that is not proportional to the current flow through the zone (steady state).
- Differential current that is proportional to current flow through the zone (proportional).
- Differential current that is transient in nature (transient).

SLP1 should be set above normal steady-state and proportional errors. SLP2 is used to accommodate transient errors. The following is a list of typical sources of error that must be considered.

- Excitation current (typically 1 to 4%)
- CT accuracy (typically less than 3% in the nominal range)
- No-Load Tap-Changer (NLTC) (typically ±5%)
- Load Tap-Changer (LTC) (typically ±10%)
- Relay accuracy (±5% plus ±0.02 • I_{NOM})

We recognize that the excitation current of the transformer is not proportional to load flow. But, it should be included as a proportional error as a conservative approach.

CTs create both steady-state and transient errors, which can result in false differential current. IEEE Standard Requirements for Instrument Transformers (C57.13-1993) specifies that a relay-accuracy CT must be 3 percent accurate at rated current and 10 percent accurate at 20 times rated current when ZB is the standard burden. It is important to note that the rated current specified in the standard is a symmetrical sinusoidal waveform (it does not have a transient DC component). Because the burden is usually designed to be much smaller than the standard burden, the error current is likely to be much less than 3 percent for current flow at low multiples of the nominal rating of the CTs.

The errors are summed to determine the total error that the SLP1 characteristic must accommodate for normal system conditions. Using that point, determine the minimum limit of the allowable slope ratio by using the following equation and adding margin to determine SLP1.

$$SLP1_{MIN}\% = \left(\frac{Err\%}{(200 - Err\%) \bullet k}\right) \bullet 100$$

where:

$SLP1_{MIN}$ = slope ratio that accommodates Err with no margin
Err = amount of error expected in normal operation
k = AVERAGE restraint scaling factor (1 for the SEL-787)

The variable restraint characteristic provided by SLP2 at high multiples of TAP for a through fault accommodates transient CT error. SLP2 can be set fairly high without jeopardizing sensitivity for low-grade partial winding faults. The CTs should be evaluated for the likelihood of going into saturation for a through fault and SLP2 adjusted accordingly. Another consideration for selecting the SLP2 setting is that the effectiveness of the variable percentage is dependent on SLP1 and IRS1, which determine the starting point of SLP2. If SLP1 is set very low, a higher SLP2 may be warranted.

Unrestrained Element Current Pickup

The instantaneous unrestrained current element is intended to react quickly to very heavy current levels that clearly indicate an internal fault. Set the pickup level (U87P) to approximately 8 to 10 times TAP. The unrestrained differential element responds only to the fundamental frequency component of the differential operating current. It is not affected by the SLP1, SLP2, IRS1, PCT2, or PCT5 settings. Thus, it must be set high enough so as not to react to large inrush currents.

Second-Harmonic Blocking

Transformer simulations show that magnetizing inrush current usually yields more than 30 percent of IF2/IF1 in the first cycle of the inrush. A setting of 15 percent usually provides a margin for security. However, some types of transformers, or the presence within the differential zone of equipment that draws a fundamental current of its own, may require setting the threshold as low as 7 percent. For example, the additional fundamental frequency charging current of a long cable run on the transformer secondary terminals could “dilute” the level of second harmonic seen at the primary to less than 15 percent.

Fourth-Harmonic Blocking

Transformer magnetizing inrush currents are generated during transformer energization when the current contains a dc offset caused by point-on-wave switching. Inrush conditions typically are detected using even harmonics and are used to prevent misoperations resulting from inrush. The largest even-harmonic current component is usually second harmonic followed by fourth harmonic. Use fourth-harmonic blocking to provide additional security against inrush conditions; set PCT4 less than PCT2.

Fifth-Harmonic Blocking

Fourier analysis of transformer currents during overexcitation indicates that a 35 percent fifth-harmonic setting is adequate to block the percentage differential element. To disable fifth-harmonic blocking, set PCT5 to OFF.

You may use the presence of fifth-harmonic differential current to assert an alarm output during startup. This alarm indicates that the rated transformer excitation current is exceeded. At full load, a TH5P setting of 0.1 corresponds to 10 percent of the fundamental current. A delay, TH5D, that you can set prevents the relay from indicating transient presence of fifth-harmonic currents.

You may consider triggering an event report if transformer excitation current exceeds the fifth-harmonic threshold.

Use the following criteria for setting TH5P:

$$\mathrm{TH5P} \geq \text{maximum } (0.05 \bullet \mathrm{I}_{\mathrm{NOM}n}/\mathrm{TAP}n)$$

where:

n = 1, 2, 3, or 4 and $\mathrm{I}_{\mathrm{NOM}n}$ is nominal current of corresponding CT

Example of Setting the SEL-787 Relay

The example represents a typical transformer application and demonstrates the use of CT compensation settings and tap calculations.

Figure 2.25 illustrates the application, which uses a 138 kV to 13.8 kV transformer with two terminals on the 13.8 kV side. The transformer has a base rating of 30 MVA. Both windings have wye-connected current transformers, with ratios of 200/5 A at 138 kV, and 2000/5 A at 13.8 kV. We have connected the transformer per IEEE standards, with the low voltage lagging the high-voltage wye by 30 degrees.

Step 1. Enable the differential settings as follows:

E87W1 := Y
E87W2 := Y
E87W3 := Y

Step 2. Select settings for the current transformer connection and ratio for each winding.

All CTs connect in wye. The ratios are equal to primary current divided by secondary current. The settings are as follows:

138 kV	13.8 kV	13.8 kV
W1CT = WYE	W2CT = WYE	W3CT = WYE
CTR1 = 40	CTR2 = 400	CTR3 = 400

Step 3. Set the transformer maximum rating.

We use this rating for all windings in the later tap calculation:

MVA = 30

Step 4. Determine compensation settings.

Because the CTs on either side of the transformer (wye and delta sides), are wye-connected, we must adjust for the phase angle shift. In the "traditional" differential relay connection the wye transformer windings have their CTs connected in delta to produce a shift in the same direction as that produced in the transformer. Using the guidelines in *Steps to Determine the Compensation Settings (WnCTC) on page O.5*, it can be determined that the phase-to-transformer bushing connections are standard. The primary current Ia (X-side) lags the system primary current IA (H-side) by 30 degrees. The CT connections are standard, which results in IAW2 and IAW3 leading IAW1 by 150 degrees as seen by the relay. Primary currents and secondary currents as measured by the relay are shown in *Figure 4.8*. For simplicity, only Terminal 1 and Terminal 2 currents are shown. Terminal 3 currents are the same as Terminal 2.

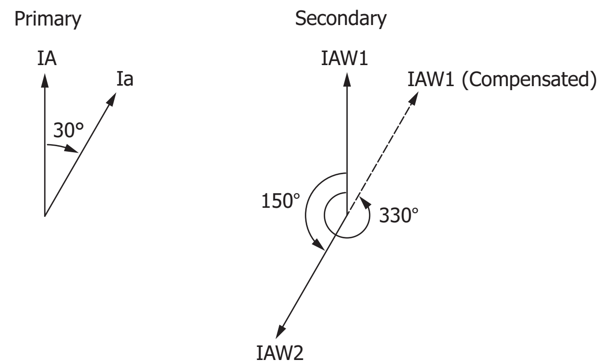


Figure 4.8 Primary Currents and Secondary Currents as Measured by the Relay

Further, select the delta winding as the reference. The X-side delta current is connected to Terminals W2 and W3 of the SEL-787 Relay. Therefore, set W2CTC = 0 and W3CTC = 0. The H-side currents are connected to Terminal W1 of the SEL-787 Relay so W1CTC must be determined. IAW1 must be rotated 330 degrees (11 multiples of 30 degrees) in the counterclockwise direction for a system with an ABC phase rotation to be 180 degrees out-of-phase with IAW2 and IAW3. Therefore, set W1CTC = 11. The resulting compensation settings are:

ICOM = Y (choose to define the CT compensation)

W1CTC = 11

W2CTC = 0

W3CTC = 0

The relay multiplies the wye CT currents from the wye transformer windings by the CTC(11) matrix to give the same results as the physical DAC CT connection.

Step 5. Enter winding line-to-line voltages.

The relay needs these voltages for the tap calculation. Voltages are in units of kV. For this example we enter the following values:

VWDG1 = 138 VWDG2 = 13.8 VWDG3 = 13.8

The relay now calculates each tap current, using the formula stated previously:

$$\mathrm{TAP}n = \frac{\mathrm{MVA} \bullet 1000}{\sqrt{3} \bullet \mathrm{VWDG}n \bullet \mathrm{CTR}n} \bullet \mathrm{C}$$

where

C = 1 for wye CTs

Thus, we have the following:

$$\mathrm{TAP1} = \frac{30\mathrm{MVA} \bullet 1000}{\sqrt{3} \bullet 138\mathrm{kV} \bullet 40}$$
$$\mathrm{TAP1} = 3.14$$

$$\mathrm{TAP2} = \frac{30\mathrm{MVA} \bullet 1000}{\sqrt{3} \bullet 13.8\mathrm{kV} \bullet 400}$$
$$\mathrm{TAP2} = 3.14$$

$$\mathrm{TAP3} = \frac{30\mathrm{MVA} \bullet 1000}{\sqrt{3} \bullet 13.8\mathrm{kV} \bullet 400}$$
$$\mathrm{TAP3} = 3.14$$

The relay calculates these taps automatically if MVA is given. If MVA is set to OFF, you must calculate the taps and enter them individually.

The relay checks to see if a violation of the maximum tap ratio has occurred, and notifies you of the violation.

Step 6. Set the differential element characteristic. Select the settings according to our suggestions in the earlier setting descriptions.

For this example, we select a two slope, variable-percentage differential characteristic for maximum sensitivity at low currents and greater tolerance for CT saturation on external high-current faults.

The minimum error for selecting SLP1 for this application is determined to be:

- Excitation current (4%)
- CT accuracy (3%)
- No-Load Tap-Changer (NLTC) (5%)
- Load Tap-Changer (LTC) (0%)
- Relay accuracy (±5% plus ±0.02 • I_{NOM}) (5%)

$$\mathrm{SLP1}_{\mathrm{MIN}}\% = \left(\frac{17}{(200-17)}\right) \bullet 100 = 9.3\%$$

The CTs have been evaluated for maximum through fault and found to be unlikely to saturate severely. So, SLP2 does not have to be set higher than normal.

The settings are as follows:

O87P = 0.3 (Operate current pickup in multiple of tap)
SLP1 = 15 (15 percent initial slope)
SLP2 = 50 (50 percent second slope)
IRS1 = 6.0 (limit of slope 1, Restraint current in multiple of tap)

U87P = 10 (unrestrained differential Operate current level, multiple of tap)
PCT4 = 15 (block operation if fourth harmonic is above 15 percent)
PCT5 = 35 (block operation if fifth harmonic is above 35 percent)
TH5P = OFF (no fifth-harmonic alarm)
HRSTR = Y (harmonic restraint enabled)
HBLK = Y (harmonic blocking enabled)

Remember that the O87P setting must yield an operating current value that is greater than or equal to the maximum of $0.1 \cdot I_{NOMn}/TAPn$, where n = 1, 2, 3, or 4. In this case, O87P = maximum $((0.1 \cdot I_{NOMn})/TAPn) = 0.5/3.14 = 0.159$. Therefore, the O87P setting of 0.3 is valid.

The differential unit settings are complete for this specific application. At this point you can also choose to set backup overcurrent elements, which we discuss at the end of this section.

Application Guidelines

It is vital that you select adequate current transformers for a transformer differential application. Use the following procedure, based on ANSI/IEEE Standard C37.110-1996, *IEEE Guide for the Application of Current Transformers Used for Protective Relaying Purposes*.

CT Arrangements

Use separate relay restraint circuits for each power source to the relay. In the SEL-787 you can apply two to four restraint inputs to the relay. You can connect CT secondary windings in parallel only if both circuits meet the following criteria:

- ➤ They are connected at the same voltage level.
- ➤ Both have CTs that are matched in ratio and C voltage ratings.
- ➤ Both circuits are radial (no fault current contributions).

CT Sizing

Sizing a CT to avoid saturation for the maximum asymmetrical fault current is ideal but not always possible. Such sizing requires CTs with C voltage ratings greater than (1 + X/R) times the burden voltage for the maximum symmetrical fault current, where X/R is the reactance-to-resistance ratio of the primary system.

As a rule of thumb, CT performance is satisfactory if the CT secondary maximum symmetrical external fault current multiplied by the total secondary burden in ohms is less than half of the C voltage rating of the CT. The following CT selection procedure uses this second guideline.

CT Ratio Selection

Step 1. Determine the secondary side burdens in ohms for all current transformers connected to the relay.

Step 2. Select the CT ratio for the highest-rated winding (e.g., CTR1) by considering the maximum continuous secondary current, I_{HS}, based on the highest MVA rating of the transformer.

For wye-connected CTs, the relay current, I_{REL}, equals I_{HS}. For delta-connected CTs, I_{REL} equals $\sqrt{3} \bullet I_{HS}$. Select the nearest standard ratio such that I_{REL} is between $0.1 \bullet I_{NOM}$ and $1.0 \bullet I_{NOM}$ A secondary, where I_{NOM} is the relay nominal secondary current, 1 A or 5 A.

Step 3. Select the remaining CT ratios (e.g., CTR2–CTR3) by considering the maximum continuous secondary current, I_{LS}.

As before, for wye-connected CTs, I_{REL} equals I_{LS}. For delta-connected CTs, I_{REL} equals $\sqrt{3} \bullet I_{LS}$. Select the nearest standard ratio such that I_{REL} is between $0.1 \bullet I_{NOM}$ and $1.0 \bullet I_{NOM}$ A secondary.

The SEL-787 calculates settings TAP1, TAP2, and TAP3 if the ratio of maximum (TAP_n/I_{NOMn}) to minimum (TAP_n/I_{NOMn}) is less than or equal to 32.00. When the relay calculates the tap settings, it reduces CT mismatch to less than 1 percent. Allowable tap settings are in the range $(0.10–31.00) \bullet I_{NOM}$.

If the ratio of maximum (TAP_n/I_{NOMn}) to minimum (TAP_n/I_{NOMn}) is greater than 32, select a different CT ratio to meet the above conditions. You can often do this by selecting a higher CT ratio for the smallest rated winding, but you may need to apply auxiliary CTs to achieve the required ratio. In this case, repeat *Step 2* and *Step 3*.

Step 4. Calculate the maximum symmetrical fault current for an external fault, and verify that the CT secondary currents do not exceed your utility standard maximum allowed CT current, typically $20 \bullet I_{NOM}$. If necessary, reselect the CT ratios and repeat *Step 2* through *Step 4*.

Step 5. For each CT, multiply the burdens calculated in *Step 1* by the magnitude, in secondary amperes, of the expected maximum symmetrical fault current for an external fault. Select a nominal accuracy class voltage for each CT that is greater than twice the calculated voltage.

If necessary, select a higher CT ratio to meet this requirement, then repeat *Step 2* through *Step 5*. This selection criterion helps reduce the likelihood of CT saturation for a fully offset fault current signal.

Please note that the effective C voltage rating of a CT is lower than the nameplate rating if a tap other than the maximum is used. Derate the CT C voltage rating by a factor of ratio used/ratio max.

Negative-Sequence Differential Element

The negative-sequence differential element provides sensitive protection for low-magnitude faults such as turn-to-turn faults. The sensitivity of the phase-percentage differential element is tied to the transformer loading, making turn-to-turn faults particularly difficult to detect. The negative-sequence differential element is unaffected by balanced load and, therefore, very sensitive to the small unbalance caused by turn-to-turn faults regardless of operating conditions. The negative-sequence differential element requires appropriate blocking during transformer energization or overexcitation conditions. The relay provides the option to block the element by using SELOGIC setting 87QBLK.

Figure 4.9 shows the trajectory of a fault that shorts out 2 percent of the A-phase winding of a three-phase transformer. In the phase differential operation portion of *Figure 4.9*, the transformer is fully loaded and the phase differential relay operates when the operate current reaches approximately 0.43 per unit. *Figure 4.9* also shows the negative-sequence differential element response for the same fault. Because balanced load does not affect negative-sequence current, the negative-sequence element operates when the operate current reaches 0.3 per unit.

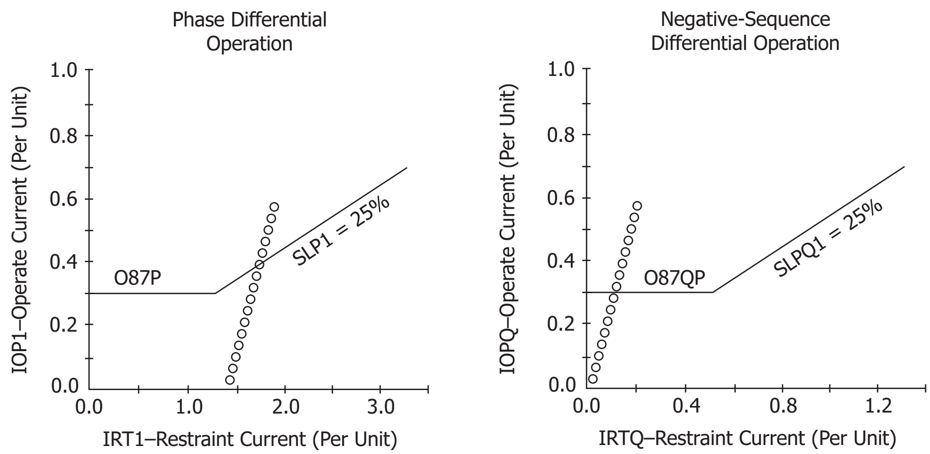


Figure 4.9 Differential Operations

NOTE: The 87Q element currents are set in per unit of the TAPn values (see Figure 4.3).

The relay uses filtered compensated fundamental frequency currents (see *Figure 4.3*) and *Equation 4.3* to calculate the negative-sequence currents for each terminal included in the differential element when you have enabled the element through the E87Q setting. The element calculates the negative-sequence operating and restraint current as shown in *Equation 4.4* and *Equation 4.5*, respectively.

$$3I2WnC = [1, k_1, k_2] \bullet \begin{bmatrix} I1WnC1 \\ I2WnC1 \\ I3WnC1 \end{bmatrix} \qquad \textbf{Equation 4.3}$$

where:

n = 1, 2, 3, 4

k_1 and k_2 = a^2 and a, respectively, when PHROT = ABC

k_1 and k_2 = a and a^2, respectively, when PHROT = ACB

a = $1\angle 120°$

$$IOPQ = \left|\sum 3I2WnC\right| \qquad \textbf{Equation 4.4}$$

$$IRTQ = \max(|3I2WnC|) \qquad \textbf{Equation 4.5}$$

Figure 4.10 shows the logic that forms the negative-sequence differential element. In the figure, the relay calculates the operating current in a similar manner to that of the phase-restrained differential element. However, the restraint current is the maximum of the negative-sequence currents among the terminals that are part of the differential calculations. After evaluating the operating and restraint currents in the differential element, the relay verifies that the negative-sequence differential element blocking bit (87QBLK) is deasserted.

NOTE: Add the 87Q Relay Word bit to a trip equation (e.g., TRXFMR, see Table 4.39) or use it to alarm, per your specific application requirements.

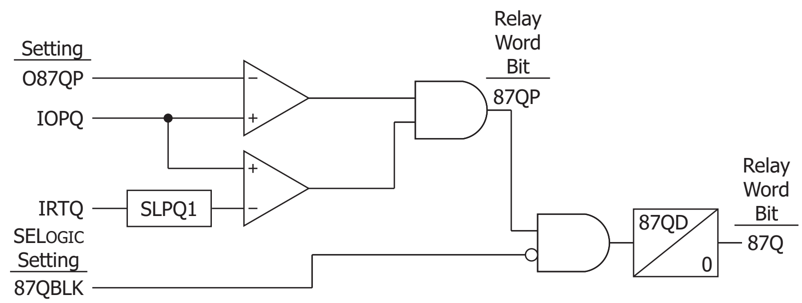
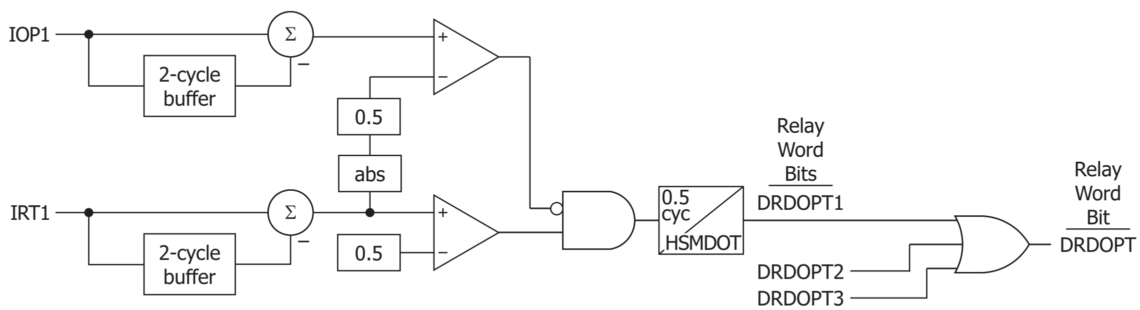


Figure 4.10 Negative-Sequence Percentage-Restraint Differential Element

Factory default setting 87QBLK (87Q BLOCK) secures the element during external faults, inrush, and excessive harmonics in the differential zone (see *Table 4.4* for details). The setting can be modified to suit specific application requirements.

The external fault detector logic shown in *Figure 4.11* is designed to detect events characterized by a sudden increase in the through current (e.g., external faults and load). Relay Word bit DRDOPT indicates an external event and is triggered before typical CT saturations.



Note: Analog Quantities IOP1 and IRT1 from Figure 4.4.

Figure 4.11 External Fault Detector Logic

Enable Negative-Sequence Differential Element

The E87Q setting enables the negative-sequence differential element when at least two windings are enabled for the phase differential element (settings E87W*n*).

Negative-Sequence Differential Element Operating Current Pickup

Set the negative-sequence differential element to improve sensitivity to internal transformer winding turn-to-turn faults during heavy load conditions. O87QP is the negative-sequence pickup threshold of the element and is set in per unit of the TAP*n* values.

If O87QP is set lower than the default value, perform an analysis to determine how much negative-sequence operating current is present because of CT measurement errors. This analysis assures the security of the 87Q element.

Negative-Sequence Differential Slope

The SLPQ1 setting defines the slope of the negative-sequence differential element. Unlike the phase-restrained differential elements, there is only one slope to set because the negative-sequence element is blocked if an external fault is detected (when the DRDOPT/87QBLK Relay Word bits assert).

Negative-Sequence Differential Element Delay

The output of the negative-sequence differential element can be delayed for added security. Set the negative-sequence differential element delay to the recommended delay of 0.2 second.

Negative-Sequence Differential Element Block

The factory default equation is chosen to secure/block the 87Q element under external faults, inrush, and excessive harmonics in the differential zone. Change this setting only when/if required by specific application.

External Fault Dropout Delay

The HSMDOT setting is intended to assure 87Q block (DRDOPT/87QBLK) during the external fault clearing time. Set the HSMDOT dropout delay to 0.25 second (factory default) or higher as needed.

Restricted Earth Fault Element

Restricted earth-fault (REF) protection comes from a zero-sequence directional element that provides sensitive detection of ground faults for a grounded wye-connected transformer winding. To provide REF protection, the element compares the direction of the polarizing current derived from the line-end CTs with the operating current obtained from the neutral CT. *Figure 4.12* shows the characteristic of the REF element, with the shaded area indicating the tripping area.

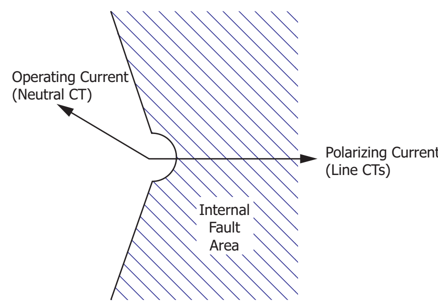


Figure 4.12 REF Directional Element

Because the REF element employs a neutral CT at one end of the winding and a set of three CTs at the line end of the winding, REF protection detects only ground faults within that particular wye-connected winding. The element is restricted in the sense that protection is limited to ground faults within a zone defined by neutral and line CT placement.

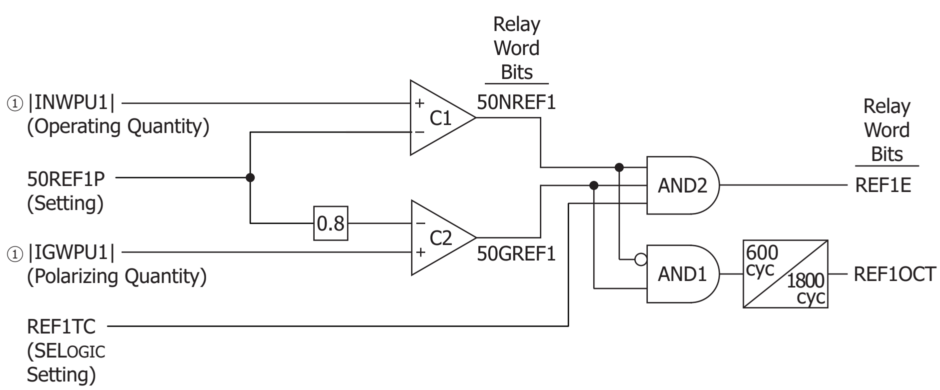
The REF element uses comparison of zero-sequence currents, so the line-end CTs must be connected in wye for the element to function. Delta-connected CTs cancel out all zero-sequence components of the currents, eliminating one of the quantities the REF element needs for comparison.

Connection of the Neutral Inputs

The SEL-787 offers as many as three REF elements—REF1, REF3A, and REF3B. Refer to *Table 1.4* for the available REF elements in each of the models. The settings associated with the three REF elements, REF1, REF3A and REF3B, are identified in *Table 4.6*. Note that the element REF1 is only available in the SEL-787-21, SEL-787-2E, and SEL-787-3E models with the neutral CT option. The elements REF3A and REF3B are available in the SEL-787-3E/3S and SEL-787-4X models. Configure E87W3 := REF in order for the elements REF3A and REF3B to be available for setting. For example, the operating quantity associated with the REF1, REF3A, and REF3B elements in the SEL-787-3E is tied to the corresponding relay inputs identified in *Table 2.8*—IN (E07–E08), IAW3 (E01–E02), and IBW3 (E03–E04). These inputs are fixed and must be observed when using the REF function. For example, if you select REF1 for your application, be sure to wire the output current from the neutral CT to IN. If REF3A is selected, wire the output current from the neutral CT to IAW3. If REF3B is selected, wire the input current from the neutral CT to IBW3. Refer to *Figure 2.24* for an example of the wiring associated with REF3A and REF3B elements in an application. For ease of description, the elements are referred to as REF*k*, where *k* equals 1, 3A, or 3B.

REF Element Logic

Figure 4.13 through *Figure 4.18* show the REF1 element logic diagrams. The logic for the REF3A and REF3B elements is similar to the REF1 element with the exception of the torque calculations (see *Figure 4.14*) and normalized negative-sequence (see *Figure 4.15*), which are shown separately. *Figure 4.13* shows the REF1 element enable output, REF1E. The operating quantity, is the output current from the neutral CT connected to Terminal IN. The polarizing quantity is the zero-sequence current from the selected terminal CTs that are part of the scheme. Both the operating and polarizing currents are normalized for use within the logic. The normalization as shown in *Figure 4.14* is explained further down. I_{NOMN1} is the nominal rating of the neutral CT, 5 A or 1 A. The comparator C1 compares the magnitude of the normalized IN1 value, INWPU1, against the 50REF1P setting and asserts 50NREF1 if the measured quantity exceeds the threshold. Comparator C2 compares 0.8 of the 50REF1P setting value against the magnitude of the polarizing current, IGWPU1, and asserts 50GREF1 if the measured quantity exceeds the threshold. The 0.8 multiplier secures the operation of the REF1F element by ensuring that 50GREF1 always asserts before 50NREF1. During an internal fault, both the neutral current and zero-sequence polarizing current exceed the 50REF1P setting. Two likely conditions when this is not true would be for a settings error or an open circuit. Program the REF1OCT Relay Word bit in the REF1TC SELOGIC torque control equation for added security of the REF element. If 50NREF1, 50GREF1, and the SELOGIC torque control, REF1TC, all evaluate to logical 1, then output REF1E is asserted. When REF1E asserts, the relay enables the logic that performs the torque calculations, as shown in *Figure 4.14*.



① See Figure 4.14(a).

Figure 4.13 REF1 Enable Logic

Figure 4.14 shows the REF1 torque control output, REFTQ1. The Switch S1*m* (*m* = a, b, or c) selects the zero-sequence vector currents from those line CTs that are part of the REF calculations, as determined by the setting REF1POL. As an example, refer to *Figure 4.17*. For a single-wye winding, the logic requires one neutral CT and one set of line CTs for the REF function. If this set of line CTs is from Terminal 1, the relay sets Switch S1a to Position 2 and Switches S1b and S1c to Position 1. Current inputs from those terminals in Position 1 are not included in any REF element calculations. After setting Switches S1a, S1b, and S1c to the appropriate positions, the relay converts the currents to primary values by multiplying each current with the appropriate CT ratio. The relay then sums these currents vectorially to produce the polarizing current in vector form. To bring this value to the same base as the neutral CT, the algorithm divides the polarizing current by the product of the CT ratio and the neutral CT nominal rating (CTRN1 • I_{NOMN1}). These calculations produce IGWPU1, the normalized polarizing current in vector form. For the operating current, the algorithm divides IN1 by I_{NOMN1} to produce INWPU1, the normalized operating current in vector form. I_{NOMN1} is the nominal rating of the neutral CT, 5 A or 1 A.

When the algorithm meets the conditions in *Figure 4.13*, REF1E asserts and enables the calculations of the directional element. To determine the direction, the algorithm calculates the real part of the product of the polarizing quantity and the conjugate of the operating quantity. This calculation yields the signed torque quantity REFTQ1 (this calculation is equivalent to $|I_{OP1}|$ times $|I_{POL1}|$ times the cosine of the angle between them). REFTQ1 is positive if the angle is within ±90 degrees, indicating a forward or internal fault. Conversely, REFTQ1 is negative if the angle is greater than +90 or less than –90 degrees, indicating a reverse or external fault.

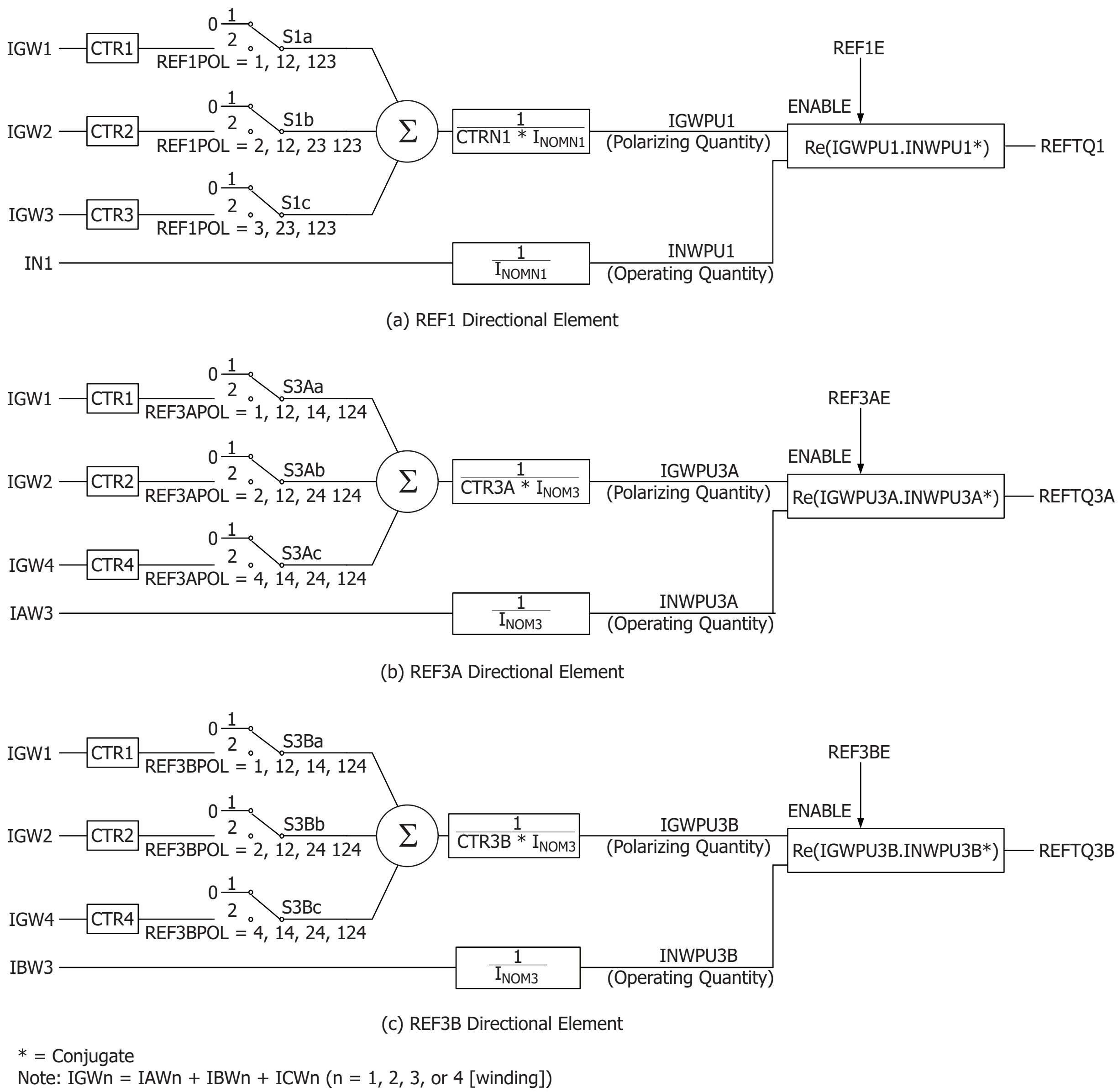


Figure 4.14 REF1, REF3A, and REF3B Torque Calculations

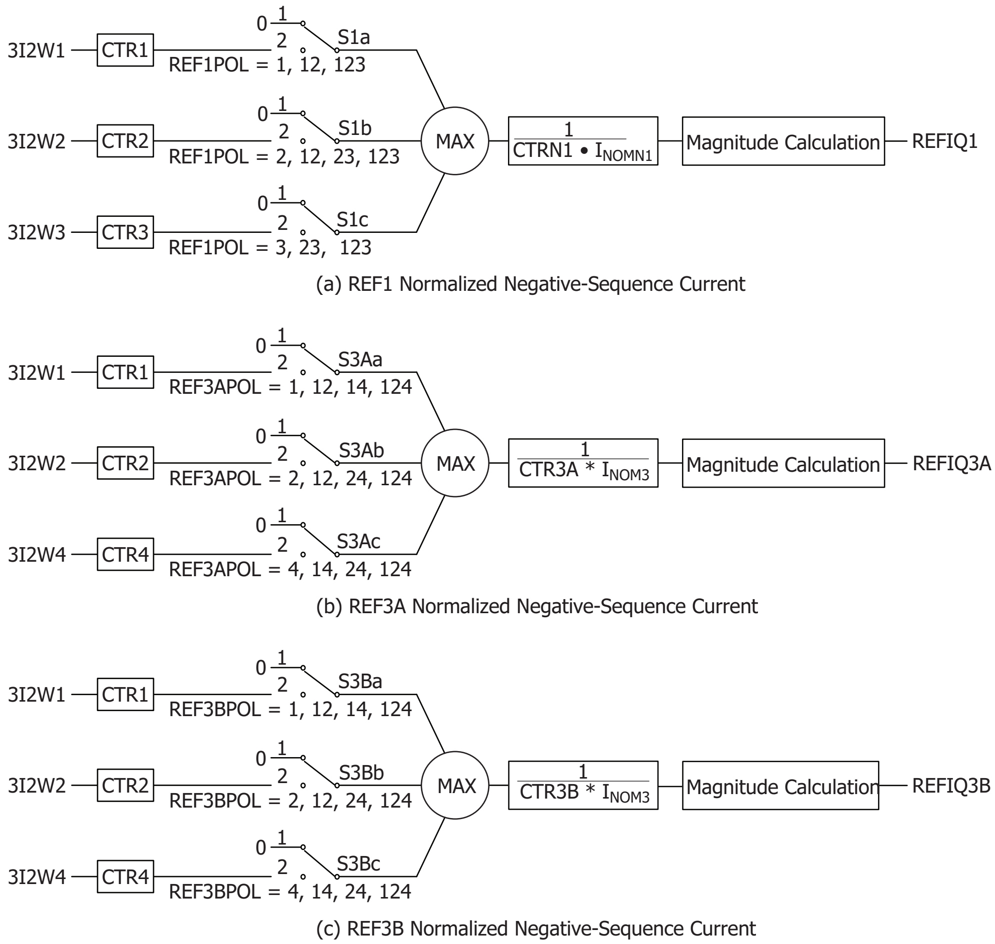


Figure 4.15 REF1, REF3A, and REF3B Normalized Negative-Sequence Current

The selection logic shown in *Figure 4.15* is similar to *Figure 4.14*. The logic routes the negative-sequence current from the appropriate terminals based on the REF*k*POL setting. Once the appropriate terminals are selected, the maximum of the currents is normalized to a per-unit quantity. The normalized negative-sequence current REFIQ1 is used in *Figure 4.16* to further secure the REF element.

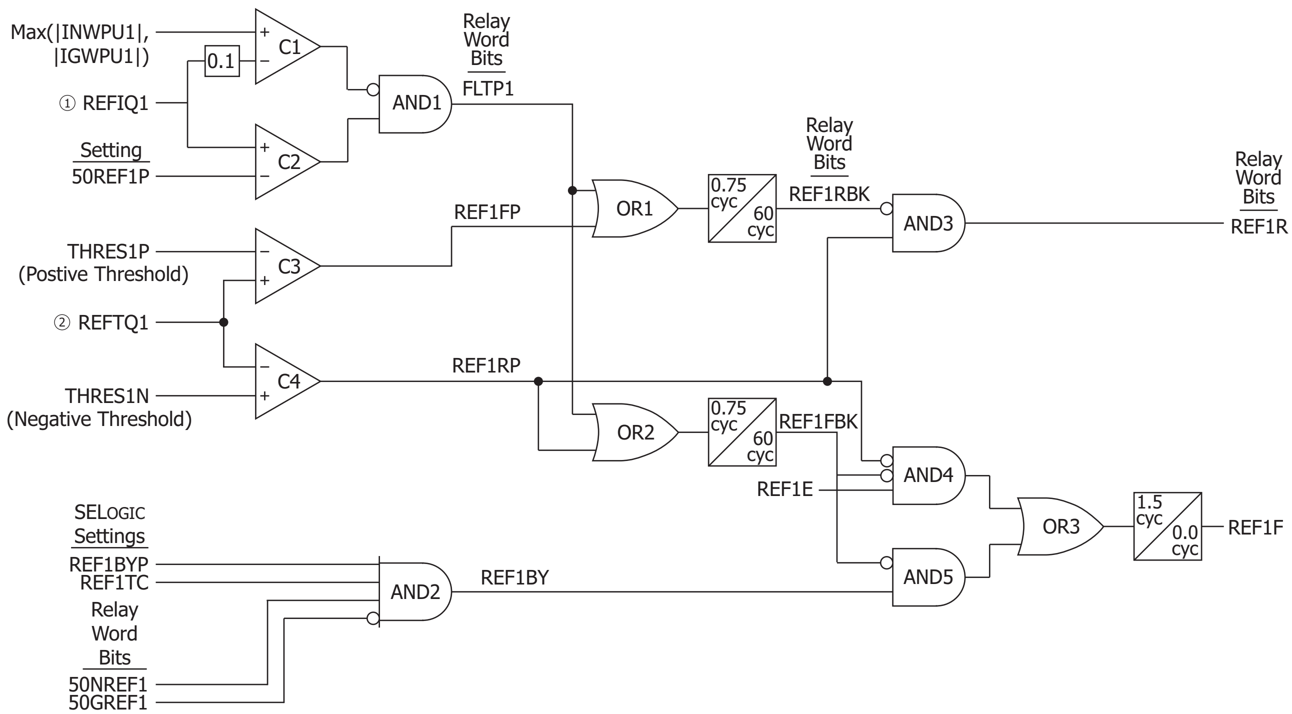
Figure 4.16 shows the logic that compares REFTQ1 to positive threshold (THRES1P) and negative threshold (THRES1N). These thresholds are designed to restrict the operating angle (±105 degrees) to account for dependability and security of the element under a variety of conditions. The threshold reference values are equal and opposite to one another.

REF schemes are susceptible to CT saturation resulting from external line-to-line-to-ground (LLG) faults. To address this, the REF is blocked if the negative-sequence current is greater than the pickup 50REF1P and more than 10 times greater than either INWPU1 or IGWPU1.

The forward REF1 element (REF1F) is blocked via the REF1FBK Relay Word bit for LLG faults (FLTP1) or reverse faults (REF1RP). The reverse REF1 element (REF1R) is blocked via the REF1RBK Relay Word bit for LLG faults (FLTP1) or forward faults (REF1FP). A 60 cycle security dropout timer is used for both the forward and reverse REF elements to ensure the supervision is secure in the event of severe CT saturation.

A reverse REF1 fault is declared by asserting the REF1R Relay Word bit if the reverse threshold THRES1N is greater than REFTQ1 and a forward (REF1FP) or LLG fault (FLTP1) is not detected.

A forward fault is declared by asserting the REF1F Relay Word bit when the element is enabled (REF1E Relay Word bit asserted) and the forward block Relay Word bit REF1FBK is deasserted. Relay Word bit REF1FBK asserts for LLG faults (FLTP1) or any reverse faults (REF1RP). This gives the forward operating region the characteristic shown in *Figure 4.12*, which is a torque angle within approximately ±105 degrees of the reference current.



① See Figure 4.15(a), ② see Figure 4.14(a).

Figure 4.16 REF Element Trip Output

A second path can also declare a forward fault (assert REF1F). This path comes from the output of the AND2 gate in *Figure 4.16*, REF1 bypass logic. The AND2 gate has four inputs, 50GREF1, 50NREF1, REF1TC, and REF1BYP. Assertion of this gate indicates substantial neutral current and no line-end current flow. *Figure 4.17* shows the need for the bypass logic. For the directional element to produce a meaningful result, both operating and restraint quantities must be present. If Fault F1 occurs with the LV breaker open, no current flows through the LV CT, and there is no polarizing quantity present. 50NREF1 and negated 50GREF1 identify this condition in *Figure 4.17*. Under this condition the output of the bypass logic, REF1BYP, causes the REF1F bit to assert to clear the internal fault. Use REF1BYP and/or REF1TC to further qualify the bypass condition by checking, for example, the status of the LV breaker.

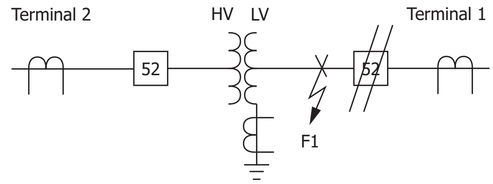


Figure 4.17 Internal Fault With LV Breaker Open

For fast tripping, include REF1F, the output of the REF1 element, into one or more of the trip equations, TR*x* (where *x* = 1, 2, 3, 4, or XFMR) as appropriate. For additional security or delayed tripping, use REF1P in the trip equation instead of REF1F. The relay is programmed to use REF1F to torque control an inverse-time curve for delayed tripping, as shown in *Figure 4.18*. Timing is on an extremely inverse-time overcurrent curve (Curve U4) at the time-dial setting (0.5) and with 50REF1P as the pickup setting.

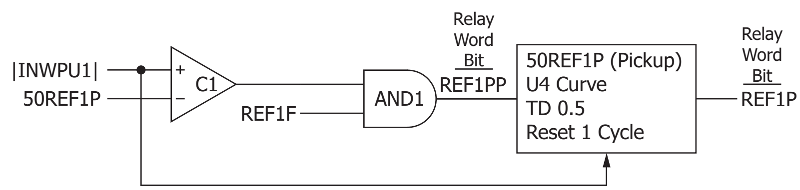


Figure 4.18 REF1 Element Protection Output (Extremely Inverse-Time O/C)

Relay Word bit REF1F (forward fault) torque controls the timing curve, and INWPU1 operates the timing function. The curve resets in one cycle if the current drops below pickup or if REF1F deasserts. When the curve times out, Relay Word bit REF1P asserts. You can use this bit directly as an input to the appropriate trip variables, TR*x* (where *x* = 1, 2, 3, 4, or XFMR), to trip the breaker or breakers that feed the fault.

Setting Descriptions and Applications

Table 4.6 identifies the settings associated with all the three REF elements—REF1, REF3, and REF3B. Configure E87W3 := REF in order for the elements REF3A and REF3B to be available for setting.

Table 4.6 Restricted Earth Fault Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
POL QTY FROM WDG	OFF, 1, 2, 3, 12, 23, 123[a] OFF, 1, 2, 12[b]	REF1POL := OFF
REF1 TRQ CTRL	SELOGIC	REF1TC := 1
REF1 CURR LEVEL	0.05–3.00 pu	50REF1P := 0.25
REF1 BYP TQCTRL	SELOGIC	REF1BYP := 1
POL QTY FROM WDG	OFF, 1, 2, 12[a] OFF, 1, 2, 4, 12, 14, 24, 124[c]	REF3APOL := OFF
REF3A TRQ CTRL	SELOGIC	REF3ATC := 1
REF3A CURR LEVEL	0.05–3.00 pu	50REF3AP := 0.25
REF3A BYP TQCTRL	SELOGIC	REF3ABYP := 1
POL QTY FROM WDG	OFF, 1, 2, 12[a] OFF, 1, 2, 4, 12, 14, 24, 124[c]	REF3BPOL := OFF
REF3B TRQ CTRL	SELOGIC	REF3BTC := 1

Table 4.6 Restricted Earth Fault Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
REF3B CURR LEVEL	0.05–3.00 pu	50REF3BP := 0.25
REF3B BYP TQCTRL	SELOGIC	REF3BBYP := 1

[a] These setting ranges are only applicable to the SEL-787-3E and SEL-787-3S models.
[b] These setting ranges are only applicable to the SEL-787-21 and SEL-787-2E models.
[c] These setting ranges are only applicable to the SEL-787-4X model.

Based on the number of REF elements appropriate for the application, set REF1POL, REF3APOL, and REF3BPOL to something besides OFF. The setting REF*k*POL tells the relay which winding or combination of windings it should use in calculating residual current, which acts as the polarizing quantity for the corresponding directional element, *Figure 4.14*. The setting REF*k*TC is a SELOGIC control equation setting that defines the conditions under which the relay enables the corresponding REF*k* element.

You can set the neutral current sensitivity threshold, 50REF*k*P, to as low as 0.05 times nominal current for a 1 A CT (0.25 A for 5 A nominal CT current), the minimum neutral current sensitivity of the relay. However, the minimum acceptable value of 50REF*k*P must meet the following two criteria.

1. 50REF*k*P must be greater than any natural residual current imbalance caused by load conditions.
2. 50REF*k*P must be greater than a minimum value determined by the relationship of the CTR*n* values used in the REF function.

You must set the threshold setting, 50REF*k*P, at the greater of the two criteria values. See sample calculations in *REF Current Pickup Level*.

Setting Calculation

Selection of the Polarizing Quantity

The operating quantity/polarizing quantity relationship is according to software assignment (instead of a fixed relationship), so you can apply the REF elements to any primary plant configuration with the correct CT arrangement. In general, identify all lines that are electrically connected to the grounded winding that you want to protect with the REF element. Then enter those terminals at the REF*k*POL setting. Following are examples of a few applications, assuming that both differential and REF elements protect the transformer in each example.

Figure 4.19 shows an ungrounded HV winding and a grounded-wye LV winding. Because three terminals are needed for the differential protection, set E87W1 := Y, E87W2 := Y, and E87W3 := Y and assign Terminal 1 to the HV side and Terminals 2 and 3 to the LV side. Configure the REF1 element for REF protection. This element requires that the neutral CT is wired to Terminal IN. Although Terminals 1, 2, and 3 are enabled, only Terminals 2 and 3 electrically connect to the winding earmarked for REF protection. Therefore, set REF1POL := 23.

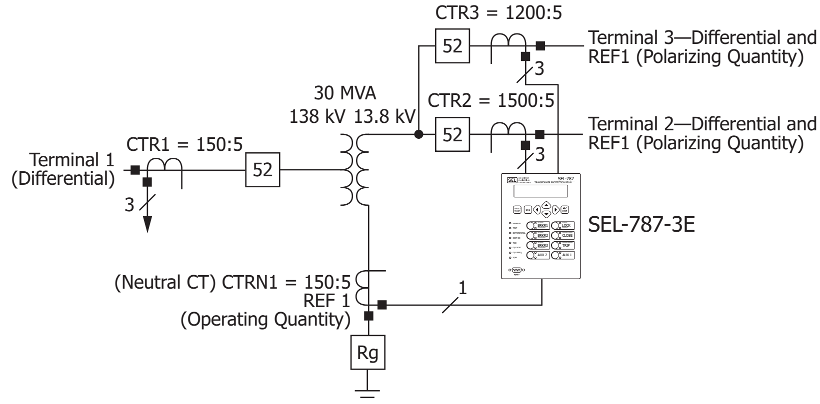


Figure 4.19 Single-Wye Winding REF Application

Figure 4.20 shows an autotransformer. Because two terminals are needed for the differential protection, set E87W1 := Y and E87W2 := Y and assign Terminal 1 to the HV side and Terminal 2 to the LV side. Configure the REF3A element for REF protection. This requires setting E87W3 := REF and the neutral CT wired to Terminal IAW3. In this case, both Terminal 1 and Terminal 2 connect electrically to the winding earmarked for REF protection. Therefore, set REF3APOL := 12.

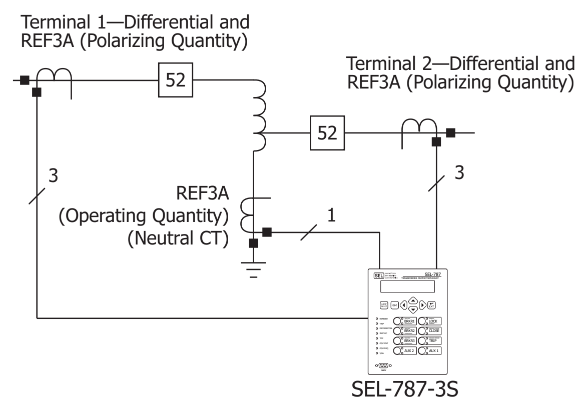


Figure 4.20 Autotransformer REF Application

Figure 4.21 also shows an autotransformer, but in this application, the HV side has two CTs (breaker-and-a-half application). Configure the REF3B element for REF protection. This requires setting E87W3 := REF and the neutral CT wired to Terminal IBW3. Because three terminals are needed for the differential protection and E87W3 is set to REF, set E87W1 := Y, E87W2 := Y, and E87W4 := Y and assign Terminals 1 and 2 to the HV side and Terminal 4 to the LV side. In this case, Terminals 1, 2, and 4 connect electrically to the winding earmarked for REF protection. Therefore, set REF3BPOL := 124.

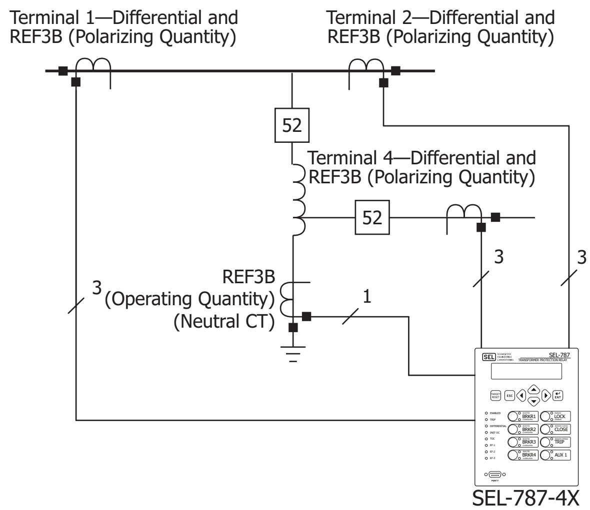


Figure 4.21 Autotransformer With Two HV Current Transformer REF

Figure 4.22 shows a three-winding wye-wye transformer with tertiary delta. Assume that no load connects to the delta, so that the differential calculations exclude the delta. In contrast to an autotransformer, the HV and MV windings of this transformer are not connected electrically, and need a separate REF for each winding. Configure the elements REF3A and REF3B for HV and LV sides, respectively, for REF protection. Given that, the neutral CT on the HV side should be wired to Terminal IAW3 and the neutral CT on the MV side should be wired to Terminal IBW3. Because two terminals are needed for the differential protection and E87W3 is set to REF, set E87W1 := Y and E87W2 := Y, and assign Terminal 1 to the HV side and Terminal 2 to the MV side. Given the terminal assignments, set REF3APOL := 1 for the HV side, and set REF3BPOL := 2 for the MV side.

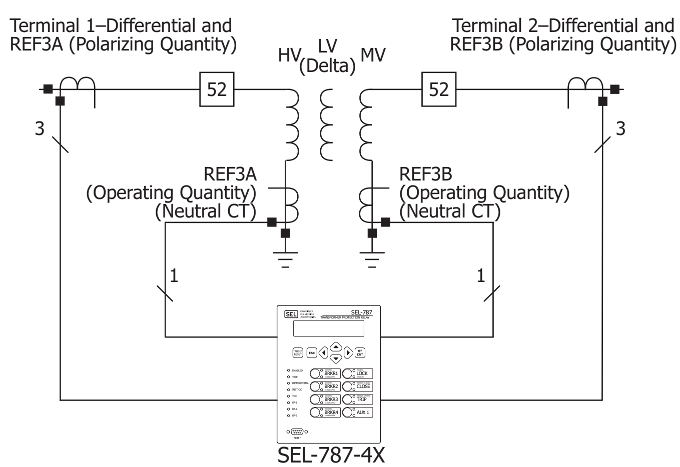


Figure 4.22 Three-Winding Transformer With Two REF Elements

REF Current Pickup Level

The minimum acceptable REF element pickup value, 50REF*k*P, must meet the following criteria and be set at the greater of the two criteria values.

1. 50REF*k*P must be greater than any natural residual current imbalance caused by load conditions.
2. 50REF*k*P must be greater than a minimum value determined by the relationship of the CTR*n* values used in the REF function.

Calculate the pickup for the application shown in *Figure 4.19*. To determine the pickup value per the first criteria, use 10% of full load as the highest expected unbalance. This can be calculated as follows:

$$\text{10\% Full Load Current (Primary Amps)} = \frac{30\ \text{MVA}}{(\sqrt{3} \bullet 13.8\ \text{kV})} \bullet 10\% = 125.5\ \text{A}$$

$$\text{10\% Full Load Current (Secondary Amps)} = \frac{125.5\ \text{A}}{\text{CTRN1}} = \frac{125.5}{30} = 4.18\ \text{A}$$

$$\text{10\% Full Load Current (per unit)} = \frac{4.18\ \text{A}}{I_{\text{NOMN1}}} = 0.84\ \text{pu}$$

The resulting pickup using criteria one is 0.84 pu.

Now apply criteria two. The second criterion of 50REF*k*P is related to the relative sensitivity of the winding CTs compared to the neutral CT. Based on the set REF*k* element and REF*k*POL setting, use the corresponding equations to determine 50REF*k*P.

$$\text{50REF1P} \ge 0.05 \bullet \left[\frac{\text{MAX}(\text{CTRn} \bullet I_{\text{NOMn}})}{(\text{CTRN1} \bullet I_{\text{NOMN1}})}\right] \quad (\text{n} = 1, 2, \text{or } 3)$$

$$\text{50REF3AP} \ge 0.05 \bullet \left[\frac{\text{MAX}(\text{CTRn} \bullet I_{\text{NOMn}})}{(\text{CTR3A} \bullet I_{\text{NOM3}})}\right] \quad (\text{n} = 1, 2, \text{or } 4)$$

$$\text{50REF3BP} \ge 0.05 \bullet \left[\frac{\text{MAX}(\text{CTRn} \bullet I_{\text{NOMn}})}{(\text{CTR3B} \bullet I_{\text{NOM3}})}\right] \quad (\text{n} = 1, 2, \text{or } 4)$$

where MAX(CTRn • $I_{\text{NOM}n}$) is the greatest primary rating of the CTs being used for the REF function. The application shown in *Figure 4.19* uses the REF1 element with REF1POL = 23. Therefore, n = 2 and 3. Calculate 50REF1P as:

$$\text{50REF1P} \ge 0.05 \bullet \frac{\text{MAX}(300 \bullet 5 \text{ or } 240 \bullet 5)}{(30 \bullet 5)}$$

$$\text{50REF1P} \ge 0.50\ \text{PU}$$

The minimum setting per criteria two is 0.50 pu. Because 50REF1P must be set at the greater of the two criteria values, we would select a setting of 0.84 pu.

Overcurrent Elements

Four levels of maximum phase, and two levels each of residual and negative sequence, instantaneous/definite-time overcurrent elements are available for each of the transformer windings as shown in *Table 4.7* through *Table 4.11* and in *Figure 4.23*. For the relay models with the neutral option, two levels of neutral instantaneous/definite-time overcurrent elements are available, see *Table 4.10* and *Figure 4.23*.

Winding 3 is unique in that it has two levels of per-phase overcurrent elements that are available at all times, as identified in *Table 4.8*. Winding 3 can be configured for REF protection by setting E87W3 := REF. Under this condition the CTR3 setting is hidden and the per-phase CTR settings (CTR3A, CTR3B, and CTR3C) are available. When E87W3 := REF, the Winding 3 maximum phase, residual, and negative-sequence overcurrent elements are not available for setting.

Each element can be torque controlled using appropriate SELOGIC control equations (e.g., when 50P11TC := IN401, the 50P11 element is operational only if IN401 is asserted).

Table 4.7 Winding n[a] Maximum Phase Overcurrent Settings

Setting Prompt	Setting Range	Setting Name := Factory Default[a]
PHASE IOC LEVEL	OFF, 0.25–96.00 A[b], 0.05–19.20 A[c]	50P*n*1P := OFF 50P*n*1P := OFF
PHASE IOC DELAY	OFF, 0.00–5.00 sec	50P*n*1D := 0.00
PH IOC TRQCTRL	SELOGIC	50P*n*1TC := 1
PHASE IOC LEVEL	OFF, 0.25–96.00 A[a], 0.05–19.20 A[b]	50P*n*2P := OFF 50P*n*2P := OFF
PHASE IOC DELAY	OFF, 0.00–5.00 sec	50P*n*2D := 0.00
PH IOC TRQCTRL	SELOGIC	50P*n*2TC := 1
PHASE IOC LEVEL	OFF, 0.25–96.00 A[a], 0.05–19.20 A[b]	50P*n*3P := OFF 50P*n*3P := OFF
PHASE IOC DELAY	OFF, 0.00–5.00 sec	50P*n*3D := 0.00
PH IOC TRQCTRL	SELOGIC	50P*n*3TC := 1
PHASE IOC LEVEL	OFF, 0.25–96.00 A[a], 0.05–19.20 A[b]	50P*n*4P := OFF 50P*n*4P := OFF
PHASE IOC DELAY	OFF, 0.00–5.00 sec	50P*n*4D := 0.00
PH IOC TRQCTRL	SELOGIC	50P*n*4TC := 1

[a] n = 1, 2, 3, or 4.
[b] For I_{NOM} = 5 A.
[c] For I_{NOM} = 1 A.

Table 4.8 Winding 3 Per Phase Overcurrent Settings

Setting Prompt	Setting Range	Setting Name := Factory Default[a]
PHASE IOC LEVEL	OFF, 0.25–96.00 A[b], 0.05–19.20 A[c]	50P3*k*AP := OFF 50P3*k*AP := OFF
PHASE IOC DELAY	OFF, 0.00–5.00 sec	50P3*k*AD := 0.00
PH IOC TRQCTRL	SELOGIC	50P3*k*ATC := 1
PHASE IOC LEVEL	OFF, 0.25–96.00 A[a], 0.05–19.20 A[b]	50P3*k*BP := OFF 50P3*k*BP := OFF
PHASE IOC DELAY	OFF, 0.00–5.00 sec	50P3*k*BD := 0.00
PH IOC TRQCTRL	SELOGIC	50P3*k*BTC := 1
PHASE IOC LEVEL	OFF, 0.25–96.00 A[a], 0.05–19.20 A[b]	50P3*k*CP := OFF 50P3*k*CP := OFF
PHASE IOC DELAY	OFF, 0.00–5.00 sec	50P3*k*CD := 0.00
PH IOC TRQCTRL	SELOGIC	50P3*k*CTC := 1

[a] k = 1 or 2 (Level).
[b] For I_{NOM} = 5 A.
[c] For I_{NOM} = 1 A.

NOTE: 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 significantly degraded. Combining the two methods provides an elegant solution for ensuring dependable short circuit overcurrent element operation.

The phase instantaneous overcurrent elements (50P*n*1 through 50P*n*4; see *Figure 4.23*) normally operate using the output of the one-cycle cosine filtered phase current. During severe CT saturation, the cosine filtered phase current magnitude may be substantially reduced because of the distorted secondary waveform. If the overcurrent element relied only on the output of the cosine filtered secondary current, the operation of any high-set instantaneous overcurrent element could be severely delayed and may even be jeopardized. For any phase instantaneous overcurrent element in the SEL-787 Relay set above eight times the relay current input rating (40 A in a 5 A relay), the overcurrent element also operates on the output of a bipolar peak detector if the current waveform is highly distorted, as is the case with severe CT saturation. This ensures fast operation of the 50P phase overcurrent elements even with severe CT saturation.

NOTE: IGWnI is forced to zero if WnCT = DELTA.

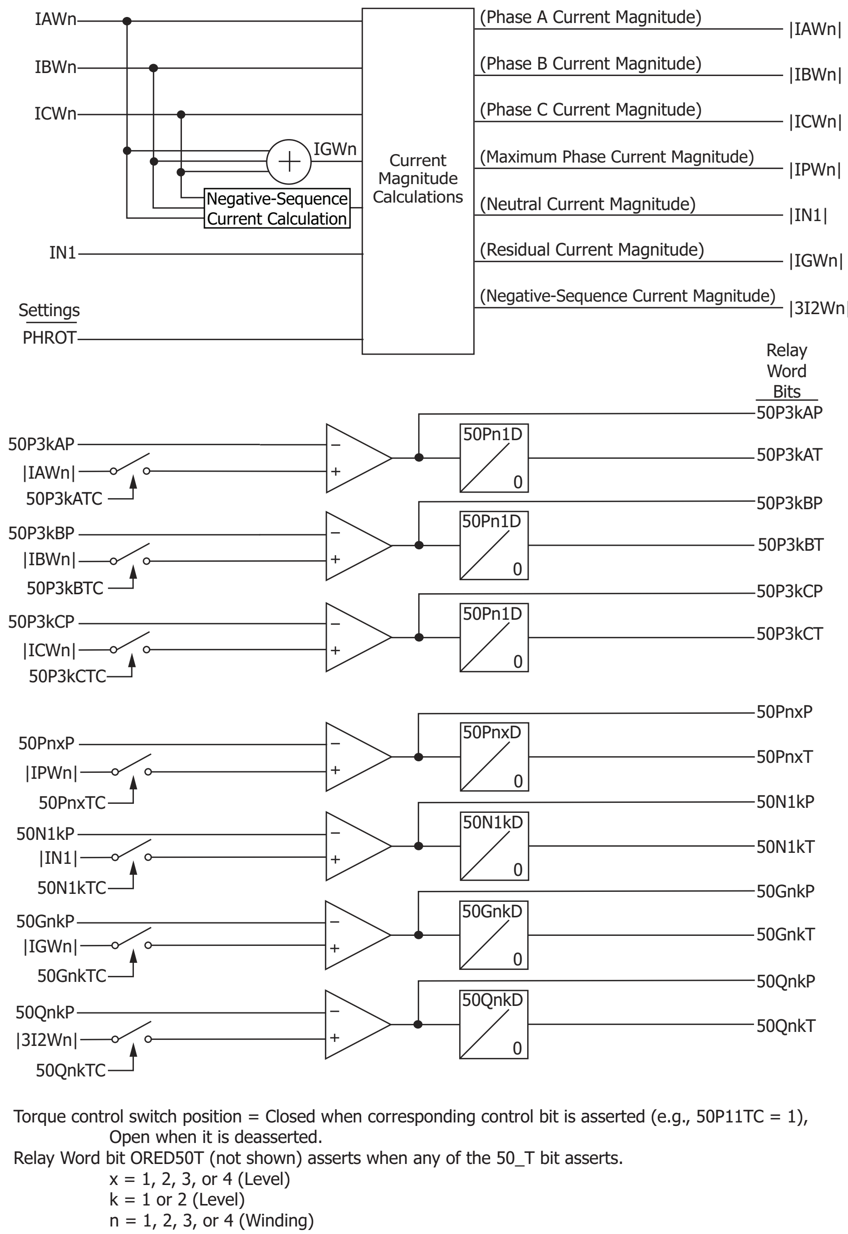


Figure 4.23 Instantaneous Overcurrent Element Logic

When the harmonic distortion index exceeds the fixed threshold, which indicates severe CT saturation, the phase overcurrent elements operate on the output of the peak detector. When the harmonic distortion index is below the fixed threshold, the phase overcurrent elements operate on the output of the cosine filter.

Table 4.9 Winding n[a] Residual Overcurrent Settings

Setting Prompt	Setting Range	Setting Name := Factory Default[a]
RES IOC LEVEL	OFF, 0.25–96.00 A[b], 0.05–19.20 A[c]	50G*n*1P := OFF
RES IOC DELAY	OFF, 0.00–5.00 sec	50G*n*1D := 0.50
RES IOC TRQCTRL	SELOGIC	50G*n*1TC := 1
RES IOC LEVEL	OFF, 0.25–96.00 A[b], 0.05–19.20 A[c]	50G*n*2P := OFF
RES IOC DELAY	OFF, 0.00–5.00 sec	50G*n*2D := 0.50
RES IOC TRQCTRL	SELOGIC	50G*n*2TC := 1

[a] n = 1, 2, 3, or 4.
[b] For I_{NOM} = 5 A.
[c] For I_{NOM} = 1 A.

The relay offers two types of ground fault detecting overcurrent elements. The neutral overcurrent elements, 50N11T and 50N12T, identified in *Table 4.10*, operate with current measured by the IN1 input. The residual (RES) overcurrent elements, 50G*n*1T and 50G*n*2T, identified in *Table 4.9*, operate with the zero-sequence current derived from each winding phase currents. The logic associated with the operation of these elements is shown in *Figure 4.23*.

Table 4.10 Neutral Overcurrent Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
NEUT IOC LEVEL	OFF, 0.25–96.00 A[a], 0.05–19.20 A[b]	50N11P := OFF
NEUT IOC DELAY	OFF, 0.00–5.00 sec	50N11D := 0.50
NEUT IOC TRQCTRL	SELOGIC	50N11TC := 1
NEUT IOC LEVEL	OFF, 0.25–96.00 A, 0.05–19.20 A[b]	50N12P := OFF
NEUT IOC DELAY	OFF, 0.00–5.00 sec	50N12D := 0.50
NEUT IOC TRQCTRL	SELOGIC	50N12TC := 1

[a] For I_{NOM} = 5 A.
[b] For I_{NOM} = 1 A.

Table 4.11 Winding n[a] Negative-Sequence Overcurrent Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default[a]
NSEQ IOC LEVEL	OFF, 0.25–96.00 A[b], 0.05–19.20 A[c]	50Q*n*1P := OFF
NSEQ IOC DELAY	OFF, 0.10–120.00 sec	50Q*n*1D := 0.20
NSEQ IOC TRQCTRL	SELOGIC	50Q*n*1TC := 1

Table 4.11 Winding n[a] Negative-Sequence Overcurrent Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default[a]
NSEQ IOC LEVEL	OFF, 0.25–96.00 A[a], 0.05–19.20 A[b]	50Q*n*2P := OFF
NSEQ IOC DELAY	OFF, 0.10–120.00 sec	50Q*n*2D := 0.20
NSEQ IOC TRQCTRL	SELOGIC	50Q*n*2TC := 1

[a] n = 1, 2, 3, or 4.
[b] For I_{NOM} = 5 A.
[c] For I_{NOM} = 1 A.

The relay offers two negative-sequence overcurrent elements, as identified in *Table 4.11*, per winding to detect phase-to-phase faults, phase reversal, single phasing, and unbalance load.

Combined Overcurrent Elements

Figure 4.24 shows a breaker-and-a-half layout on the transformer HV side and a single busbar on the LV side. On the HV side, the HV current flows through Terminal 1 CTs and Terminal 2 CTs, but the total current flows through Terminal 3 CTs on the LV side. Current distribution through Terminal 1 and Terminal 2 is a function of the system conditions, and proper coordination of Terminal 3 requires using the sum of the Terminal 1 and Terminal 2 currents. *Figure 4.25* shows the result of the combined current values in the SEL-787. The relay adds the currents from Terminal 1 and Terminal 2 to form the equivalent output of a single CT. The combined winding instantaneous/definite-time overcurrent elements (and combined winding inverse time overcurrent elements) operate on the combined current from corresponding terminals.

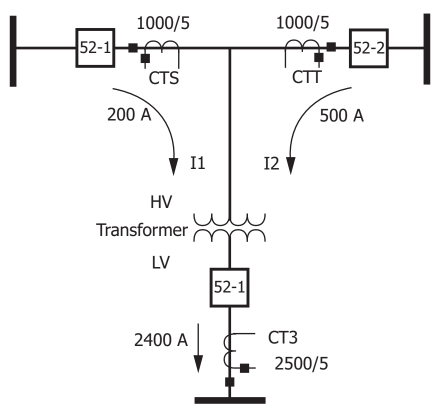


Figure 4.24 Two CTs on HV Side

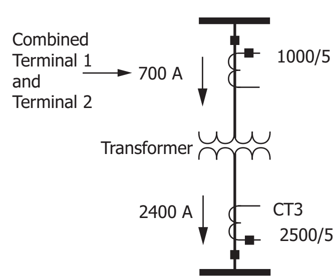


Figure 4.25 Equivalent Single CT on HV Side

The SEL-787 allows you to configure the relay to combine currents on Terminals 1 and 2, Terminals 2 and 3, and Terminals 3 and 4. Other combinations are not permitted. The combined winding definite-time overcurrent and inverse time-overcurrent elements are available when the settings CCW12, CCW23, and CCW34 are set to Y. The relay allows you to combine currents on Terminals 1 and 2 by setting CCW12 := Y, Terminals 2 and 3 by setting CCW23 := Y and Terminals 3 and 4 by setting CCW34 := Y. The CCW12 and CCW23 settings are not available in the SEL-787-21/2E/2X models. The CCW34 setting is only available in the SEL-787-4X model. The CCW12 and CCW34 can be enabled together. The CCW23 cannot be enabled simultaneously with CCW12 or CCW34. For the setting CCW12 to be available, the following criteria must be met at Terminals 1 and 2.

- Nominal CT ratings of both the terminals must be equal (IW1NOM = IW2NOM)
- Both CTs must be connected in WYE; DELTA connection is not supported (W1CT = W2CT = WYE)
- Both CT ratios (or LEA scales in the case of LEA card) must be equal (CTR1 = CTR2 or ILEA_S1 = ILEA_S2)
- Nominal line-to-line terminal voltage ratings must be equal (VWDG1 = VWDG2)

NOTE: The bipolar peak detector is not available in the combined overcurrent elements.

The previous set of criteria can be extended to the CCW23 and CCW34 settings for Terminals 2 and 3 and Terminals 3 and 4, respectively.

The relay offers two levels of combined winding maximum phase overcurrent elements and two levels of combined winding residual overcurrent elements. The settings and logic associated with the combined winding overcurrent elements are identified in *Table 4.12* and *Table 4.13*, respectively, and *Figure 4.26*. Refer to *Combined Time-Overcurrent Elements on page 4.58* for the settings and logic associated with the combined winding inverse time-overcurrent elements.

Table 4.12 Combined Winding Maximum Phase Overcurrent Settings

Setting Prompt	Setting Range	Setting Name := Factory Default[a]
PHASE IOC LEVEL	OFF, 0.25–96.00 A[b], 0.05–19.20 A[c]	50P*n*1P : = OFF
PHASE IOC DELAY	OFF, 0.00–5.00 sec	50P*n*1D := 0.00
PH IOC TRQCTRL	SELOGIC	50P*n*1TC := 1
PHASE IOC LEVEL	OFF, 0.25–96.00 A[b], 0.05–19.20 A[c]	50P*n*2P : = OFF
PHASE IOC DELAY	OFF, 0.00–5.00 sec	50P*n*2D := 0.00
PH IOC TRQCTRL	SELOGIC	50P*n*2TC := 1

[a] n = 12, 23, or 34.
[b] For INOM := 5 A.
[c] For INOM := 1 A.

Table 4.13 Combined Winding Residual Overcurrent Settings

Setting Prompt	Setting Range	Setting Name := Factory Default[a]
PHASE IOC LEVEL	OFF, 0.25–96.00 A[b], 0.05–19.20 A[c]	50G*n*1P : = OFF 50G*n*1P : = OFF
PHASE IOC DELAY	OFF, 0.00-5.00 sec	50G*n*1D := 0.50
PH IOC TRQCTRL	SELOGIC	50G*n*1TC := 1
PHASE IOC LEVEL	OFF, 0.25–96.00 A[b], 0.05–19.20 A[c]	50G*n*2P : = OFF 50G*n*2P : = OFF
PHASE IOC DELAY	OFF, 0.00-5.00 sec	50G*n*2D := 0.50
PH IOC TRQCTRL	SELOGIC	50G*n*2TC := 1

[a] n = 12, 23, or 34.
[b] For INOM = 5 A.
[c] For INOM = 1 A.

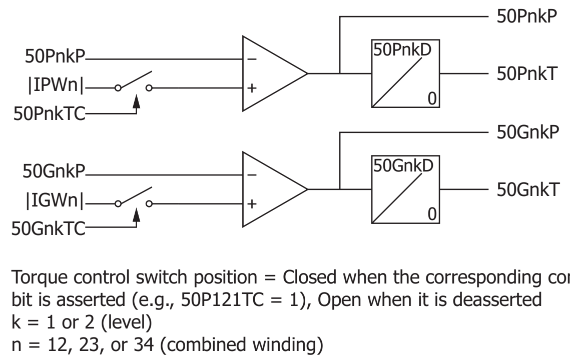


Figure 4.26 Combined Winding Instantaneous Overcurrent Element Logic

Relay Word Bit ORED50T

Relay Word bit ORED50T is asserted if any of the Relay Word bits 50P11T, 50P12T, 50P13T, 50P14T, 50P21T, 50P22T, 50P23T, 50P24T, 50P31T, 50P32T, 50P33T, 50P34T, 50P41T, 50P42T, 50P43T, 50P44T, 50P121T, 50P122T, 50P231T, 50P232T, 50P341T, 50P342T, 50G11T, 50G12T, 50G21T, 50G22T, 50G31T, 50G32T, 50G41T, 50G42T, 50G121T, 50G122T, 50G231T, 50G232T, 50G341T, 50G342T, 50Q11T, 50Q12T, 50Q21T, 50Q22T, 50Q31T, 50Q32T, 50Q41T, 50Q42T, 50P31AT, 50P32AT, 50P31BT, 50P32BT, 50P31CT, 50P32CT, 50N11T, or 50N12T are asserted.

Time-Overcurrent Elements

One level of inverse-time element is available for maximum phase, residual, and negative-sequence overcurrent per transformer winding. See *Table 4.14* through *Table 4.17* for available settings. For the relay models with the neutral option, one level of neutral inverse-time overcurrent element is available, see *Table 4.18* and *Figure 4.31*.

Winding 3 is unique in that it has one level of inverse time element that is available for A-phase, B-phase, and C-phase on Winding 3 when configured for REF, as identified in *Table 4.15*. Winding 3 can be configured for REF protection by setting E87W3 := REF. Under this condition, the CTR3 setting is hidden and per-phase CTR settings CTR3A, CTR3B, and CTR3C are available. When E87W3 := REF, the Winding 3 maximum phase, residual, and negative-sequence overcurrent elements are not available for setting.

You can select from five U.S. and five IEC inverse characteristics. *Table 4.21* and *Table 4.22* show equations for the curves and *Figure 4.34* through *Figure 4.43* show the curves. The curves and equations shown do not account for constant time adder and minimum response time (settings 51_CT and 51_MR respectively, each assumed equal to zero). Use the 51_CT if you want to raise the curves by a constant time. Also, you can use the 51_MR if you want to ensure the curve times no faster than a minimum response time.

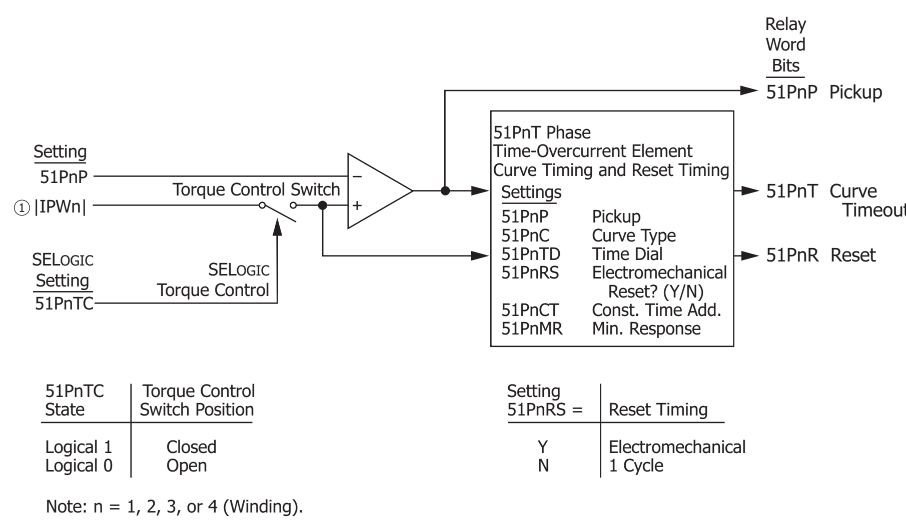
Each element can be torque controlled using appropriate SELOGIC control equations (e.g., when 51P1TC := IN401, the 51P1P element is operational only if IN401 is asserted).

Table 4.14 Winding n[a] Maximum Phase Time-Overcurrent

Setting Prompt	Setting Range	Setting Name := Factory Default[a]
PHASE TOC LEVEL	OFF, 0.25–16.00 A[b], 0.05–3.20 A[c]	51P*n*P := OFF 51P*n*P := OFF
PHASE TOC CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51P*n*C := U3
PHASE TOC TDIAL	0.50–15.00[d], 0.05–1.00[e]	51P*n*TD := 3.00
EM RESET DELAY	Y, N	51P*n*RS := N
CONST TIME ADDER	0.00–1.00 sec	51P*n*CT := 0.00
MIN RESPONSE TIM	0.00–1.00 sec	51P*n*MR := 0.00
PH TOC TRQCTRL	SELOGIC	51P*n*TC := 1

[a] n = 1, 2, 3, or 4.
[b] For I_{NOM} = 5 A.
[c] For I_{NOM} = 1 A.
[d] For 51_C := U_.
[e] For 51_C := C_.

The maximum phase time-overcurrent element, 51P*n*T, responds to the highest of corresponding winding A, B, and C-phase currents as shown in *Figure 4.27*.



① From Figure 4.23.

Figure 4.27 Maximum Phase Time-Overcurrent Element 51PnT

The phase time-overcurrent elements, 51P3AT, 51P3BT, and 51P3CT, respond to the A-, B-, and C-phase currents for Winding 3, respectively, as shown in *Figure 4.28*.

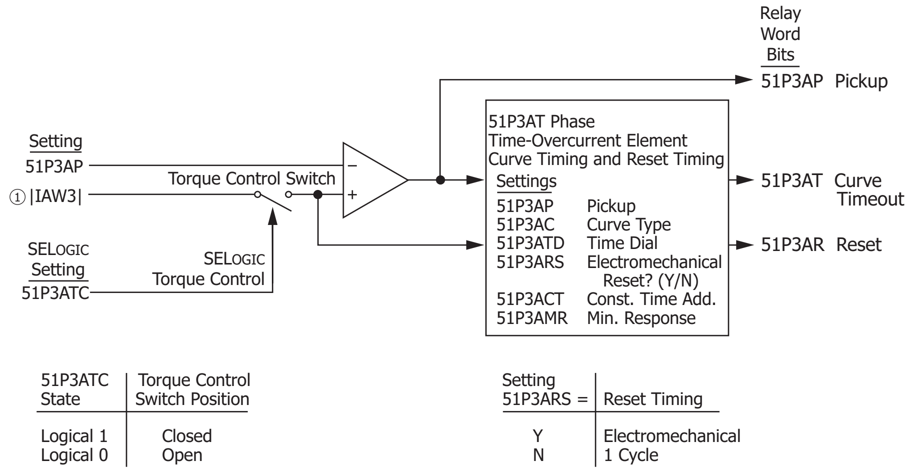


Figure 4.28 Winding 3 Phase A, B, and C Time-Overcurrent Elements

Table 4.15 Winding 3 Phase A, B, and C Time-Overcurrent (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
PHASE TOC LVL	OFF, 0.25–16.00 A[a], 0.05–3.20 A[b]	51P3AP := OFF
PHASE TOC CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51P3AC := U3
PHASE TOC TDIAL	0.50–15.00[c], 0.05–1.00[d]	51P3ATD := 3.00
EM RESET DELAY	Y, N	51P3ARS := N
CONST TIME ADDER	0.00–1.00 sec	51P3ACT := 0.00
MIN RESPONSE TIM	0.00–1.00 sec	51P3AMR := 0.00
PH A TOC TRQCTRL	SELOGIC	51P3ATC := 1
PHASE TOC LVL	OFF, 0.25–16.00 A[a], 0.05–3.20 A[b]	51P3BP := OFF
PHASE TOC CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51P3BC := U3
PHASE TOC TDIAL	0.50–15.00[c], 0.05–1.00[d]	51P3BTD := 3.00
EM RESET DELAY	Y, N	51P3BRS := N
CONST TIME ADDER	0.00–1.00 sec	51P3BCT := 0.00
MIN RESPONSE TIM	0.00–1.00 sec	51P3BMR := 0.00
PH B TOC TRQCTRL	SELOGIC	51P3BTC := 1
PHASE TOC LVL	OFF, 0.25–16.00 A[a], 0.05–3.20 A[b]	51P3CP := OFF
PHASE TOC CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51P3CC := U3

Table 4.15 Winding 3 Phase A, B, and C Time-Overcurrent (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
PHASE TOC TDIAL	0.50–15.00[c], 0.05–1.00[d]	51P3CTD := 3.00
EM RESET DELAY	Y, N	51P3CRS := N
CONST TIME ADDER	0.00–1.00 sec	51P3CCT := 0.00
MIN RESPONSE TIM	0.00–1.00 sec	51P3CMR := 0.00
PH A TOC TRQCTRL	SELOGIC	51P3CTC := 1

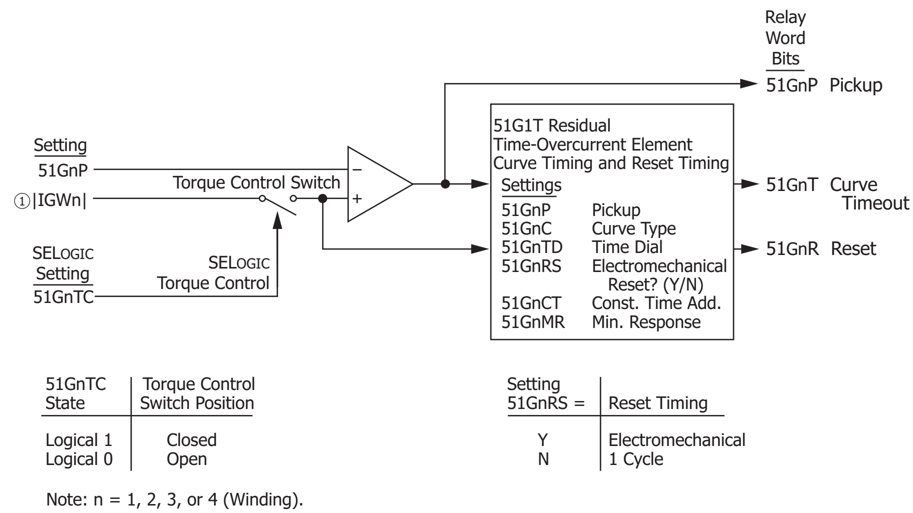
[a] For I_{NOM} = 5 A.
[b] For I_{NOM} = 1 A.
[c] For 51_C := U_.
[d] For 51_C := C_.

Table 4.16 Residual Time-Overcurrent Settings

Setting Prompt	Setting Range	Setting Name := Factory Default[a]
RES TOC LEVEL	OFF, 0.25–16.00 A[b], 0.05–3.20 A[c]	51G*n*P := OFF 51G*n*P := OFF
RES TOC CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51G*n*C := U3
RES TOC TDIAL	0.50–15.00[d], 0.05–1.00[e]	51G*n*TD := 1.50
EM RESET DELAY	Y, N	51G*n*RS := N
CONST TIME ADDER	0.00–1.00 sec	51G*n*CT := 0.00
MIN RESPONSE TIM	0.00–1.00 sec	51G*n*MR := 0.00
RES TOC TRQCTRL	SELOGIC	51G*n*TC := 1

[a] n = 1, 2, 3, or 4 (Winding).
[b] For I_{NOM} = 5 A.
[c] For I_{NOM} = 1 A.
[d] For 51_C := U_.
[e] For 51_C := C_.

The residual time-overcurrent element, 51G*n*T, responds to residual current magnitude IGW*n* of the corresponding winding, as shown in *Figure 4.29*.



① From Figure 4.23.

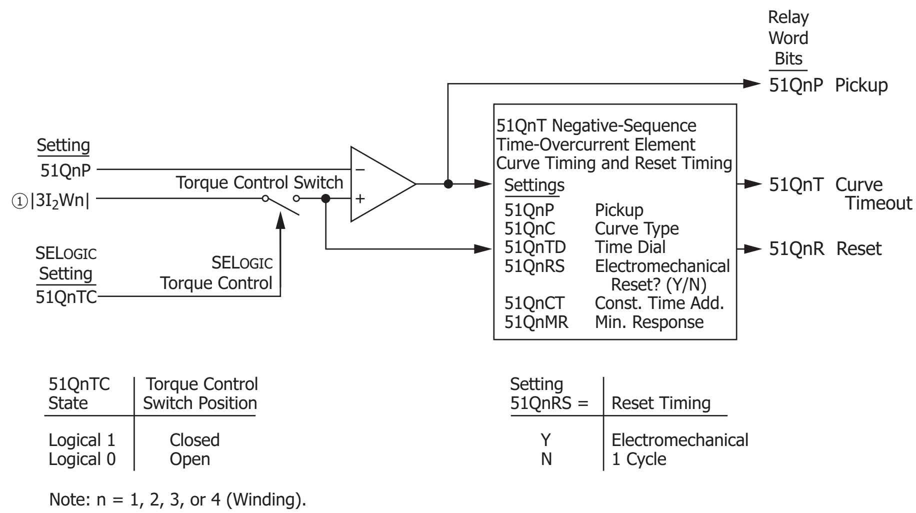
Figure 4.29 Residual Time-Overcurrent Elements 51GnT

Table 4.17 Winding n[a] Negative-Sequence Time-Overcurrent Settings

Setting Prompt	Setting Range	Setting Name := Factory Default[a]
NSEQ TOC LEVEL	OFF, 0.25–16.00 A[b], 0.05–3.20 A[c]	51Q*n*P :=OFF 51Q*n*P := OFF
NSEQ TOC CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51Q*n*C := U3
NSEQ TOC TDIAL	0.50–15.00[d], 0.05–1.00[e]	51Q*n*TD := 3.00
EM RESET DELAY	Y, N	51Q*n*RS := N
CONST TIME ADDER	0.00–1.00 sec	51Q*n*CT := 0.00
MIN RESPONSE TIM	0.00–1.00 sec	51Q*n*MR := 0.00
NSEQ TOC TRQCTRL	SELOGIC	51Q*n*TC := 1

[a] n = 1, 2, 3, or 4.
[b] For I_{NOM} = 5 A.
[c] For I_{NOM} = 1 A.
[d] For 51_C := U_.
[e] For 51_C := C_.

The negative-sequence time-overcurrent element 51Q*n*T responds to the corresponding winding 3I2W*n* current magnitude, as shown in *Figure 4.30*. False 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, do not use a time-dial setting that results in curve times less than three cycles.



① From Figure 4.23.

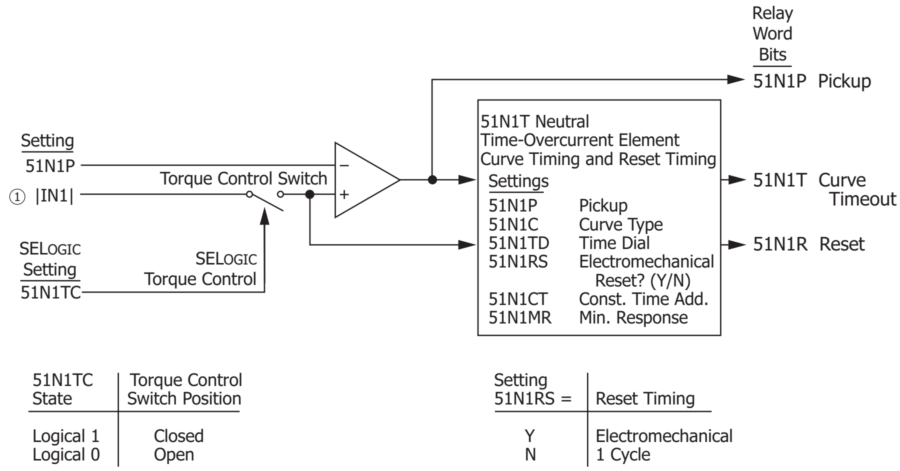
Figure 4.30 Negative-Sequence Time-Overcurrent Element 51Q1T and 51Q2T

Table 4.18 Neutral Time-Overcurrent Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
NEUT TOC LEVEL	OFF, 0.25–16.00 A[a], 0.05–3.20 A[b],	51N1P := OFF
NEUT TOC CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51N1C := U3
NEUT TOC TDIAL	0.50–15.00[c] 0.05–1.00[d]	51N1TD := 1.50
EM RESET DELAY	Y, N	51N1RS := N
CONST TIME ADDER	0.00–1.00 sec	51N1CT := 0.00
MIN RESPONSE TIM	0.00–1.00 sec	51N1MR := 0.00
NEUT TOC TRQCTRL	SELOGIC	51N1TC := 1

[a] For I_{NOM} = 5 A.
[b] For I_{NOM} = 1 A.
[c] For 51_C := U_.
[d] For 51_C := C_.

The time-overcurrent element 51N1T, identified in *Table 4.18*, responds to neutral channel current IN1, as shown in *Figure 4.31*.



① From Figure 4.23.

Figure 4.31 Neutral Time-Overcurrent Elements 51N1T and 51N2T

Combined Time-Overcurrent Elements

As explained in *Combined Overcurrent Elements on page 4.50*, the SEL-787 allows you to configure the relay to combine currents on Terminals 1 and 2, Terminals 2 and 3, and Terminals 3 and 4. The relay allows you to combine currents on Terminals 1 and 2 by setting CCW12 := Y, Terminals 2 and 3 by setting CCW23 := Y, and Terminals 3 and 4 by setting CCW34 := Y. Refer to *Combined Overcurrent Elements on page 4.50* for more information on the combined winding overcurrent elements.

The settings and logic associated with the combined maximum phase and residual time-overcurrent elements are identified in *Table 4.19* and *Table 4.20* and *Figure 4.32* and *Figure 4.33*, respectively.

Table 4.19 Combined Winding Maximum Phase Time-Overcurrent Elements

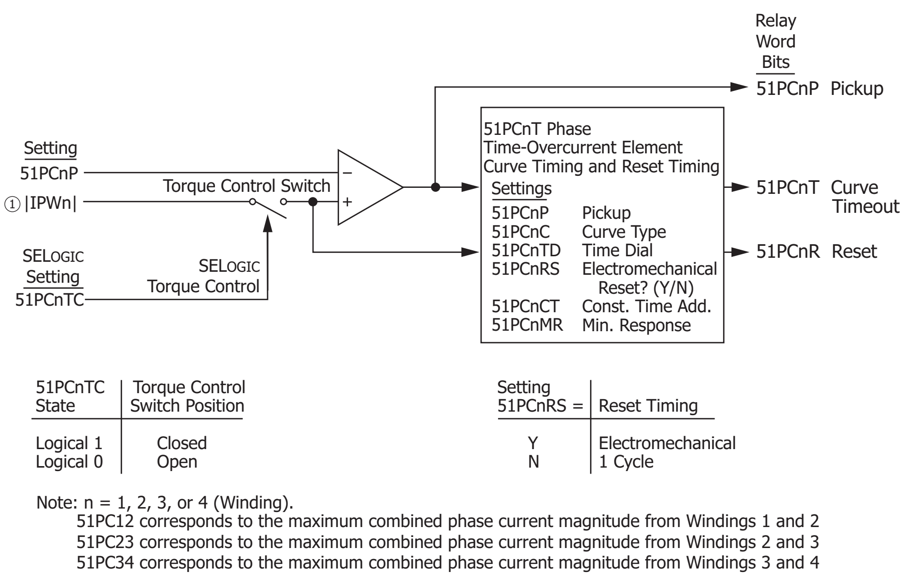
Setting Prompt	Setting Range	Setting Name := Factory Default[a]
PHASE TOC LEVEL	OFF, 0.25–16.00 A[b], 0.05–3.20 A[c]	51PC*n*P := OFF 51PC*n*P := OFF
PHASE TOC CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51PC*n*C := U3
PHASE TOC TDIAL	0.50–15.00[d], 0.05–1.00[e]	51PC*n*TD := 3.00
EM RESET DELAY	Y, N	51PC*n*RS := N
CONST TIME ADDER	0.00–1.00 sec	51PC*n*CT := 0.00
MIN RESPONSE TIM	0.00–1.00 sec	51PC*n*MR := 0.00
PH TOC TRQCTRL	SELOGIC	51PC*n*TC := 1

[a] n = 12, 23, or 34 (Combined Windings).
[b] For I_{NOM} = 5 A.
[c] For I_{NOM} = 1 A.
[d] For 51_C := U_.
[e] For 51_C := C_.

Table 4.20 Combined Winding Residual Ground Time-Overcurrent Elements

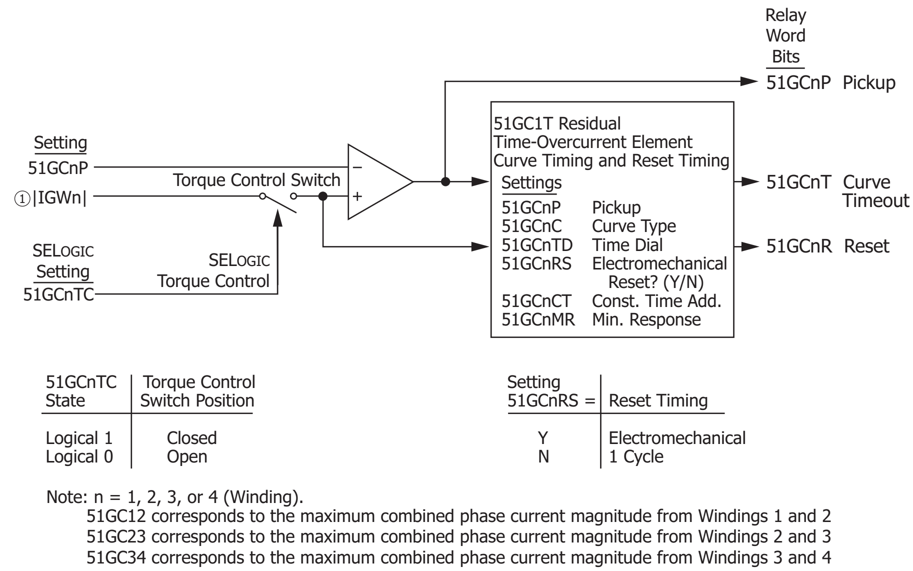
Setting Prompt	Setting Range	Setting Name := Factory Default[a]
PHASE TOC LEVEL	OFF, 0.25–16.00 A[b], 0.05–3.20 A[c]	51GC*n*P := OFF 51GC*n*P := OFF
PHASE TOC CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51GC*n*C := U3
PHASE TOC TDIAL	0.50–15.00[d], 0.05–1.00[e]	51GC*n*TD := 3.00
EM RESET DELAY	Y, N	51GC*n*RS := N
CONST TIME ADDER	0.00–1.00 sec	51GC*n*CT := 0.00
MIN RESPONSE TIM	0.00–1.00 sec	51GC*n*MR := 0.00
PH TOC TRQCTRL	SELOGIC	51GC*n*TC := 1

[a] n = 12, 23, or 34 (Combined Winding).
[b] For I_{NOM} = 5 A.
[c] For I_{NOM} = 1 A.
[d] For 51_C := U_.
[e] For 51_C := C_.



① From Figure 4.23.

Figure 4.32 Combined Winding Maximum Phase Time-Overcurrent Elements



① From Figure 4.23.

Figure 4.33 Combined Winding Residual Time-Overcurrent Elements

Relay Word Bit ORED51T

Relay Word bit ORED51T is asserted if any of the Relay Word bits 51P1T, 51P2T, 51P3T, 51P4T, 51P3AT, 51P3BT, 51P3CT, 51G1T, 51G2T, 51G3T, 51G4T, 51Q1T, 51Q2T, 51Q3T, 51Q4T, 51PC12T, 51PC23T, 51PC34T, 51GC12T, 51GC23T, 51GC34T, or 51N1T are asserted.

Time-Overcurrent Curves

The following information describes the curve timing for the curve and time dial settings made for the time-overcurrent elements (see *Table 4.21* and *Table 4.22*). The U.S. and IEC time-overcurrent relay curves are shown in *Figure 4.34* through *Figure 4.43*. Curves U1, U2, and U3 (*Figure 4.34* through *Figure*) conform to IEEE C37.112-1996, Standard Inverse-Time Characteristic Equations for Overcurrent Relays.

Table 4.21 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 4.34*
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 4.35*
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*

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 ≤ 1]

Table 4.21 Equations Associated With U.S. Curves

Curve Type	Operating Time	Reset Time	Figure
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*
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 4.38*

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 ≤ 1]

Table 4.22 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 4.39*
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 4.40*
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 4.41*
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 4.42*
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 4.43*

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 ≤ 1]

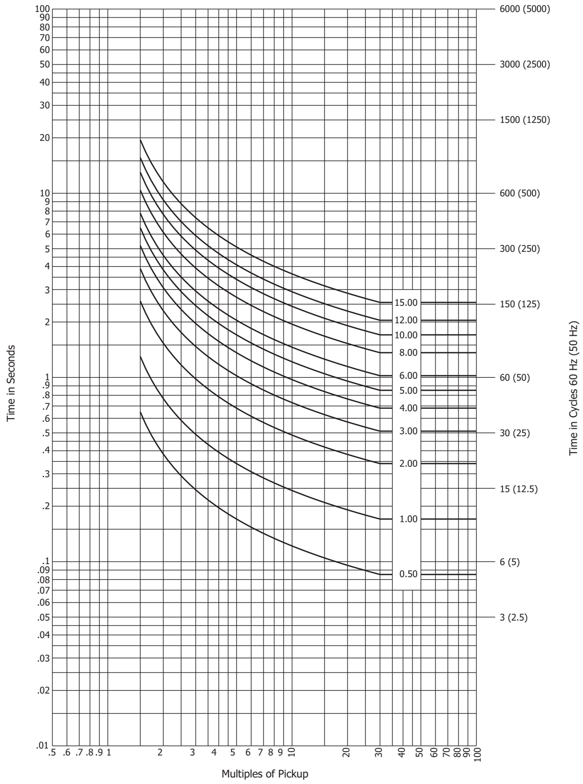


Figure 4.34 U.S. Moderately Inverse Curve: U1

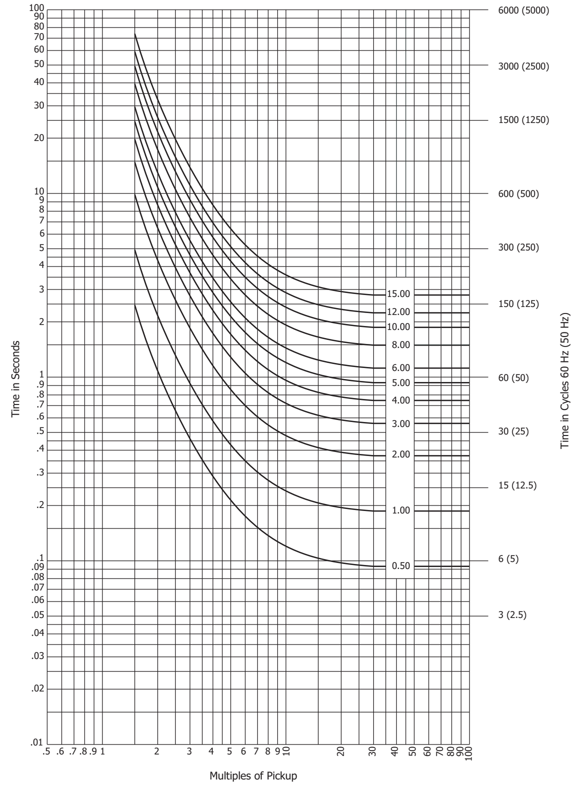


Figure 4.35 U.S. Inverse Curve: U2

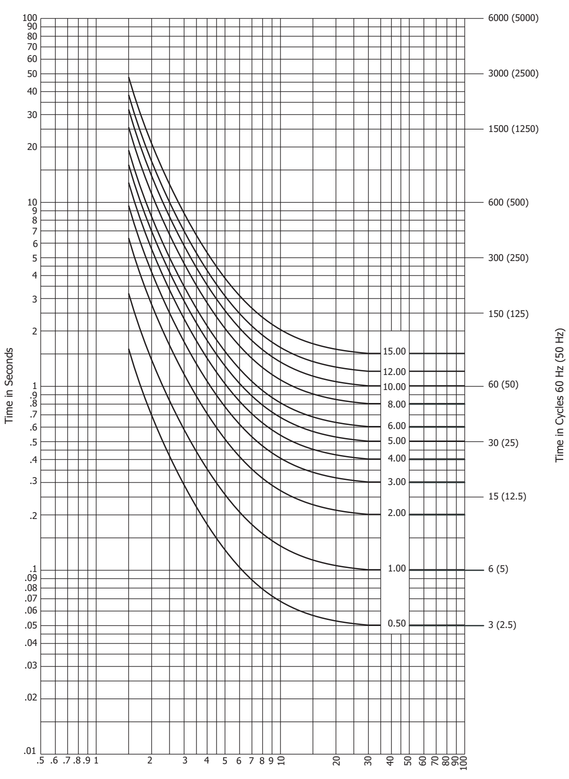


Figure 4.36 U.S. Very Inverse Curve: U3

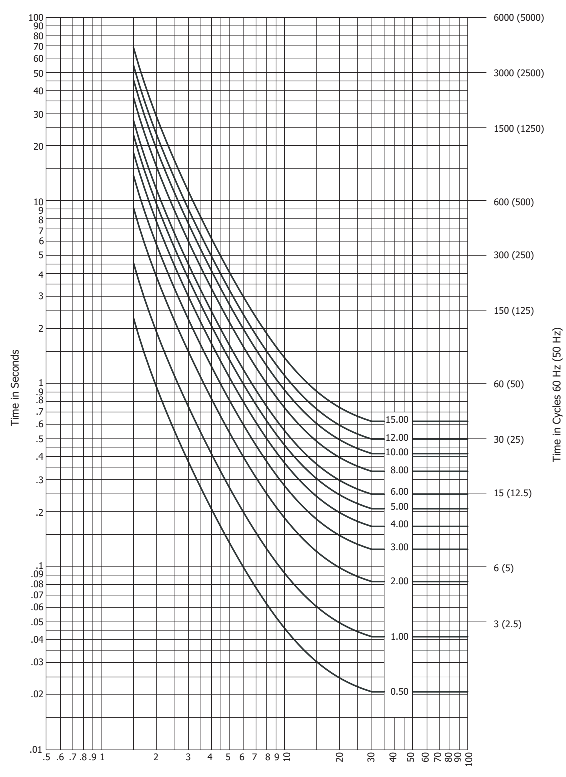


Figure 4.37 U.S. Extremely Inverse Curve: U4

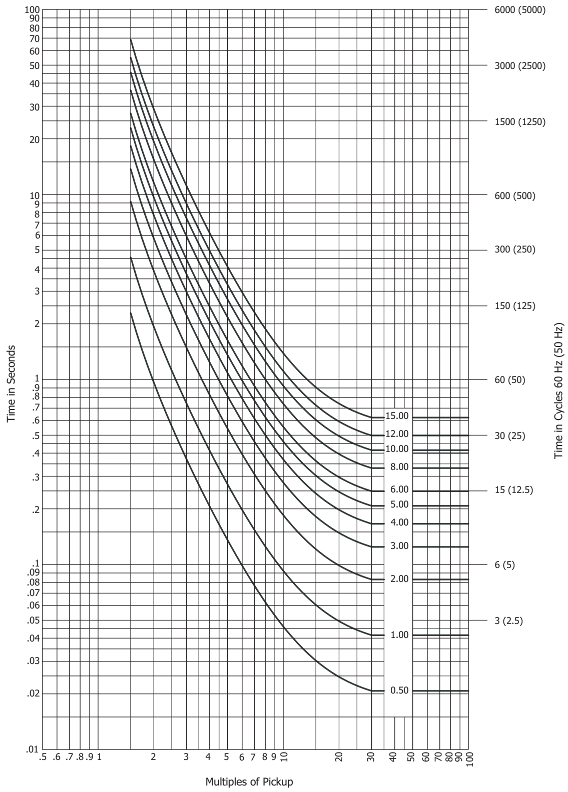


Figure 4.38 U.S. Short-Time Inverse Curve: U5

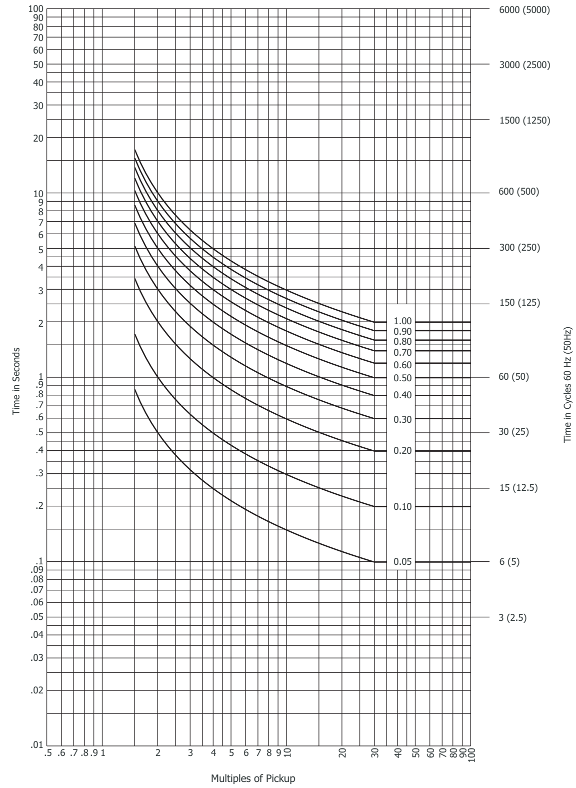


Figure 4.39 IEC Class A Curve (Standard Inverse): C1

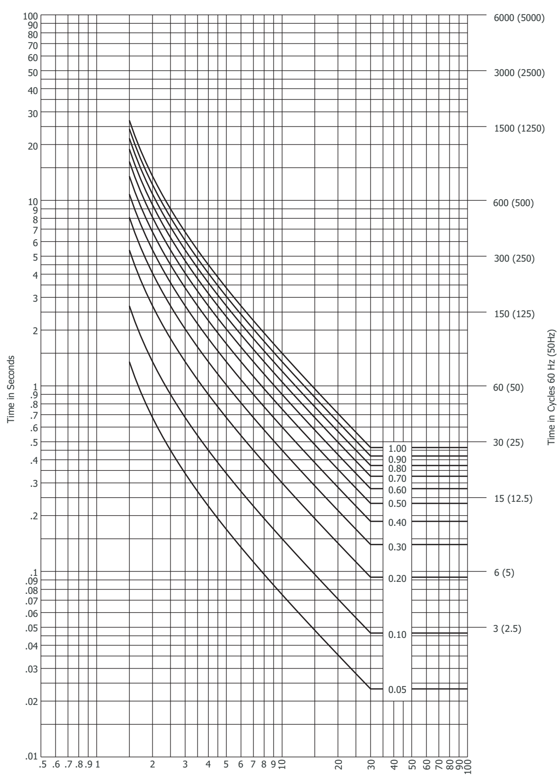


Figure 4.40 IEC Class B Curve (Very Inverse): C2

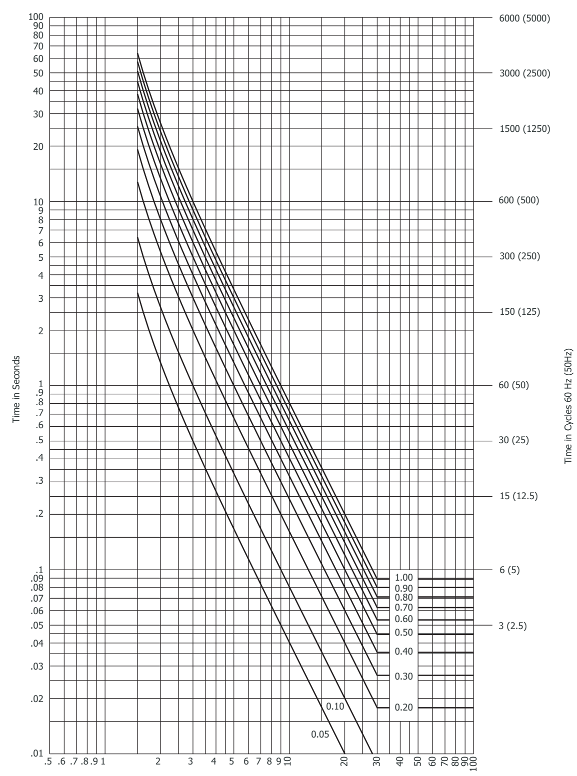


Figure 4.41 IEC Class C Curve (Extremely Inverse): C3

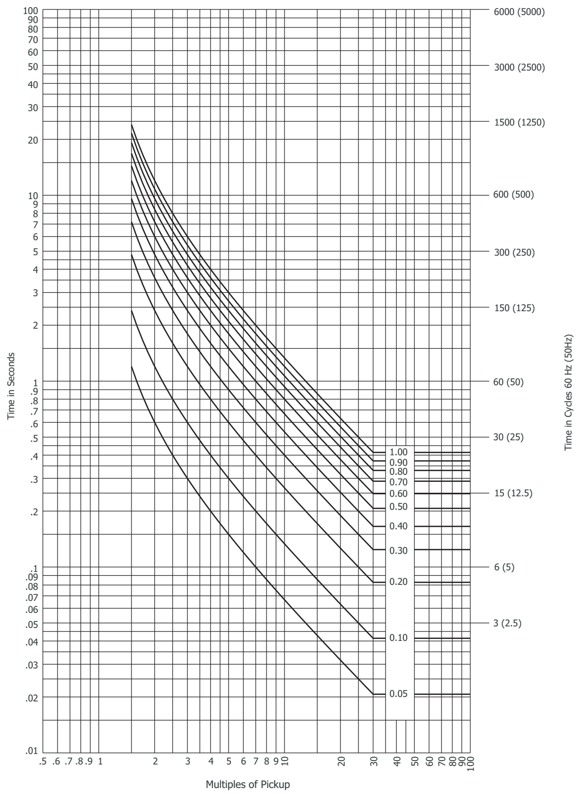


Figure 4.42 IEC Long-Time Inverse Curve: C4

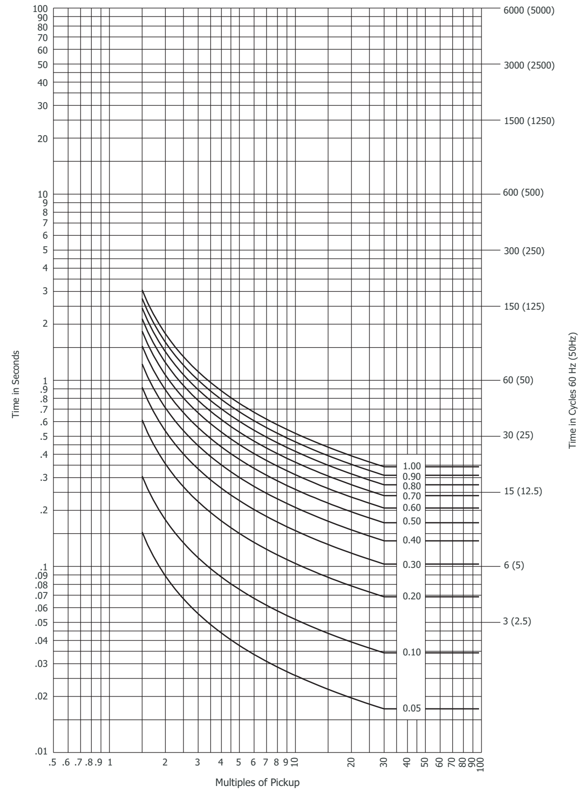


Figure 4.43 IEC Short-Time Inverse Curve: C5

RTD-Based Protection

RTD Input Function

When you connect an SEL-2600 RTD Module (set E49RTD := EXT) or order the internal RTD card (set E49RTD := INT) option, the SEL-787 offers several protection and monitoring functions, settings for which are described in *Table 4.23*. See *Figure 2.17* for the RTD module fiber-optic cable connections. If the relay does not have internal or external RTD inputs, set E49RTD := NONE.

NOTE: The SEL-787 can monitor as many as 10 RTDs connected to an internal RTD card or as many as 12 RTDs connected to an external SEL-2600 RTD Module. Table 4.23 shows Location, Type, and Trip/Warn Level settings only for RTD1; settings for RTD2–RTD12 are similar.

NOTE: RTD curves in SEL products are based on the DIN/IEC 60751 standard.

Table 4.23 RTD Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
RTD ENABLE	INT, EXT, NONE	E49RTD := NONE
RTD1 LOCATION	OFF, AMB, OTH	RTD1LOC := OFF
RTD1 IDENTIFIER	10 characters	RTD1NAM :=
RTD1 TYPE	PT100, NI100, NI120, CU10	RTD1TY := PT100
RTD1 TRIP LEVEL	OFF, 1–250 °C	TRTMP1 := OFF
RTD1 WARN LEVEL	OFF, 1–250 °C	ALTMP1 := OFF
• • •	• • •	• • •
RTD12 LOCATION	OFF, AMB, OTH	RTD12LOC := OFF
RTD12 IDENTIFIER	10 characters	RTD12NAM :=

Table 4.23 RTD Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
RTD12 TYPE	PT100, NI100, NI120, CU10	RTD12TY := PT100
RTD12 TRIP LEVEL	OFF, 1–250 °C	TRTMP12 := OFF
RTD12 WARN LEVEL	OFF, 1–250 °C	ALTMP12 := OFF

RTD Location

The relay allows you to independently define the location of each monitored RTD by using the RTD location settings.

Define the RTD location settings through use of the following suggestions:

➤ If an RTD is not connected to an input or has failed in place and is not being replaced, set the RTD location for that input equal to OFF.

➤ For the input connected to an RTD measuring ambient air temperature, set the RTD location equal to AMB. Only one ambient temperature RTD is allowed.

➤ For inputs connected to monitor temperatures of apparatus, such as transformer oil and winding temperature, set the RTD location equal to OTH. Use the RTD identifier setting to assign an appropriate name to the RTD, for example set RTD1NAM := XFRMR1 OIL.

If an RTD location setting is equal to OFF, the relay does not request that an RTD type setting be entered for that input.

RTD Type

The four available RTD types are:

➤ 100-ohm platinum (PT100)

➤ 100-ohm nickel (NI100)

➤ 120-ohm nickel (NI120)

➤ 10-ohm copper (CU10)

RTD Trip/Warning Levels

NOTE: An open condition for an RTD is detected if the temperature is greater than 250°C and a short condition is detected if the temperature is less than –50°C.

NOTE: To improve security, RTD FAULT, ALARM, and TRIP indicators are delayed by 12 seconds.

The SEL-787 provides temperature warnings and trips through use of the RTD temperature measurements and the warning and trip temperature settings in *Table 4.23*.

The relay issues a temperature warning if any of the healthy RTDs indicates a temperature greater than the relay RTD warning temperature setting. The relay issues a temperature trip if one of the healthy RTDs indicates a temperature greater than the RTD trip temperature setting.

To disable any of the temperature warning or trip functions, set the appropriate temperature setting to OFF.

Only healthy RTDs can contribute temperatures to the warning and trip functions. The relay includes specific logic to indicate if RTD leads are shorted or open. Refer to *Application Guide AG2016-10: How to Identify a Faulty RTD Connected to an SEL-700 Series Relay* to determine if an RTD connected to an SEL-787 relay is faulty. *Table 4.24* lists the RTD resistance versus temperature for the four supported RTD types.

Table 4.24 RTD Resistance Versus Temperature

Temp (°F)	Temp (°C)	100 Platinum	120 Nickel	100 Nickel	10 Copper
–58	–50.00	80.31	86.17	74.30	7.10
–40	–40.00	84.27	92.76	79.10	7.49
–22	–30.00	88.22	99.41	84.20	7.88
–4	–20.00	92.16	106.15	89.30	8.26
14	–10.00	96.09	113.00	94.60	8.65
32	0.00	100.00	120.00	100.00	9.04
50	10.00	103.90	127.17	105.60	9.42
68	20.00	107.79	134.52	111.20	9.81
86	30.00	111.67	142.06	117.10	10.19
104	40.00	115.54	149.79	123.00	10.58
122	50.00	119.39	157.74	129.10	10.97
140	60.00	123.24	165.90	135.30	11.35
158	70.00	127.07	174.25	141.70	11.74
176	80.00	130.89	182.84	148.30	12.12
194	90.00	134.70	191.64	154.90	12.51
212	100.00	138.50	200.64	161.80	12.90
230	110.00	142.29	209.85	168.80	13.28
248	120.00	146.06	219.29	176.00	13.67
266	130.00	149.83	228.96	183.30	14.06
284	140.00	153.58	238.85	190.90	14.44
302	150.00	157.32	248.95	198.70	14.83
320	160.00	161.05	259.30	206.60	15.22
338	170.00	164.77	269.91	214.80	15.61
356	180.00	168.47	280.77	223.20	16.00
374	190.00	172.17	291.96	231.80	16.39
392	200.00	175.85	303.46	240.70	16.78
410	210.00	179.15	315.31	249.80	17.17
428	220.00	183.17	327.54	259.20	17.56
446	230.00	186.82	340.14	268.90	17.95
464	240.00	190.45	353.14	278.90	18.34
482	250.00	194.08	366.53	289.10	18.73

Under- and Overvoltage Functions

When you connect the SEL-787 voltage inputs to phase-to-phase connected VTs (single-phase or three-phase), as in *Figure 2.22* or *Figure 2.23*, the relay provides two levels of phase-to-phase overvoltage and undervoltage elements.

When you connect the SEL-787 voltage inputs to phase-to-neutral connected VTs (single-phase or three-phase), as shown in *Figure 2.22* or *Figure 2.23*, the relay provides two levels of phase-to-neutral overvoltage and undervoltage elements. Two levels of negative-sequence overvoltage elements are available when the VTs are connected in three-phase as shown in *Figure 2.23*. Two levels of zero-sequence overvoltage elements are available when the VTs are connected in three-phase WYE-WYE configuration as shown in *Figure 2.23*. The SEL-787-3S model also provides two levels of VS under- and overvoltage elements. For the VS-related elements to be available, under Global settings, set VS_VBAT := VS. Each of the elements has an associated time delay, except the three-phase under- and overvoltage elements 3P27 and 3P59. You can use these elements as you choose for alarming or tripping.

Figure 4.44 and *Figure 4.45* show the logic diagrams for the undervoltage and overvoltage elements, respectively. To disable any of these elements, set the level settings equal to OFF.

Table 4.25 Undervoltage Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
PHASE UV LEVEL	OFF, 12.5–300.0 V	27P1P := OFF
PHASE UV DELAY	0.00–120.00 sec	27P1D := 0.5
PHASE UV LEVEL	OFF, 12.5–300.0 V	27P2P := OFF
PHASE UV DELAY	0.00–120.00 sec	27P2D := 5
PP UV LEVEL	OFF, 12.5–300.0[a], OFF, 12.5–520.00[b]	27PP1P := OFF
PP UV DELAY	0.00–120.00 sec	27PP1D := 5
PP UV LEVEL	OFF, 12.5–300.0[a], OFF, 12.5–520.00[b]	27PP2P := OFF
PP UV DELAY	0.00–120.00 sec	27PP2D := 5
PHASE UVS LEVEL	OFF, 12.5–300.0 V	27S1P := OFF
PHASE UVS DELAY	0.00–120.00 sec	27S1D := 0.5
PHASE UVS LEVEL	OFF, 12.5–300.0 V	27S2P := OFF
PHASE UVS DELAY	0.00–120.00 sec	27S2D := 0.5

[a] Setting range shown is for DELTA_Y := DELTA.
[b] Setting range shown is for DELTA_Y := WYE.

Table 4.26 Overvoltage Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
PHASE OV LEVEL	OFF, 12.5–300.0 V	59P1P := OFF
PHASE OV DELAY	0.00–120.00 sec	59P1D := 0.5
PHASE OV LEVEL	OFF, 12.5–300.0 V	59P2P := OFF
PHASE OV DELAY	0.00-120.00 sec	59P2D := 5
PP OV LEVEL	OFF, 12.5–300.0[a], OFF, 12.5–520.00[b]	59PP1P := OFF
PP OV DELAY	0.00–120.00 sec	59PP1D := 0.5
PP OV LEVEL	OFF, 12.5–300.0[a], OFF, 12.5–520.00[b]	59PP2P := OFF
PP OV DELAY	0.00–120.00 sec	59PP2D := 0.5
ZS OV LEVEL	OFF, 12.5–300.0 V	59G1P := OFF
ZS OV DELAY	0.00-120.00 sec	59G1D := 0.5
ZS OV LEVEL	OFF, 12.5–300.0 V	59G2P := OFF
ZS OV DELAY	0.00–120.00 sec	59G2D := 0.5
NSEQ OV LEVEL	OFF, 12.5–200.0 V	59Q1P := OFF

Table 4.26 Overvoltage Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
NSEQ OV DELAY	0.00–120.00 sec	59Q1D := 0.5
NSEQ OV LEVEL	OFF, 12.5–200.0 V	59Q2P := OFF
NSEQ OV DELAY	0.00–120.00 sec	59Q2D := 0.5
PHASE OVS LEVEL	OFF, 12.5–300.0 V	59S1P := OFF
PHASE OVS DELAY	0.00–120.00 sec	59S1D := 0.5
PHASE OVS LEVEL	OFF, 12.5–300.0 V	59S2P := OFF
PHASE OVS DELAY	0.00–120.00 sec	59S2D := 0.5

[a] Setting range shown is for DELTA_Y := DELTA.
[b] Setting range shown is for DELTA_Y := WYE.

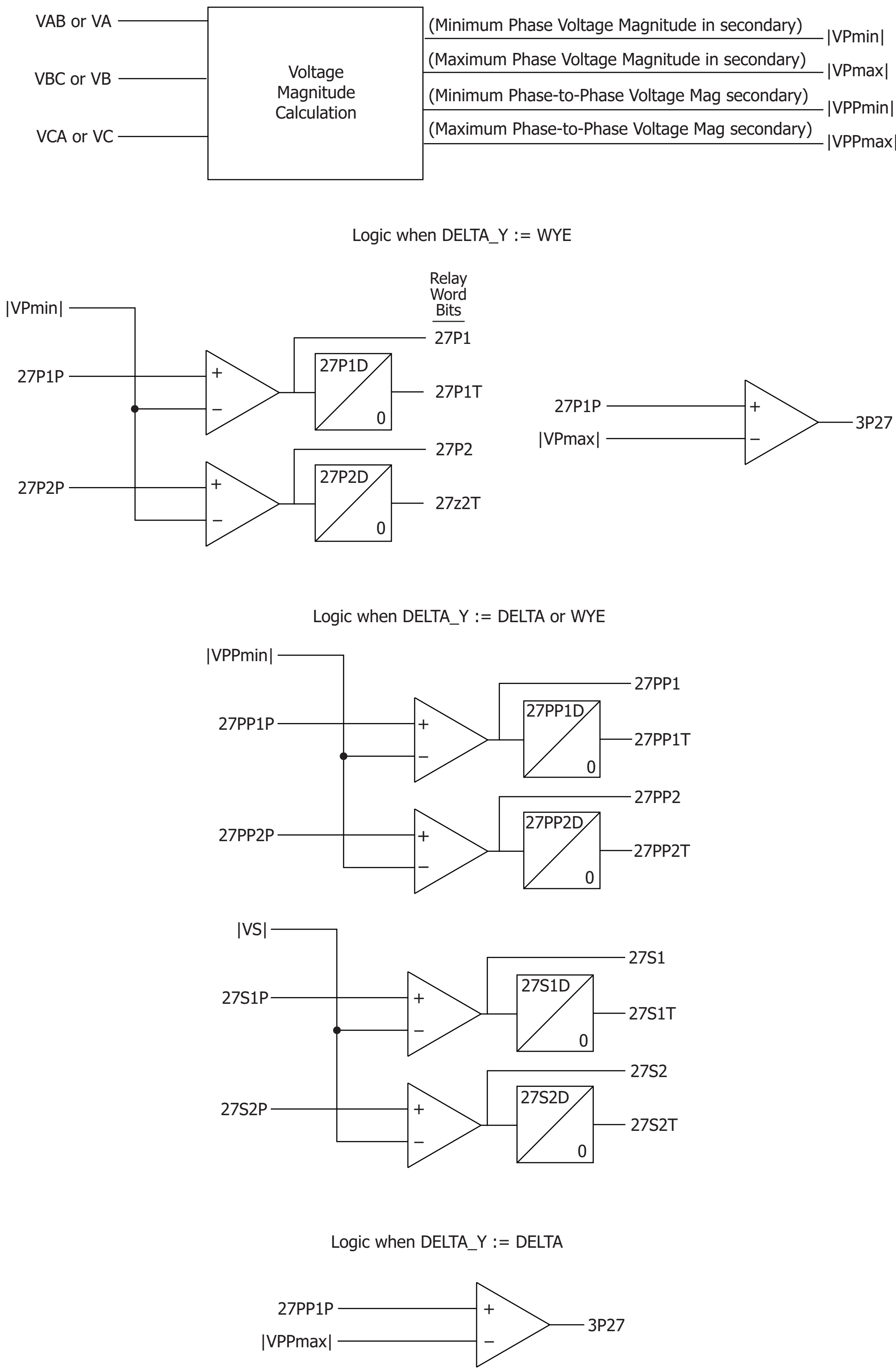


Figure 4.44 Undervoltage Element Logic

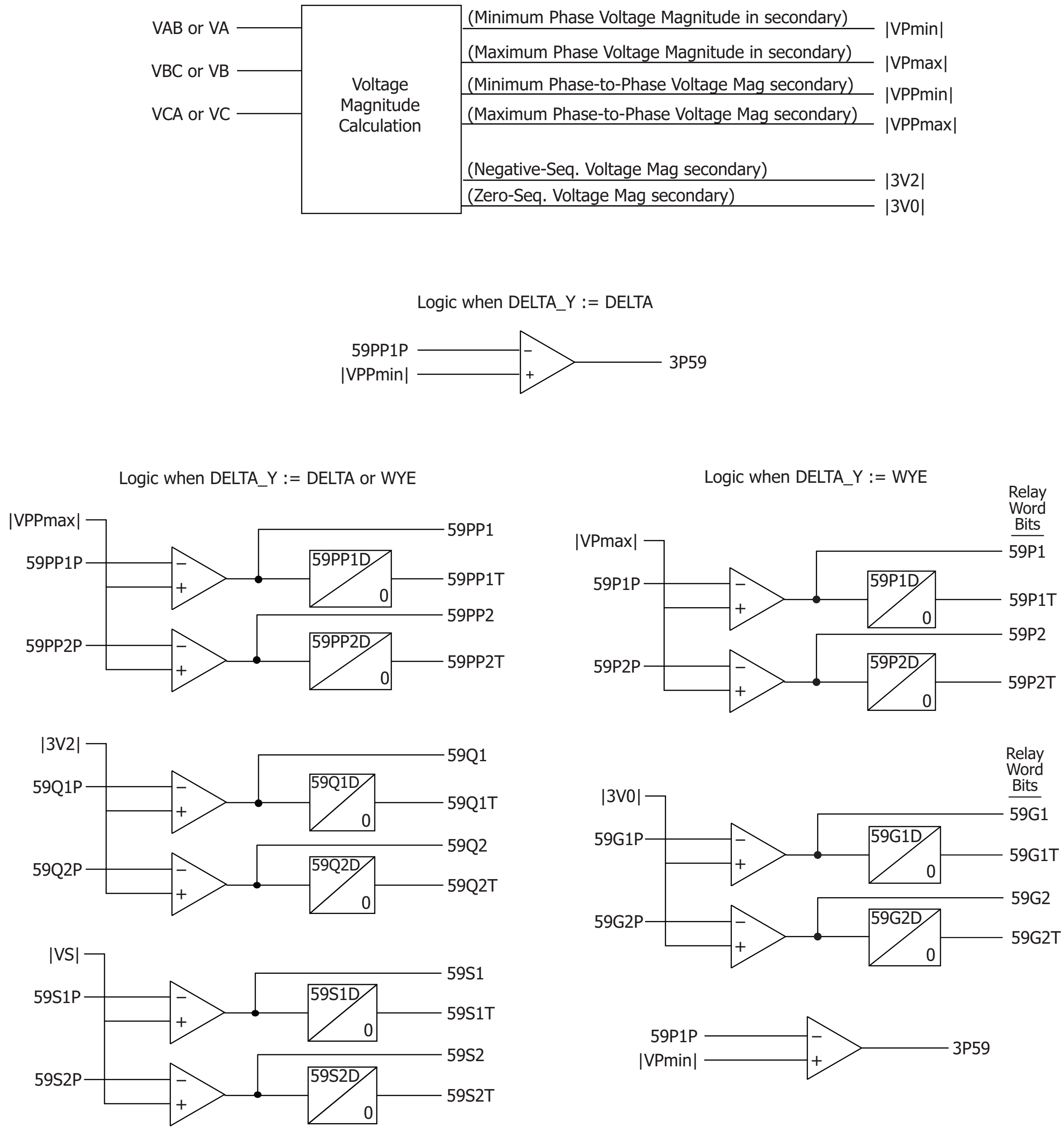


Figure 4.45 Overvoltage Element Logic

Inverse-Time Undervoltage Protection

The SEL-787 provides two inverse-time undervoltage protection elements (27I1 and 27I2). Based on relay hardware options and settings, the 27I element offers the flexibility of using various analog quantities as operating quantities. The availability of these analog quantities is contingent on the settings DELTA_Y, VS_BAT, and SINGLEV, as indicated in *Table 4.27*.

Table 4.27 Operating Quantities for the 27I Element

Settings			Operating Quantities Available in 27InOQ Setting Range[a]									
DELTA_Y	**VS_VBAT**	**SINGLEV**	**VAB**	**VBC**	**VCA**	**VA**	**VB**	**VC**	**V1**	**VS**	**MINLL**	**MINLN**
DELTA	VBAT	N	#	#	#	—	—	—	#	—	#	—
DELTA	VBAT	Y	#	—	—	—	—	—	—	—	—	—
DELTA	VS	N	#	#	#	—	—	—	#	#	#	—
DELTA	VS	Y	#	—	—	—	—	—	—	#	—	—
WYE	VS	N	$	$	$	#	#	#	#	#	$	#
WYE	VS	Y	—	—	—	#	—	—	—	#	—	—
WYE	VBAT	N	$	$	$	#	#	#	#	—	$	#
WYE	VBAT	Y	—	—	—	#	—	—	—	—	—	—

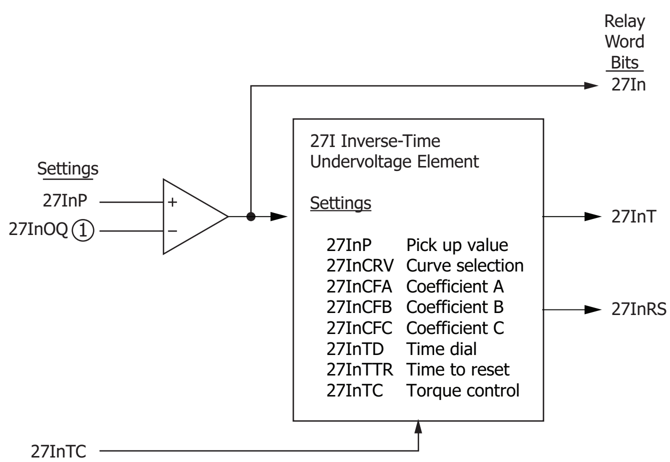
= 2.00–300.00 V $ = 2.00–520.00 V — Operating quantity is not available

The "#" and "$" signs indicate the setting range for 27InP (n = 1 or 2).

[a] The physical meanings of the operating quantities are described as follows:

VAB: Magnitude of A-to-B-phase voltage
VBC: Magnitude of B-to-C-phase voltage
VCA: Magnitude of C-to-A-phase voltage
VA: Magnitude of A-phase voltage
VB: Magnitude of B-phase voltage
VC: Magnitude of C-phase voltage
V1: Magnitude of positive-sequence voltage
VS: Magnitude of Vsync voltage
MINLL: Magnitude of the minimum phase-to-phase voltage
MINLN: Magnitude of the minimum phase-to-neutral voltage

Figure 4.46 shows the inputs, settings, and outputs of the inverse-time undervoltage element.



n = 1 or 2. ① Refer to Table 4.27.

Figure 4.46 Logic Diagram of the Inverse-Time Undervoltage Element

When the fundamental frequency component of the operating quantity falls below the pickup setting (27I*n*P), Relay Word bit 27I*n* asserts. The timer does not start to integrate unless the operating quantity falls below 0.975 • 27I*n*P. The inverse-time undervoltage protection element has the characteristic defined by *Equation 4.6*.

$$TTT_n = 27InTD \bullet \left(27InCFB + \frac{27InCFA}{\left(1 - \frac{27InOQ}{27InP}\right)^{27InCFC}} \right)$$

Equation 4.6

The settings used are listed in *Table 4.28*.

Table 4.28 Inverse-Time Undervoltage Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
27I ENABLE	Y, N	E27I*n* := N
OPERATING QTY	Refer to *Table 4.27*	27I*n*OQ := VAB
PICKUP LVL	Refer to *Table 4.27*	27I*n*P := 120.00
CURVE	CURVEA, CURVEB, COEF	27I*n*CRV := CURVEA
COEFF A	0.00–3.00	27I*n*CFA := 1
COEFF B	0.00–3.00	27I*n*CFB := 0
COEFF C	0.01–3.00	27I*n*CFC := 1
TIME DIAL	0.00–16.00	27I*n*TD := 1.00
RESET TIME	0.00–1.00 sec	27I*n*TTR := 0.01
TRQ CONTROL	SELOGIC	27I*n*TC := 1

The SEL-787 provides three curve options for each of the 27I elements, settable via the 27I*n*CRV setting—CURVEA, CURVEB, and COEF (user programmable curve). CURVEA is compliant with IEC 60255-127 and is the IEC standard curve as shown in *Figure 4.47*. CURVEB is a non-standard curve as shown in *Figure 4.47*. The curve option COEF is the user programmable curve. Set the coefficient related settings 27I*n*CFA, 27I*n*CFB and 27I*n*CFC to realize the curve that meets your application needs. *Table 4.29* shows the parameters of the three curves. Note that when 27I*n*CRV is set to CURVEA or CURVEB the coefficient related settings 27I*n*CFA, 27I*n*CFB and 27I*n*CFC are forced to the values shown in *Table 4.29* and hidden.

Table 4.29 Specification of Inverse-Time Undervoltage Protection Element

Curve Description	Curve Defining Constants		
	27InCFA	27InCFB	27InCFC
Curve A	1	0	1
Curve B	0.98	1.28	2.171
Programmable Curve	0.00–3.00	0.00–3.00	0.01–3.00

n = 1 or 2.

When the operating quantity exceeds the pickup level, 27I*n*P, then the output remains deasserted. If the operating quantity exceeds the pickup level for the reset time setting, 27I*n*TTR, then the time integrator resets to 0.

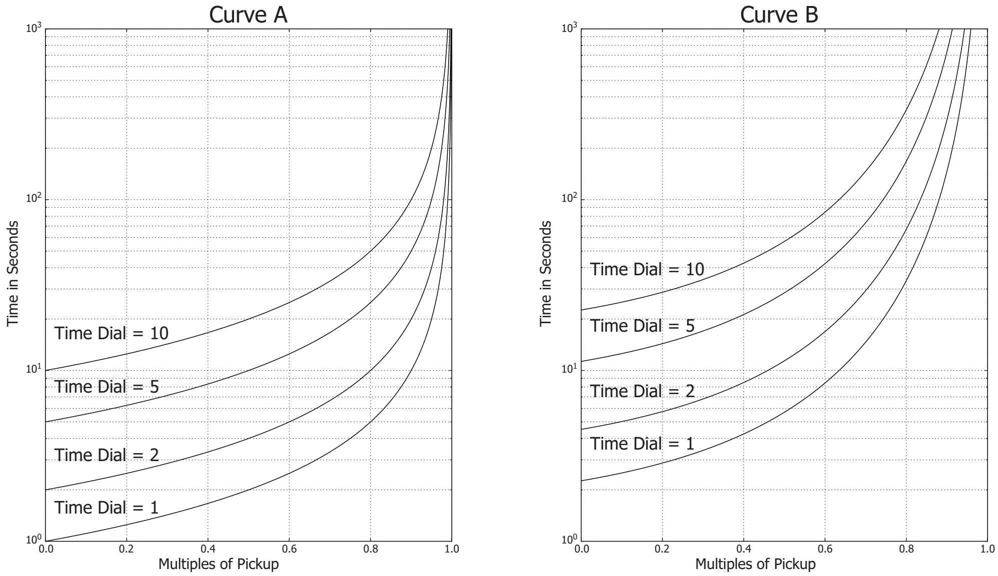


Figure 4.47 Inverse Time-Undervoltage Element Curves

Inverse-Time Overvoltage Protection

There are four inverse-time overvoltage elements (59I) available. Based on relay hardware options and settings, the 59I element offers the flexibility of using various analog quantities as operating quantities. The availability of these analog quantities is contingent on the settings DELTA_Y, VS_BAT, and SINGLEV, as indicated in *Table 4.30*.

Table 4.30 Operating Quantities for the 59I Element

Settings			Operating Quantities Available in 59InOQ Setting Range[a]											
DELTA_Y	**VS_VBAT**	**SINGLEV**	**VAB**	**VBC**	**VCA**	**VA**	**VB**	**VC**	**VG**	**V1**	**3V2**	**VS**	**MAXLL**	**MAXLN**
DELTA	VBAT	N	#	#	#	—	—	—	—	#	#	—	#	—
DELTA	VBAT	Y	#	—	—	—	—	—	—	—	—	—	—	—
DELTA	VS	N	#	#	#	—	—	—	—	#	#	#	#	—
DELTA	VS	Y	#	—	—	—	—	—	—	—	—	#	—	—
WYE	VS	N	$	$	$	#	#	#	#	#	#	#	$	#
WYE	VS	Y	—	—	—	#	—	—	—	—	—	#	—	—
WYE	VBAT	N	$	$	$	#	#	#	#	#	#	—	$	#
WYE	VBAT	Y	—	—	—	#	—	—	—	—	—	—	—	—

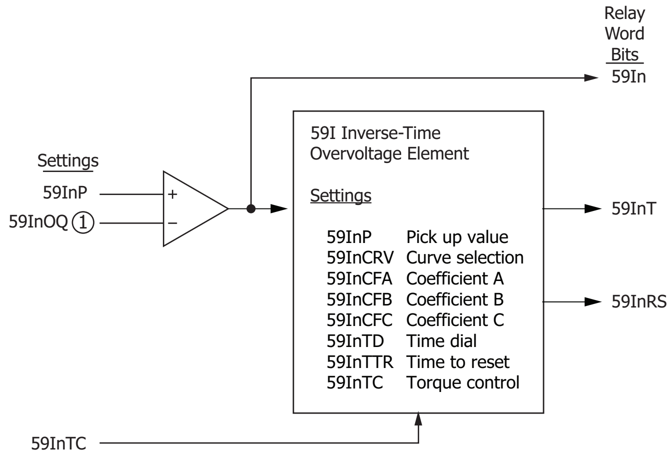
= 2.00–300.00 V $ = 2.00–520.00 V — Operating quantity is not available

The "#" and "$" signs indicate the setting range for 59InP (n = 1, 2, 3, or 4).

[a] The physical meanings of the operating quantities are described as follows:

VAB: Magnitude of A-to-B phase voltage
VBC: Magnitude of B-to-C phase voltage
VCA: Magnitude of C-to-A phase voltage
VA: Magnitude of A-phase voltage
VB: Magnitude of B-phase voltage
VC: Magnitude of C-phase voltage
VG: Magnitude of zero-sequence voltage
V1: Magnitude of positive-sequence voltage
3V2: Magnitude of negative-sequence voltage
VS: Magnitude of Vsync voltage
MAXLL: Magnitude of the maximum phase-to-phase voltage
MAXLN: Magnitude of the maximum phase-to-neutral voltage

Figure 4.48 shows the inputs, settings and outputs of the inverse-time overvoltage element.



n = 1, 2, 3, or 4. ① Refer to Table 4.30.

Figure 4.48 Logic Diagram of the Inverse-Time Overvoltage Element

When the fundamental frequency component of the operating quantity exceeds the pickup setting, 59I*n*P, Relay Word bit 59I*n* asserts. The timer won't start to integrate unless the operating quantity exceeds 1.025 • 59I*n*P. The inverse-time overvoltage protection element has the characteristic defined by *Equation 4.7*.

$$\mathrm{TTT_n} = \mathrm{59InTD} \bullet \left(\mathrm{59InCFB} + \frac{\mathrm{59InCFA}}{\left(\frac{\mathrm{59InOQ}}{\mathrm{59InP}}\right)^{\mathrm{59InCFC}} - 1} \right)$$

Equation 4.7

The settings used are listed in *Table 4.31*.

Table 4.31 Inverse-Time Overvoltage Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
59I ENABLE	Y, N	E59I*n* := N
OPERATING QTY	Refer to *Table 4.30*	59I*n*OQ := VAB
PICKUP LVL	Refer to *Table 4.30*	59I*n*P := 120.00
CURVE	CURVEA, CURVEB, CURVEC, COEF	59I*n*CRV := CURVEA
COEFF A	0.00–6.00	59I*n*CFA := 3.88
COEFF B	0.00–3.00	59I*n*CFB := 0.96
COEFF C	0.01–3.00	59I*n*CFC := 2.00
TIME DIAL	0.00–16.00	59I*n*TD := 1.00
RESET TIME	0.00–1.00 sec	59I*n*TTR := 0.01
TRQ CONTROL	SELOGIC	59I*n*TC := 1

The SEL-787 provides four curve options for each of the 59I elements, settable via the 59I*n*CRV setting—CURVEA, CURVEB, CURVEC, and

COEF (user-programmable curve). The characteristics of Curve A, Curve B, and Curve C are shown in *Figure 4.49*.

The curve option COEF is the user-programmable curve. Set the coefficient related settings 59I*n*CFA, 59I*n*CFB, and 59I*n*CFC to realize the curve that meets your application needs. *Table 4.32* shows the parameters of the three curves. Note that when 59I*n*CRV is set to CURVEA, CURVEB, or CURVEC the coefficient related settings 59I*n*CFA, 59I*n*CFB, and 59I*n*CFC are forced to the values shown in *Table 4.32* and hidden.

Table 4.32 Specification of Inverse-Time Overvoltage Protection Element

Curve Description	Curve Defining Constants		
	59InCFA	**59InCFB**	**59InCFC**
Curve A	3.88	0.96	2
Curve B	5.64	0.24	2
Curve C	0.14	0	0.02
Programmable Curve	0.00–6.00	0.00–3.00	0.01–3.00

n = 1, 2, 3, or 4.

When the operating quantity remains lower than the pickup level, 59I*n*P, then the output remains deasserted. If the operating quantity gets lower than the pickup level for the reset time setting, 59I*n*TTR, then the time integrator resets to 0.

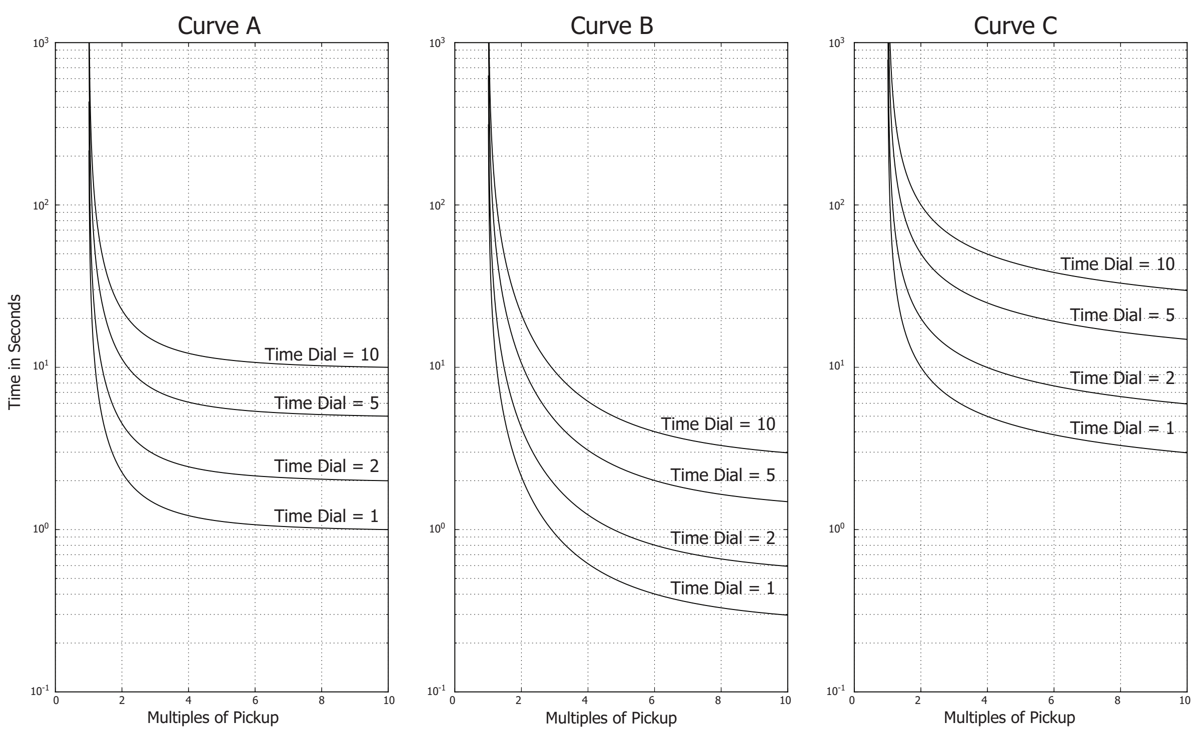


Figure 4.49 Inverse-Time Overvoltage Element Curves

Synchronism-Check Elements

Figure 2.25 on page 2.40 shows an example 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**, **VC**, **VAB**, **VBC**, or **VCA** 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), frequency window (FNOM ±5 Hz), and slip frequency settings (see *Figure 4.50* and *Figure 4.51*). They have separate angle settings.

If the voltages are static (voltages not slipping with respect to one another) or setting TCLOSD := OFF, the two synchronism-check elements operate as shown in the top of *Figure 4.51*. 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 4.51*. 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.

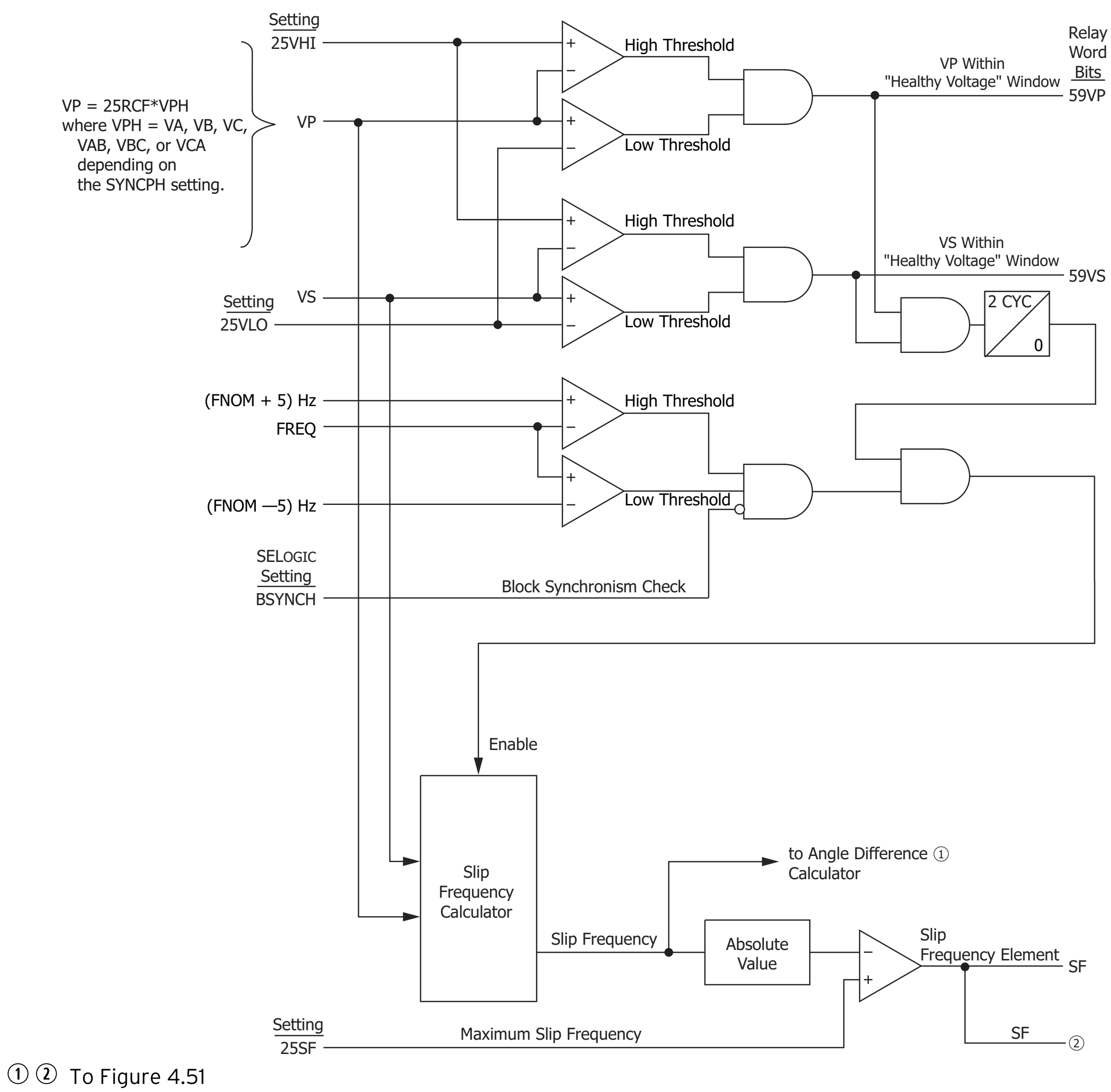


Figure 4.50 Synchronism-Check Voltage Window and Slip Frequency Elements

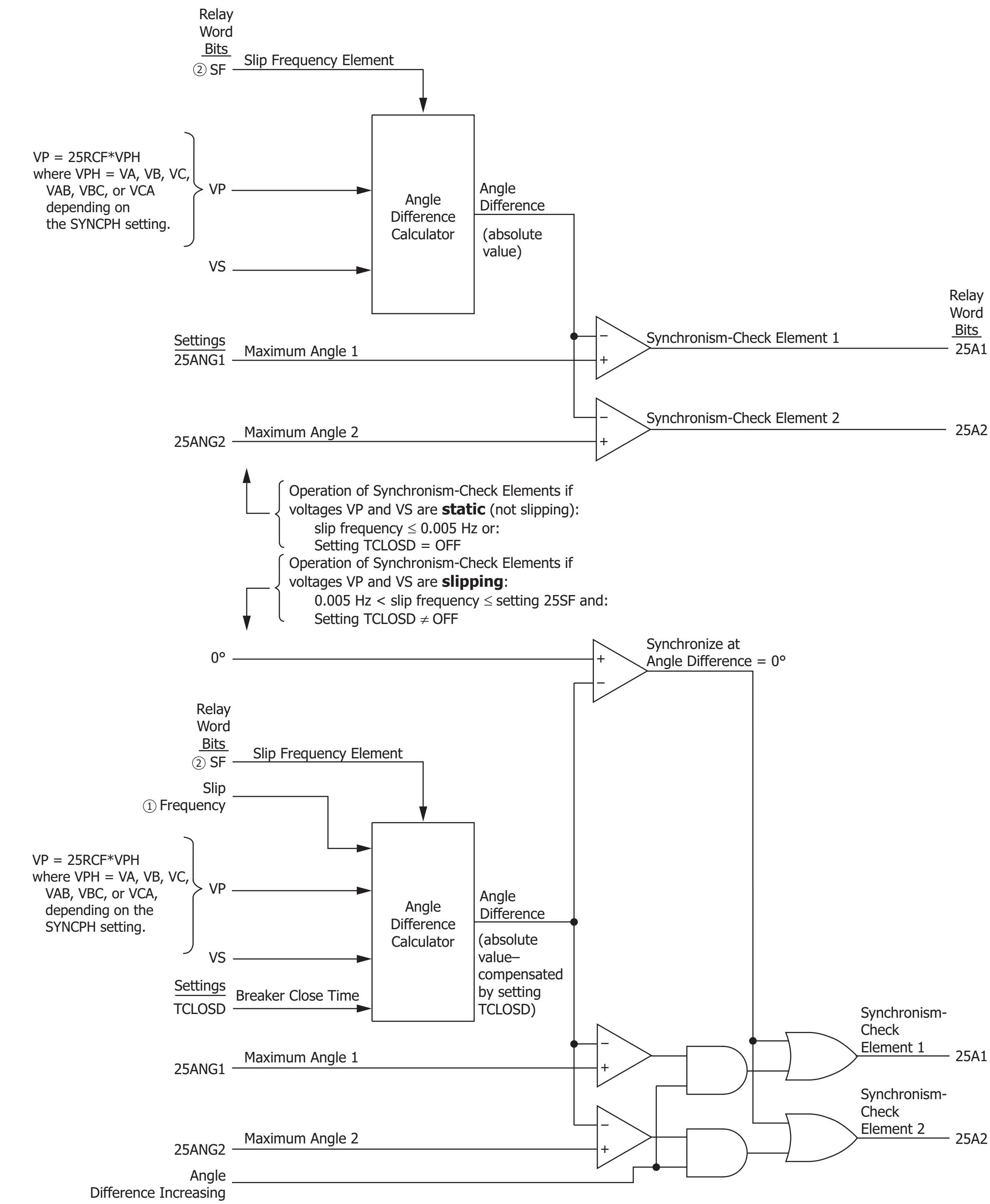


Figure 4.51 Synchronism-Check Elements

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

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

Sometimes synchronism-check voltage **VS** cannot be in phase with voltage VA, VB, VC, VAB, VBC, or VCA (wye connected PTs) or VAB, VBC, or VCA (delta-connected PTs). This happens in applications where voltage input **VS** is connected.

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

For such applications requiring **VS** to be at a constant phase angle difference from any of the possible synchronizing voltages (VA, VB, or VC; VAB, VBC, or VCA), an angle setting is made with the SYNCPH setting (see *Table 4.33* and *Setting SYNCPH on page 4.78*). The SEL-787 allows additional setting selections of VAB, VBC, or VCA for SYNCPH if VS is connected phase-to-phase when DELTAY_X := WYE.

Table 4.33 Synchronism-Check Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
SYNCH CHECK	Y, N	E25 := N
VS WINDOW LOW	0.00–300.00 V	25VLO := 105.00
VS WINDOW HIGH	0.00–300.00 V	25VHI := 130.00
V RATIO COR FAC	0.50–2.00	25RCF := 1.00
MAX SLIP FREQ	0.05–0.50 Hz	25SF := 0.20
MAX ANGLE 1	0–80 deg	25ANG1 := 25
MAX ANGLE 2	0–80 deg	25ANG2 := 40
SYNCH PHASE	VA, VB, VC, VAB, VBC, VCA or 0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330 deg lag VA[a]	SYNCPH := VA
SYNCH PHASE	VAB, VBC, VCA, or 0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330 deg lag VAB[b]	SYNCPH := VAB
BRKR CLOSE TIME	OFF, 1–1000 ms	TCLOSD := 50
BLK SYNCH CHECK	SV	BSYNCH := 52A

[a] Range shown for DELTA_Y := WYE.
[b] Range shown for DELTA_Y := DELTA.

Setting SYNCPH

Enable the two single-phase synchronism-check elements by setting E25 := Y.

NOTE: Settings SYNCPH := 0 and SYNCPH := VA are effectively the same (voltage VS is directly synchronism checked with voltage VA; VS does not lag VA). The relay displays the setting entered (SYNCPH := VA or SYNCPH := 0).

Wye-Connected Voltages. The angle setting choices (0, 30, …, 300, or 330 degrees) for setting SYNCPH are referenced to VA, and they indicate how many degrees VS constantly lags VA. In this case, voltage input **VA-N** has to be connected and has to meet the "healthy voltage" criteria (settings 25VHI and 25VLO—see *Figure 4.51*). For situations where VS cannot be in phase with VA, VB, VC, VAB, VBC, or VCA, the angle setting choices (0, 30, …, 300, or 330 degrees) are referenced to VA.

Delta-Connected Voltages. The angle setting choices (0, 30, …, 300, or 330 degrees) for setting SYNCPH are referenced to VAB, and they indicate how many degrees VS constantly lags VAB. In this application, voltage input **VA-VB** has to be connected and has to meet the "healthy voltage" criteria

NOTE: Settings SYNCPH := 0 and SYNCPH := VAB are effectively the same (voltage VS is directly synchronism checked with voltage VAB; VS does not lag VAB). The relay displays the setting entered (SYNCPH := VAB or SYNCPH := 0).

(settings 25VHI and 25VLO—see *Figure 4.50*). For situations where VS cannot be in phase with VAB, VBC, or VCA, the angle setting choices (0, 30, …, 300, or 330 degrees) are referenced to VAB.

Figure 2.25 shows a relay wired with delta-connected phase PTs, and a C-phase-to-ground connected VS-NS input. With ABC rotation, the correct SYNCPH setting for this example is 270 degrees, the amount that VC lags VAB. However, the setting angle is 90 degrees for the ACB phase rotation.

Use the voltage ratio correction factor (setting 25RCF) to compensate magnitude of the phase voltage to match the synchronism voltage VS. Many applications require 25RCF := 1.00, however some applications may need a different setting. For example, *Figure 2.25* requires 25RCF := PTR / (1.732*PTRS). This is 0.58 if the PTR and PTRS are equal.

See the Application Guide entitled *Compensate for Constant Phase Angle Difference in Synchronism Check with the SEL-351 Relay Family* (also applies to SEL-787) for more information on setting SYNCPH with an angle setting.

Synchronism-Check Elements Voltage Inputs

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

1. VP Phase input voltage (VA, VB, VC, VAB, VBC, or VCA*25RCF for Delta_Y := Wye; VAB, VBC, or VCA*25RCF for Delta_Y := Delta), designated by setting SYNCPH (If SYNCPH is set to one of the angle settings, then VP = VA*25RCF or VAB*25RCF depending on the Delta_Y setting.)
2. VS Synchronism-check voltage, from SEL-787 rear-panel voltage input VS

For example, if the rear-panel voltage input VS-NS is connected to B-phase (or BC phase-to-phase for delta) then set SYNCPH := VB (or VBC for delta). The voltage across terminals VB-N (or VB-VC for delta) is synchronism checked with the voltage across terminals VS-NS.

System Frequencies Determined from Voltages VA (or VAB for Delta) and VS. To determine slip frequency, first determine the system frequencies on both sides of the circuit breaker. Voltage VS determines the frequency on one side. Voltage VP determines the frequency on the other side.

Synchronism-Check Elements Operation

Refer to *Figure 4.50 on page 4.76* and *Figure 4.51 on page 4.77*.

Voltage Window. Refer to *Figure 4.50*. Single-phase voltage inputs VP and VS 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 VP is within voltage window setting limits 25VLO and 25VHI

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

Other Uses for Voltage Window Elements. If voltage limits 25VLO and 25VHI are applicable to other control schemes, Relay Word bits 59VP and 59VS 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 and 59VS 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 25LO, 25HI, and 25RCF. Apply Relay Word bits 59VP and 59VS in 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 4.50*. The synchronism-check element slip frequency calculator runs if both voltages VP and VS 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 needed when the circuit breaker is open):

BSYNCH := **52A1** (see *Figure 4.65*)

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

BSYNCH := **... OR TRIP**

Slip Frequency Calculator. Refer to *Figure 4.50*. The synchronism-check element Slip Frequency Calculator in *Figure 4.50* runs if voltages VP and VS are healthy (59VP and 59VS 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 = fP – fS (in units of Hz = slip cycles/second)

fP = frequency of voltage VP (in units of Hz = cycles/second)

fS = frequency of voltage VS (in units of Hz = cycles/second)

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

For example, in *Figure 4.50*, if voltage VP has a frequency of 59.95 Hz and voltage VS 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 VS is not “slipping” behind voltage VP, but in fact “slipping” ahead of voltage VP. In a time period of one second, the angular distance between voltage VP and voltage VS 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 VP and voltage VS 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.

Angle Difference Calculator. The synchronism-check element Angle Difference Calculator in *Figure 4.51* runs if the slip frequency is less than the maximum slip frequency setting 25SF (Relay Word bit SF is asserted).

Voltages VP and VS Are "Static". Refer to the top of *Figure 4.51*. If the slip frequency is less than or equal to 0.005 Hz, the Angle Difference Calculator does *not* take into account breaker close time—it presumes voltages VP and VS are "static" (not "slipping" with respect to one another). This would usually be the case for an open breaker with voltages VP and VS that are paralleled via some other electric path in the power system. The Angle Difference Calculator calculates the angle difference between voltages VP and VS:

Angle Difference = $|(\angle VP - \angle VS)|$

For example, if SYNCPH := 90 (indicating VS constantly lags VP = VA by 90 degrees), but VS actually lags VA by 100 angular degrees on the power system at a given instant, the Angle Difference Calculator automatically accounts for the 90 degrees and:

Angle Difference = $|(\angle VP - \angle VS)| = 10°$

Also, if breaker close time setting TCLOSD = OFF, 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 corresponding maximum angle setting 25ANG1 or 25ANG2.

Voltages VP and VS Are "Slipping". Refer to the bottom of *Figure 4.51*. If the slip frequency is greater than 0.005 Hz and breaker close time setting TCLOSD ≠ OFF, the Angle Difference Calculator takes the breaker close time into account with breaker close time setting TCLOSD (set in ms; see *Figure 4.52*). The Angle Difference Calculator calculates the Angle Difference between voltages VP and VS, compensated with the breaker close time:

Angle Difference = $|(\angle VP - \angle VS) + [(fP - fS) \cdot TCLOSD \cdot (1 / 1000) \cdot (360°/\text{slip cycle})]|$

Angle Difference Example (Voltages VP and VS are "Slipping"). Refer to the bottom of *Figure 4.51*. For example, if the breaker close time is 100 ms, set TCLOSD := 100. Presume the slip frequency is the example slip frequency calculated previously. The Angle Difference Calculator calculates the angle difference between voltages VP and VS, compensated with the breaker close time:

Angle Difference = $|(\angle VP - \angle VS) + [(fP - fS) \cdot TCLOSD \cdot (1 / 1000) \cdot (360°/\text{slip cycle})]|$

NOTE: The angle compensation in Figure 4.52 appears much greater than 3.6 degrees. Figure 4.52 is for general illustrative purposes only.

Intermediate calculations:

$(fP - fS) = (59.95 \text{ Hz} - 60.05 \text{ Hz}) = -0.10 \text{ Hz} = -0.10$ slip cycles/second
$TCLOSD \cdot (1 / 1000) = 0.1$ second

Resulting in:

Angle Difference

$= |(\angle VP - \angle VS) + [(fP - fS) \cdot TCLOSD \cdot (1 / 1000) \cdot (360°/\text{slip cycle})]|$
$= |(\angle VP - \angle VS) + [-0.10 \cdot 0.1 \cdot 360°]|$
$= |(\angle VP - \angle VS) - 3.6°|$

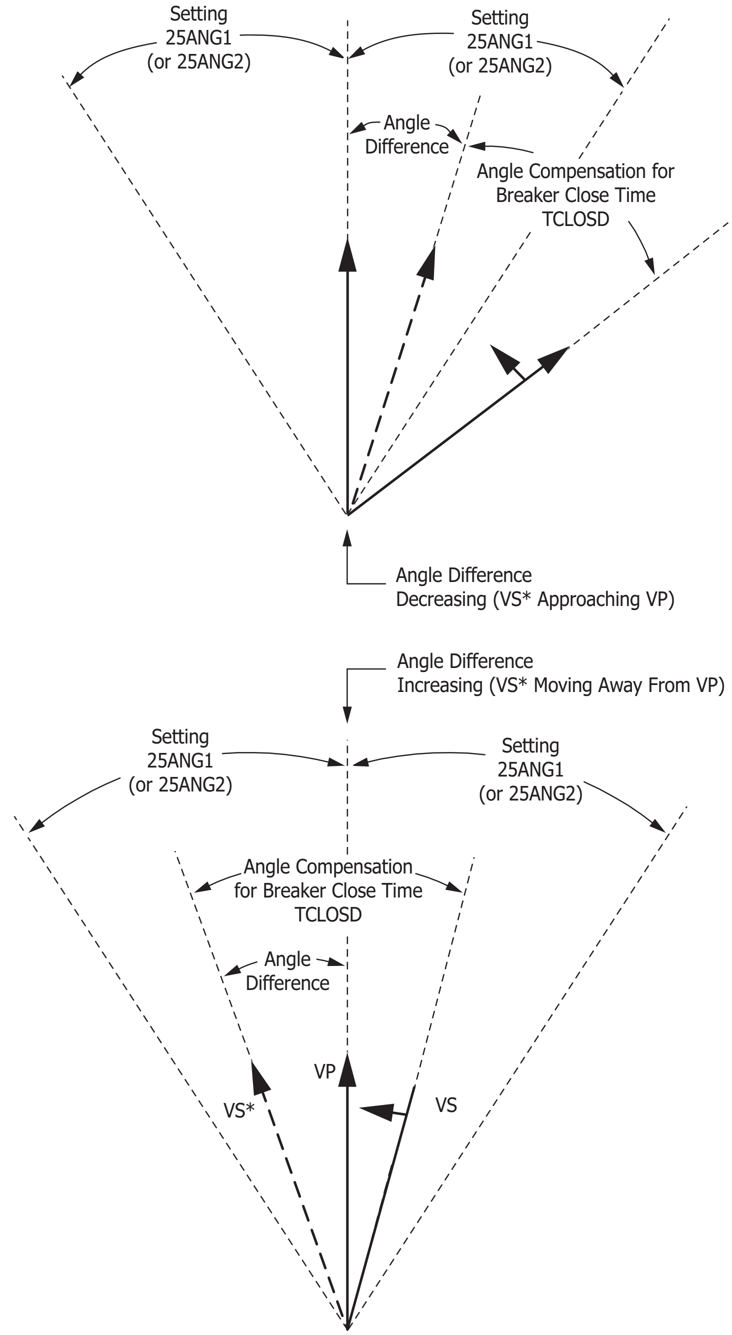


Figure 4.52 Angle Difference Between VP and VS Compensated by Breaker Close Time (fP < fS and VP Shown as Reference in This Example)

During the breaker close time (TCLOSD), the voltage angle difference between voltages VP and VS changes by 3.6 degrees. This angle compensation is applied to voltage VS, resulting in derived voltage VS*, as shown in *Figure 4.52*.

The top of *Figure 4.52* shows the Angle Difference *decreasing*—VS* is approaching VP. Ideally, circuit breaker closing is initiated when VS* is in phase with VP (Angle Difference = 0 degrees). Then when the circuit breaker main contacts finally close, VS is in phase with VP, minimizing system shock.

The bottom of *Figure 4.52* shows the Angle Difference *increasing*—VS* is moving away from VP. Ideally, circuit breaker closing is initiated when VS* is in phase with VP (Angle Difference = 0 degrees). Then when the circuit breaker main contacts finally close, VS is in phase with VP. But in this case, VS* has already moved past VP. To initiate circuit breaker closing when VS* is in phase with VP (Angle Difference = 0 degrees), VS* has to slip around another revolution, relative to VP.

Synchronism-Check Element Outputs. Synchronism-check element outputs (Relay Word bits 25A1 and 25A2 in *Figure 4.51*) assert to logical 1 for the conditions explained in the following text.

Voltages VP and VS Are "Static" or Setting TCLOSD = OFF. To implement a simple fixed-angle synchronism-check scheme, set TCLOSD := OFF and 25SF = 0.50. With these settings, the synchronism check is performed as described in the top of *Figure 4.51*.

If there is the possibility of a high slip frequency, exercise caution if synchronism-check elements 25A1 or 25A2 are used to close a circuit breaker. A high slip frequency and a slow breaker close could result in closing the breaker outside the synchronism-check window. Qualify the breaker close command with a time delay, such as:

```
SV06 := 25A1
CL := CC and SV06T
```

Set SV06PU with enough pickup delay to ensure that the slip frequency is low enough for the circuit breaker to close within the synchronism-check window.

Voltages VP and VS Are "Slipping" and Setting TCLOSD ≠ OFF. Refer to the bottom of *Figure 4.51*. If VP and VS are "slipping" with respect to one another and breaker close time setting TCLOSD ≠ OFF, 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 4.52* shows the Angle Difference *decreasing*—VS* is approaching VP. When VS* is in phase with VP (Angle Difference = 0 degrees), synchronism-check elements 25A1 and 25A2 assert to logical 1.
2. The bottom of *Figure 4.52* shows the Angle Difference *increasing*—VS* is moving away from VP. VS* was in phase with VP (Angle Difference = 0 degrees), but has now moved past VP. 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 VS* to slip around again in phase with VP (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.

Synchronism-Check Applications for Manual Closing

Set 25ANG2 := 25° and use the resultant synchronism-check element in manual close logic to supervise manual closing (for example, assert **IN301** to initiate manual close), e.g.,

`CL := IN301 AND (25A2 OR ...) (see Figure 4.67)`

Program an output contact (e.g., OUT102 := CLOSE) for manual closing (see *Figure 4.67*) logic output.

Volts Per Hertz Elements

Overexcitation occurs when a transformer magnetic core becomes saturated. When this happens, stray flux is induced in nonlaminated components, causing overheating. In the SEL-787 Relay a volts/hertz element detects overexcitation. The SEL-787 provides a sensitive definite time volts/hertz element, plus a tripping element with a composite operating time. The relay calculates the present transformer volts/hertz as a percent of nominal, based on the present and nominal voltages and frequencies. The settings VNOM and FNOM define the nominal transformer voltage and frequency, respectively.

Figure 4.53 shows a logic diagram of the volts/hertz elements. If the torque-control 24TC SELOGIC control equation is true and the present volts/hertz exceed the 24D1P setting, the relay asserts the 24D1 Relay Word bit and starts the 24D1D timer. If the condition remains for 24D1D seconds, the relay asserts the 24D1T Relay Word bit. Typically, you should apply this element as an overexcitation alarm.

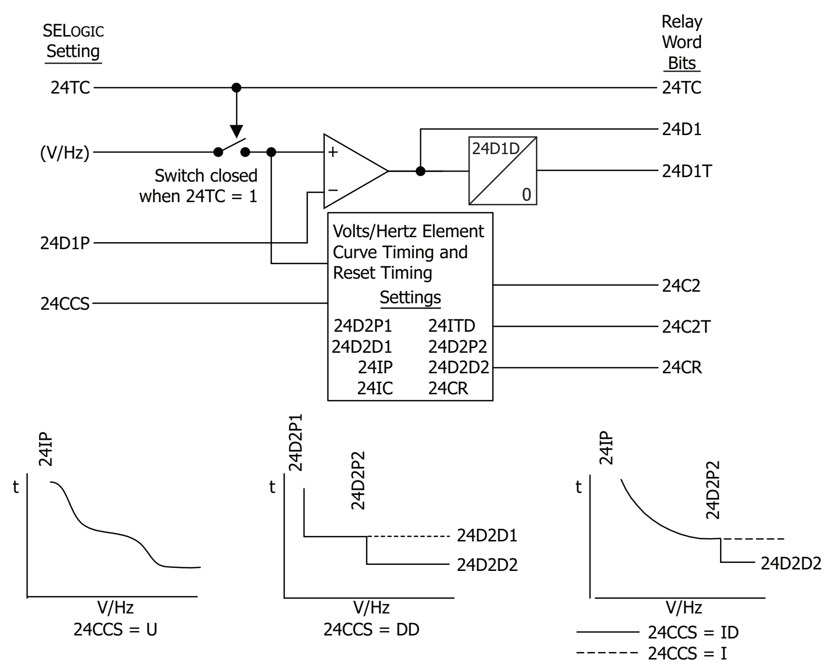


Figure 4.53 Overvoltage Element Logic

For volts/hertz tripping the relay provides a time-integrating element with a settable operating characteristic. You can set the element to operate as an inverse-time element; a user-defined curve element (using the SEL-5806 PC Software); a composite element with an inverse-time characteristic and a definite-time characteristic; or as a dual-level, definite-time element. In any case, the element provides a linear reset characteristic with a settable reset time. This element also is supervised by the 24TC torque-control setting.

The volts/hertz tripping element has a percent-travel operating characteristic similar to that employed by an induction-disk time-overcurrent element. This characteristic coincides well with the heating effect that overexcitation has on transformer components.

The element compares the three phase voltages and uses the highest of the values for the volts/hertz magnitude calculations. The relay asserts 24C2 Relay Word bit without time delay when the transformer volts/hertz exceeds the element pickup setting, and asserts 24C2T Relay Word bit after a delay determined by the characteristic setting. The relay tracks the frequency over the range 15 to 70 Hz.

Volts/hertz tripping elements are usually used to trip the transformer breaker. Volts/hertz logic is discussed in the following section.

Figure 4.54 and *Figure 4.55* are similar to IEEE C37.102-2006, Guide for AC Generator Protection, Figure 4.5.4-1 and Figure 4.5.4-2.

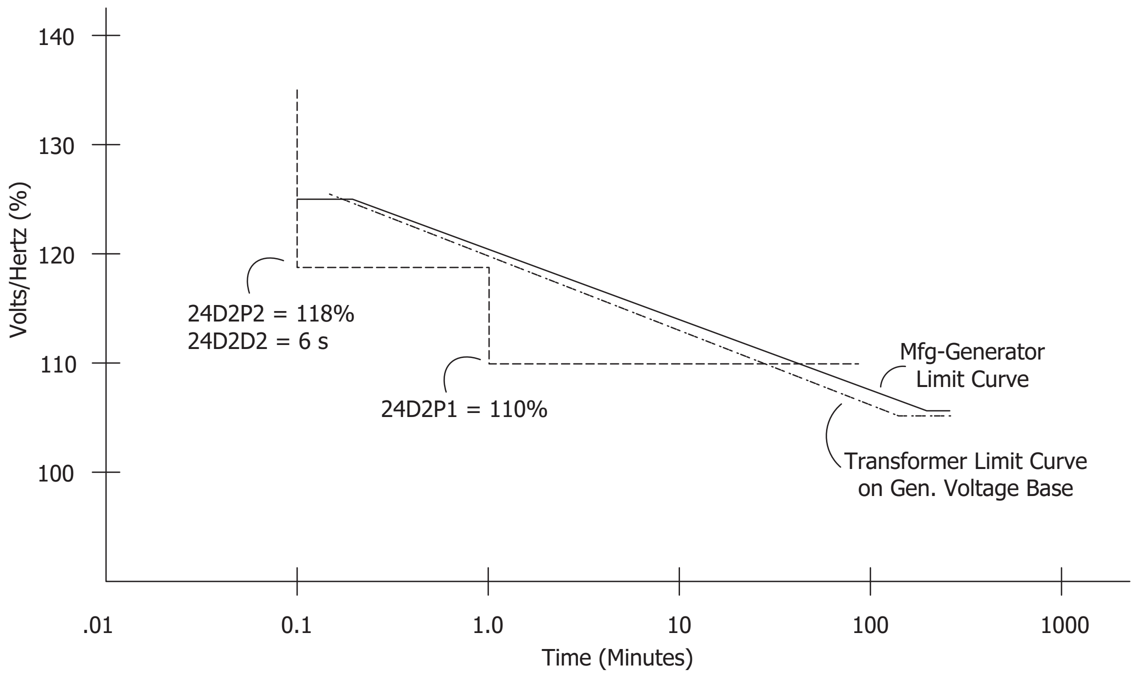


Figure 4.54 Dual-Level Volts/Hertz Time-Delay Characteristic, 24CCS = DD

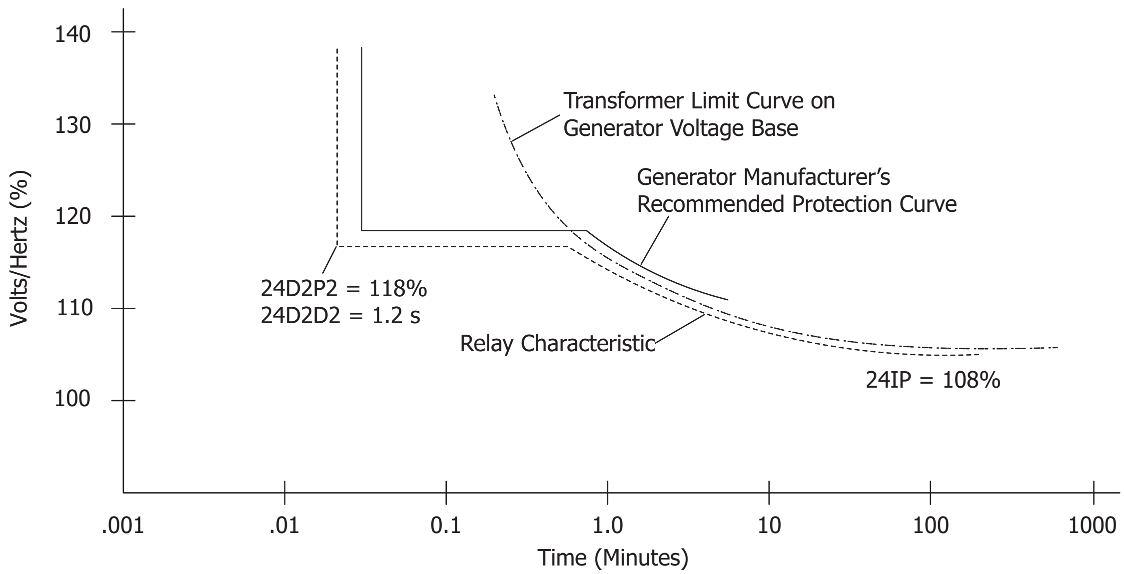


Figure 4.55 Composite Inverse/Definite-Time Overexcitation Characteristic, 24CCS = ID

Table 4.34 Volts Per Hertz Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE V/HZ PROT	Y, N	E24 := Y
XFMR WDG CONN	DELTA, WYE	24WDG := WYE
LVL1 V/HZ PICKUP	100%–200%	24D1P := 105
LVL1 TIME DLY	0.04–400.00 sec	24D1D := 1.00
LVL2 CURVE SHAPE	OFF, DD, ID, I, U	24CCS := ID
LVL2 INV-TM PU	100%–200%	24IP := 105
LVL2 INV-TM CURV	0.5, 1.0, 2.0	24IC := 2.0
LVL2 INV-TM FCTR	0.1–10.0 sec	24ITD := 0.1
LVL2 PICKUP 2	101%–200%	24D2P2 := 176
LVL2 TIME DLY 2	0.04–400.00 sec	24D2D2 := 3.00
LVL2 RESET TIME	0.00–400.00 sec	24CR := 240.00
24 ELEM TRQ-CNTRL	SELOGIC	24TC := 1

Collect this information before calculating volts/hertz element settings:

- Transformer manufacturer's overexcitation limit curve
- Transformer nominal phase-to-phase voltage

Select the transformer winding that is most likely to suffer overexcitation. The relay voltage input should be from a source that most reliably reflects that winding voltage.

Set E24 := Y to enable volts/hertz protection elements. If you do not need volts/hertz protection, set E24 := N. When E24 := N, the 24TC, 24D1, 24D1T, 24C2, 24C2T, and 24CR Relay Word bits are inactive. The relay hides corresponding settings; you do not need to enter these settings.

When three PTs are available, the most common PT winding connection is to connect both HV and LV sides in wye, leaving the power transformer winding connections as the only variable. For wye-connected power transformer windings, the power transformer phase-to-neutral voltage is readily measured through wye-wye connected PTs, so 24WDG should be set to WYE.

For delta-connected power transformer windings, the power transformer phase-to-phase voltage is calculated by the relay. Voltage value selection for the volts/hertz protection and sequence components is based on the 24WDG selection, i.e., phase-to-phase for 24WDG := DELTA and phase-to-neutral for 24WDG = WYE. *Table 4.35* shows which voltage to use based on the PT connection and the 24WDG setting.

Table 4.35 Voltage Selection for Volts/Hertz Element

PT Connection	24WDG Setting	24 Element
Wye	Wye	Max phase-to-neutral voltage
Wye	Delta	Max phase-to-phase voltage
Delta	Wye	Max phase-to-phase voltage
Delta	Delta	Max phase-to-phase voltage

Use the Level 1 volts/hertz element as an overexcitation alarm. Set 24D1P equal to or greater than 105 percent, but less than the minimum pickup of the Level 2 element. Use a 24D1D time delay of 1.0 second to allow time for correction of an overexcitation condition prior to an alarm.

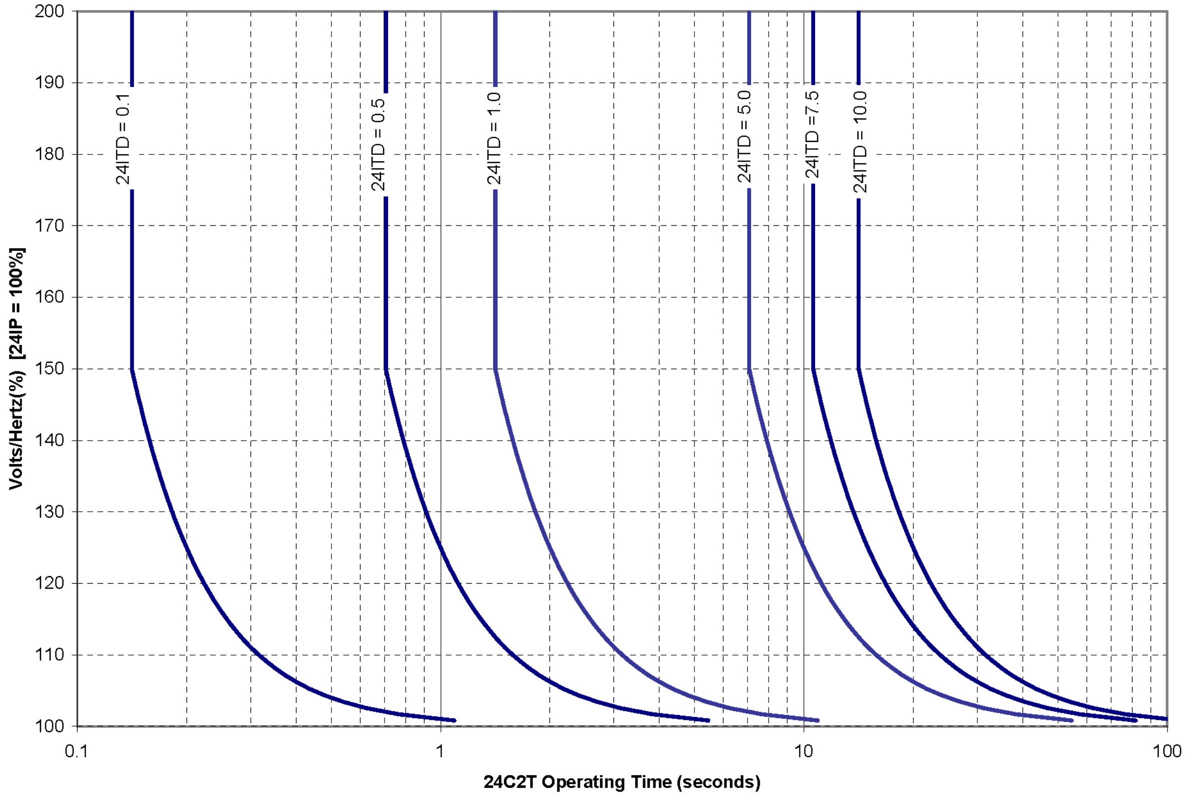
The 24CCS setting defines the overexcitation tripping element time-delay characteristic as shown in *Figure 4.44*. Set 24CCS := OFF if you do not require Level 2 volts/hertz protection. When 24CCS := OFF, the other Level 2 settings are hidden and do not need to be entered.

- When 24CCS := DD the element operates with a dual-level definite-time characteristic with pickup and delay of 24D2P*n* and 24D2D*n* (*n* = 1 or 2).
- When 24CCS := ID the element operates with a composite inverse-time and definite-time characteristic with pickup of 24IP (Inverse-time) and 24D2P2 (definite-time). The 24IC and 24ITD settings define the inverse-time curve shape (see *Figure 4.56* through *Figure 4.58*).
- When 24CCS := I the element operates with a simple inverse-time characteristic, defined by the 24IP, 24IC and 24ITD settings described above.
- When 24CCS := U the element operates with a user-defined inverse-time characteristic with a pickup of 24IP. The user curve should be set using SEL-5806 PC Software. This program handles individual mapping of points to make a curve that matches any transformer characteristic. It also handles all relay communication by either uploading the current curve or programming a new curve.

The 24CR setting defines the composite element reset time. When the element times out to trip, it fully resets 24CR seconds after the applied volts/hertz drops below the element pickup setting. The reset characteristic is linear, so if the element times 60 percent toward a trip, it fully resets (0.6 • 24CR) seconds after the applied volts/hertz drops below the element pickup setting. When the element is reset, the relay asserts the 24CR Relay Word bit.

Both volts/hertz elements are disabled when the 24TC SELOGIC control equation equals logical 0. The elements are allowed to operate when the 24TC

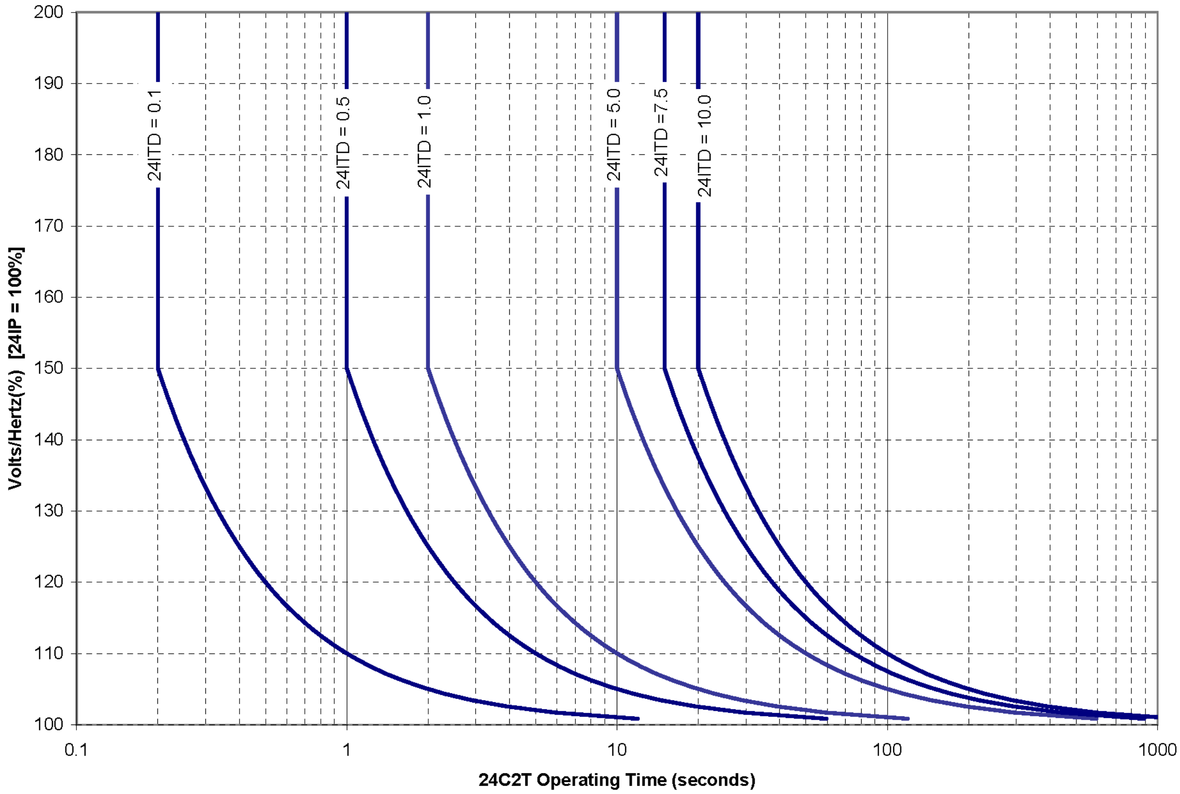
SELOGIC control equation equals logical 1, the default setting. You can add other supervisory conditions if you need these for your application.



$$t_p = \frac{24ITD}{\left(\left(\frac{\frac{VPP \bullet PTR}{freq} \bullet \frac{FNOM}{VNOM \bullet 10^3}}{\frac{24IP}{100}}\right) - 1\right)^{0.5}} \text{ seconds} \qquad \text{if V/Hz} \le 1.5 \bullet 24IP$$

$$t_p = 1.414 \bullet 24ITD \text{ seconds} \qquad \text{if V/Hz} > 1.5 \bullet 24IP$$

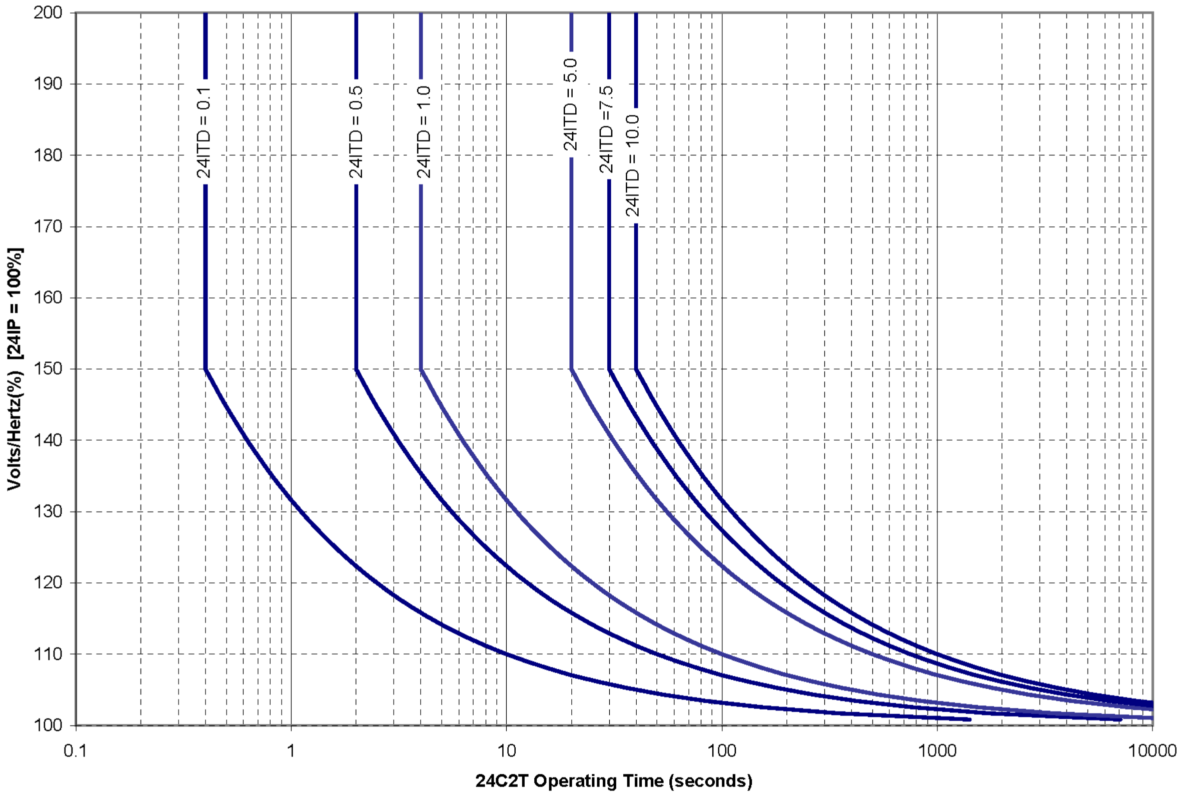
Figure 4.56 Volts/Hertz Inverse-Time Characteristic, 24IC = 0.5



$$t_p = \frac{24ITD}{\left(\left(\frac{\frac{VPP \bullet PTR}{freq} \bullet \frac{FNOM}{VNOM \bullet 10^3}}{\frac{24IP}{100}}\right) - 1\right)^{1.0}} \text{ seconds} \qquad \text{if V/Hz} \le 1.5 \bullet 24IP$$

$$t_p = 2.0 \bullet 24ITD \text{ seconds} \qquad \text{if V/Hz} > 1.5 \bullet 24IP$$

Figure 4.57 Volts/Hertz Inverse-Time Characteristic, 24IC = 1



$$t_p = \frac{24ITD}{\left(\left(\frac{\frac{VPP \bullet PTR}{freq} \bullet \frac{FNOM}{VNOM \bullet 10^3}}{\frac{24IP}{100}}\right) - 1\right)^{2.0}} \text{ seconds} \qquad \text{if V/Hz} \leq 1.5 \bullet 24IP$$

$$t_p = 4.0 \bullet 24ITD \text{ seconds} \qquad \text{if V/Hz} > 1.5 \bullet 24IP$$

Figure 4.58 Volts/Hertz Inverse-Time Characteristic, 24IC = 2

Power Elements

You can enable as many as two independent three-phase power elements in the SEL-787 relay. Each enabled element can be set to detect real power or reactive power. The winding on which the power element is enabled depends on the VIWDG setting. Set the VIWDG setting accordingly based on the location of PT with respect to the transformer winding. When voltage inputs to the relay are from delta connected PTs or when single voltage input is used, the relay cannot account for unbalance in the voltages in calculating the power. Take this into consideration in applying the power elements.

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

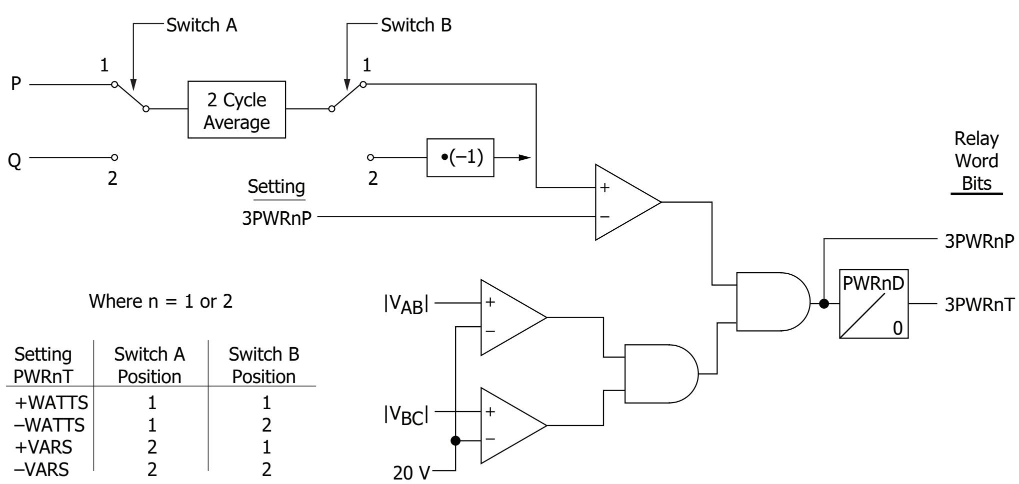
Table 4.36 Power Element Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE PWR ELEM	N, 3P1, 3P2	EPWR := N
3PH PWR ELEM PU	OFF, 1.0–6500.0 VA (secondary)[a]	3PWR1P := OFF
PWR ELEM TYPE	+WATTS, –WATTS, +VARS, –VARS	PWR1T := +VARS
PWR ELEM DELAY	0.0–240.0 sec	PWR1D := 0.0
3PH PWR ELEM PU	OFF, 1.0–6500.0 VA (secondary)[a]	3PWR2P := OFF
PWR ELEM TYPE	+WATTS, –WATTS, +VARS, –VARS	PWR2T := +VARS
PWR ELEM DELAY	0.0–240.0 sec	PWR2D := 0.0

[a] The range shown is for 5 A input; range for 1 A input is OFF, 0.2–1300.0 VA.

EPWR := 3P1 enables one three-phase power element. Set EPWR := 3P2 if you want to use both elements.

Set the element pickup, 3PH PWR ELEM PU to desired values in secondary VA units. *Figure 4.59* shows the power element logic diagram and *Figure 4.60* shows the operation in the Real/Reactive power plane.



Setting PWRnT	Switch A Position	Switch B Position
+WATTS	1	1
–WATTS	1	2
+VARS	2	1
–VARS	2	2

Figure 4.59 Three-Phase Power Elements Logic

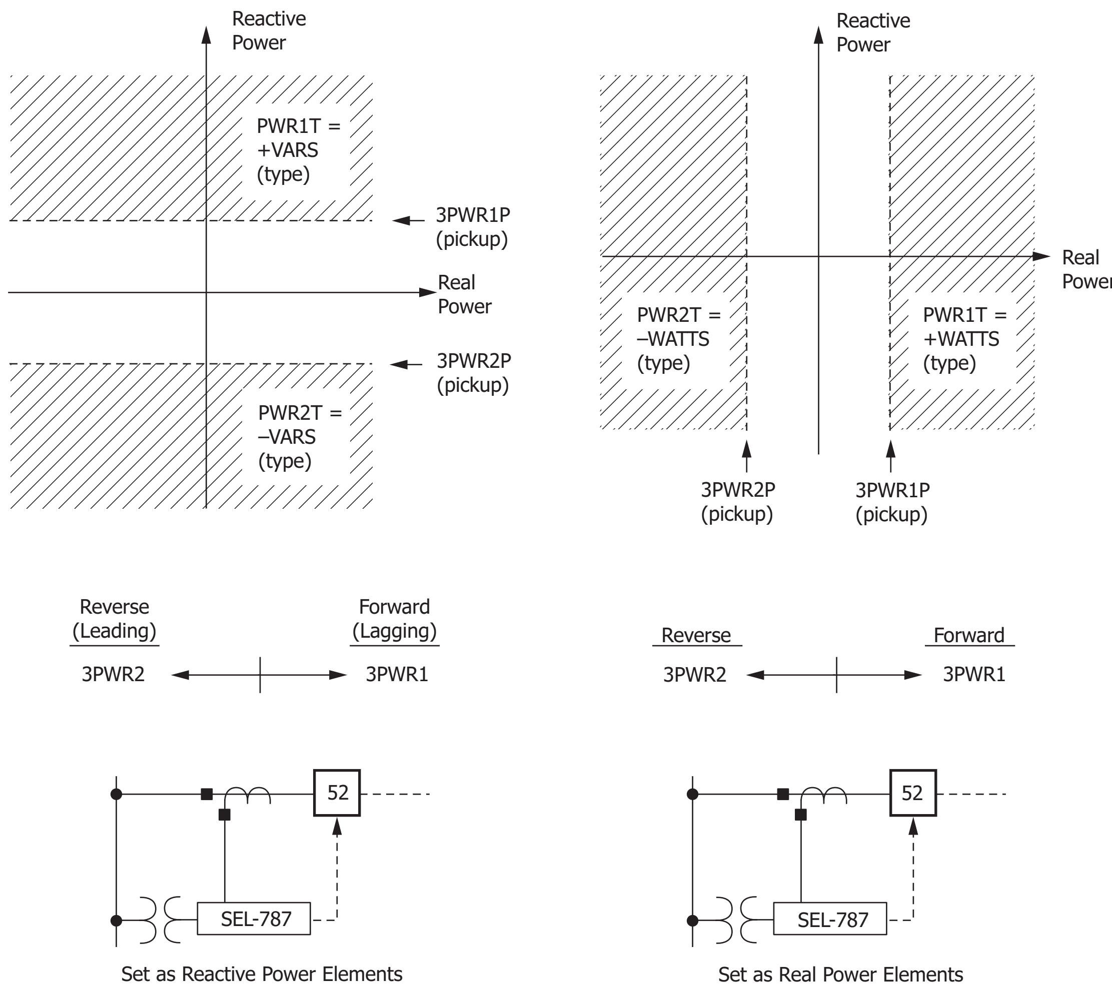


Figure 4.60 Power Elements Operation in the Real/Reactive Power Plane

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)

The two power element time delay settings (PWR1D and PWR2D) 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 0.1 second 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.

The power elements are not supervised by any relay elements other than the minimum voltage check shown in *Figure 4.59*. 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. Use the power element time delay setting to avoid such race conditions.

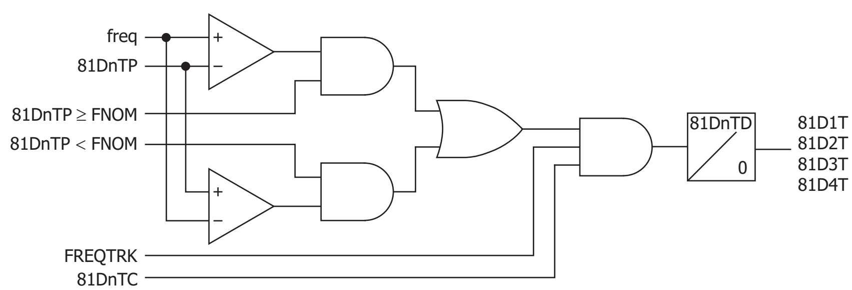
Frequency Elements

Table 4.37 Frequency Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
FREQ1 TRIP LEVEL	OFF, 15.00–70.00 Hz	81D1TP := OFF
FREQ1 TRIP DELAY[a]	0.00–400.00 sec	81D1TD := 1.0
FREQ1 TRQCTRL	SELOGIC	81D1TC := 1
FREQ2 TRIP LEVEL	OFF, 15.00–70.00 Hz	81D2TP := OFF
FREQ2 TRIP DELAY[a]	0.00–400.00 sec	81D2TD := 1.0
FREQ2 TRQCTRL	SELOGIC	81D2TC := 1
FREQ3 TRIP LEVEL	OFF, 15.00–70.00 Hz	81D3TP := OFF
FREQ3 TRIP DELAY[a]	0.00–400.00 sec	81D3TD := 1.0
FREQ3 TRQCTRL	SELOGIC	81D3TC := 1
FREQ4 TRIP LEVEL	OFF, 15.00–70.00 Hz	81D4TP := OFF
FREQ4 TRIP DELAY[a]	0.00–400.00 sec	81D4TD := 1.0
FREQ4 TRQCTRL	SELOGIC	81D4TC := 1

[a] Frequency element time delays are best set to at least three cycles at the lowest 81U pickup setting.

The SEL-787 provides four trip over- or underfrequency elements with independent level and time-delay settings. When an element level setting is less than the nominal frequency setting, the element operates as an underfrequency element. When the level setting is greater than the nominal frequency setting, the element operates as an overfrequency element. *Figure 4.61* shows the logic diagram for the frequency elements.



n = Frequency Elements 1–4
freq = Measured Frequency
81DnTP = Frequency Pickup Setting
FNOM = Nominal Frequency Setting
81DnTD = Over- and Underfrequency Element Pickup Time Delay
81DnT = Definite-Time Delayed Over- and Underfrequency Element Relay Word Bit
FREQTRK = Relay Is Tracking Frequency
81DnTC = SELOGIC Setting for Torque Control of Frequency Element

Figure 4.61 Over- and Underfrequency Element Logic

The SEL-787 tracks frequency only on the models with the voltage option. The relay uses the positive-sequence voltage (V1) to measure and track frequency. The frequency tracking bit (FREQTRK) asserts if the applied V1 magnitude is greater than 10 V rms for at least three cycles. The FREQTRK bit drops out if the V1 magnitude is less than 10 V for longer than 10 cycles. If no voltages are applied or the V1 magnitude is less than 10 V for longer than 10 cycles, the relay assumes the frequency is the same as the nominal frequency, or the FNOM setting.

Loss-of-Potential (LOP) Protection

Refer to *Figure 4.62* for the LOP logic. The SEL-787 sets Relay Word bit LOP (loss-of-potential) upon detecting a loss of relay ac voltage input such as that caused by blown potential fuses or by the operation of molded-case circuit breakers. Because accurate relaying potentials are required by certain protection elements (undervoltage 27 elements, for example), you can use the LOP function to supervise these protection elements.

The relay declares an LOP when there is more than a 20 percent drop in the measured positive-sequence voltage (V1) with no corresponding magnitude or angle change (above a predetermined threshold) in positive-sequence (I1), negative-sequence (I2), or zero-sequence currents (I0). If this condition persists for 1 second, then the relay latches the LOP Relay Word bit at logical 1. The relay resets the LOP Relay Word bit when the conditions of the RESET input of the latch are met, as shown in *Figure 4.62*.

Settings

The LOP function, when available in a given SEL-787 model, is always active unless blocked by the corresponding SELOGIC control equation, LOPBLK (see *Table 4.39* for the setting). Certain switching operations can result in LOP assertion when the drop in V1 is greater than 20 percent with no or very little change in sequence currents. Consider setting LOPBLK to avoid assertion of LOP under such conditions. Note that I1, I2, and I0 shown in *Figure 4.62* are utilized from the terminal that the VIWDG setting is set to. For example, if VIWDG := 1, then the relay utilizes I1, I2, and I0 from Terminal 1. If VIWDG := 12, then the relay utilizes I1, I2, and I0 from the combined currents of Terminal 1 and Terminal 2.

Table 4.38 Loss-of-Potential (LOP) Setting

Setting Prompt	Setting Range	Setting Name := Factory Default
LOP BLOCK	SELOGIC	LOPBLK := 0

LOP Impact on Other Protection Elements

Undervoltage and directional power elements require accurate relaying potentials for correct operation. It is critical that the relay detects an LOP condition and prevents operation of these elements. For example, when dropping a wrench on the phase-voltage input fuse holders, the relay LOP logic accurately determines that this loss of input voltages is an LOP condition and does not trip (if the LOP Relay Word bit supervises selected tripping elements, see *Example 4.9*). If you are using voltage-determined relay elements for tripping decisions, then blocking these elements is crucial when the voltage component is no longer valid.

EXAMPLE 4.9 Supervising Voltage-Element Tripping With LOP

To supervise undervoltage by LOP one of the trip equations can be set as follows:

TR2 := **. . . OR ((27P1T OR 27P2T) AND NOT LOP)**

Similarly, if you want the additional voltage-affected elements (e.g., 3PWR1T) to act only when there are correct relaying potentials voltage, use the following in the equation:

. . . OR ((27P1T OR 27P2T OR 3PWR1T) AND NOT LOP)

You can supervise each element separately or as a group when these elements occur in the trip equations, as shown in this example.

LOP Monitoring and Alarms

You should take steps to immediately correct an LOP problem so that normal protection is rapidly re-established. Include the LOP Relay Word bit in an output contact alarm to notify operation personnel of abnormal voltage input conditions and failures that can be detrimental to the protection system performance if not quickly corrected.

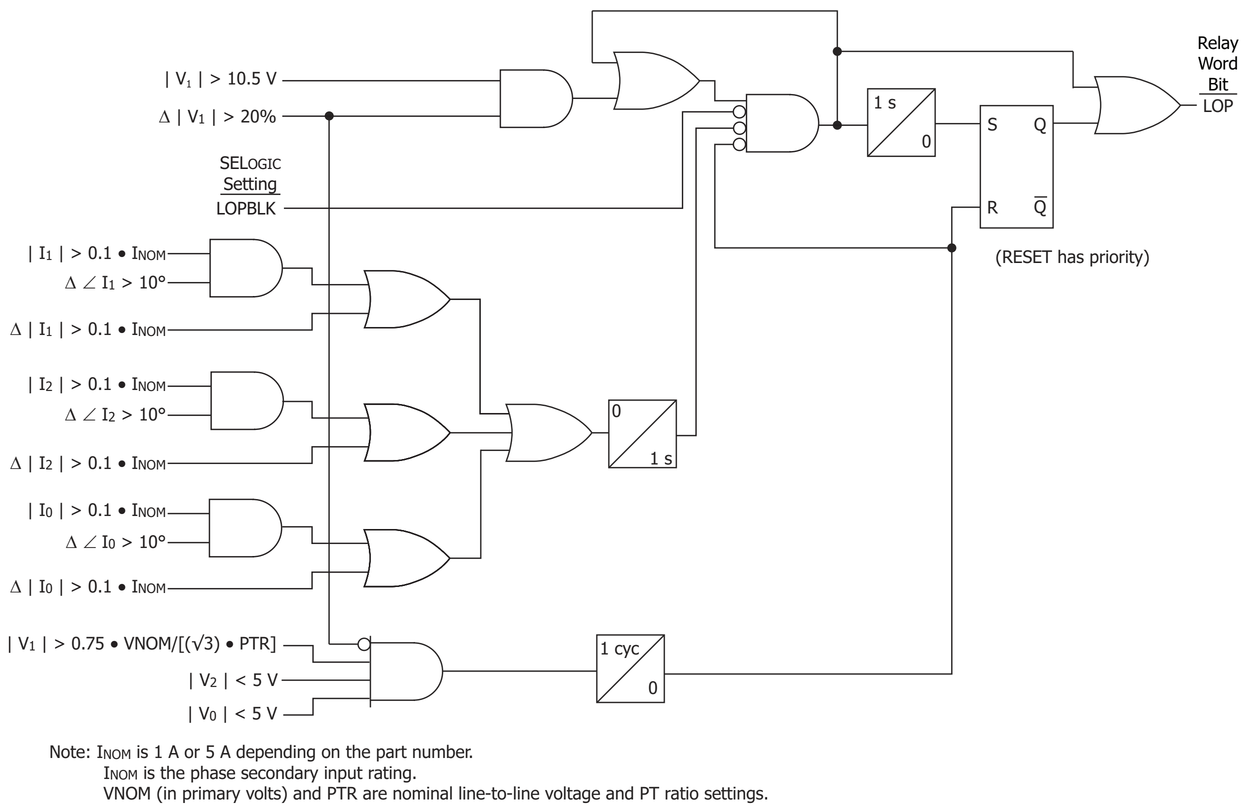


Figure 4.62 Loss-of-Potential (LOP) Logic

Demand Metering

The SEL-787 provides demand and peak demand metering, selectable between thermal and rolling demand types, for the following values for Windings 1, 2, 3, or 4; combined Windings 1 and 2; combined Windings 2 and 3; or combined Windings 3 and 4 currents:

- IA, IB, IC, phase currents (A primary)
- IG Residual ground current (A primary; IG = 3I0 = IA + IB + IC)
- 3I2 Negative-sequence current (A primary)

When EDEM := W12, W23, or W34, the relay uses corresponding combined phase, residual, and negative-sequence currents.

Table 4.39 shows the demand metering settings and the options available under the EDEM setting range for different models. Also refer to *Section 5: Metering and Monitoring* and *Section 7: Communications* for other related information for the demand meter.

Table 4.39 Demand Meter Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE DEM MTR	OFF, W1, W2, W3, W4, W12, W23, W34[a]	EDEM := OFF
DEMAND MTR TYPE	THM, ROL	DEMTY := THM
DEM TIME CONSTNT	5, 10, 15, 30, 60 min	DMTC := 5
PH CURR DEM LVL	OFF, 0.50-16.00 A[b] OFF. 0.10-3.20 A[c]	PHDEMP := 5.00[a] PHDEMP := 1.00[b]
RES CURR DEM LVL	OFF, 0.50-16.00 A[b] OFF, 0.10-3.2 A[c]	GNDEMP := 1.00[a] GNDEMP := 0.20[b]
3I2 CURR DEM LVL	OFF, 0.50-16.00 A[b] OFF, 0.10-3.2 A[c]	3I2DEMP := 1.00[a] 3I2DEMP := 0.20[b]

[a] Settings W1 and W2 are available for all the models.
Setting W3 is available in the SEL-787-3E, SEL-787-3S, and SEL-787-4X models when E87W3 is not set to REF.
Setting W4 is available in the SEL-787-4X model.
Setting W12 is available in the SEL-787-3E, SEL-787-3S, and SEL-787-4X models when CCW12 = Y.
Setting W23 is available in the SEL-787-3E, SEL-787-3S, and SEL-787-4X models when CCW23 = Y and when E87W3 is not set to REF.
Setting W34 is available in the SEL-787-4X model when CCW34 = Y and when E87W3 is not set to REF.
[b] For I_{NOM} = 5 A.
[c] For I_{NOM} = 1 A.

The demand current level settings are applied to demand current meter outputs as shown in *Figure 4.63*. For example, when residual ground demand current IGD goes above corresponding demand pickup GNDEMP, Relay Word bit GNDEM asserts to logical 1. Use these demand current logic outputs (PHDEM, GNDEM, and 3I2DEM) to alarm for high loading or unbalance conditions.

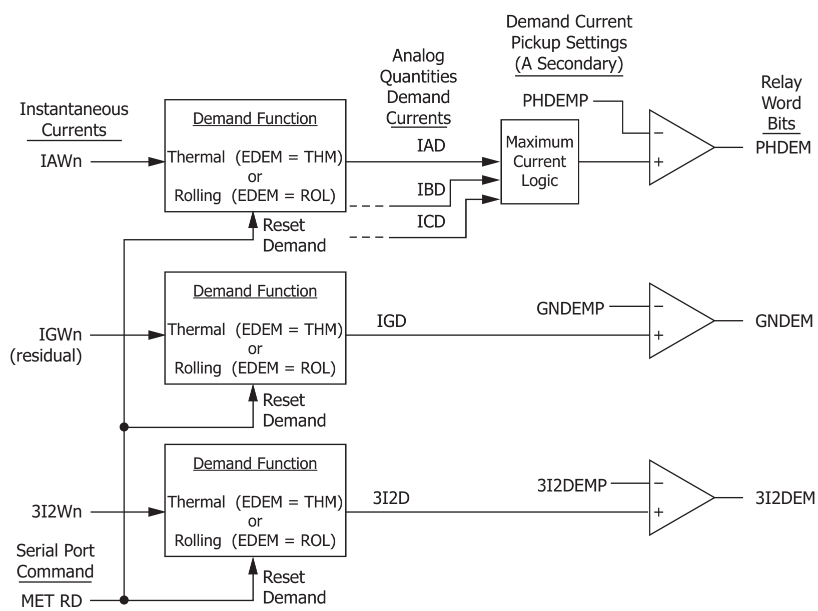


Figure 4.63 Demand Current Logic Outputs

The demand values are updated approximately once a second. The relay stores peak demand values to nonvolatile storage every six hours (it overwrites the previous stored value if it is exceeded). Should the relay lose control power, it restores the peak demand values saved by the relay.

Demand metering peak recording is momentarily suspended when SELOGIC control equation setting FAULT is asserted (= logical 1).

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 4.64* 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").

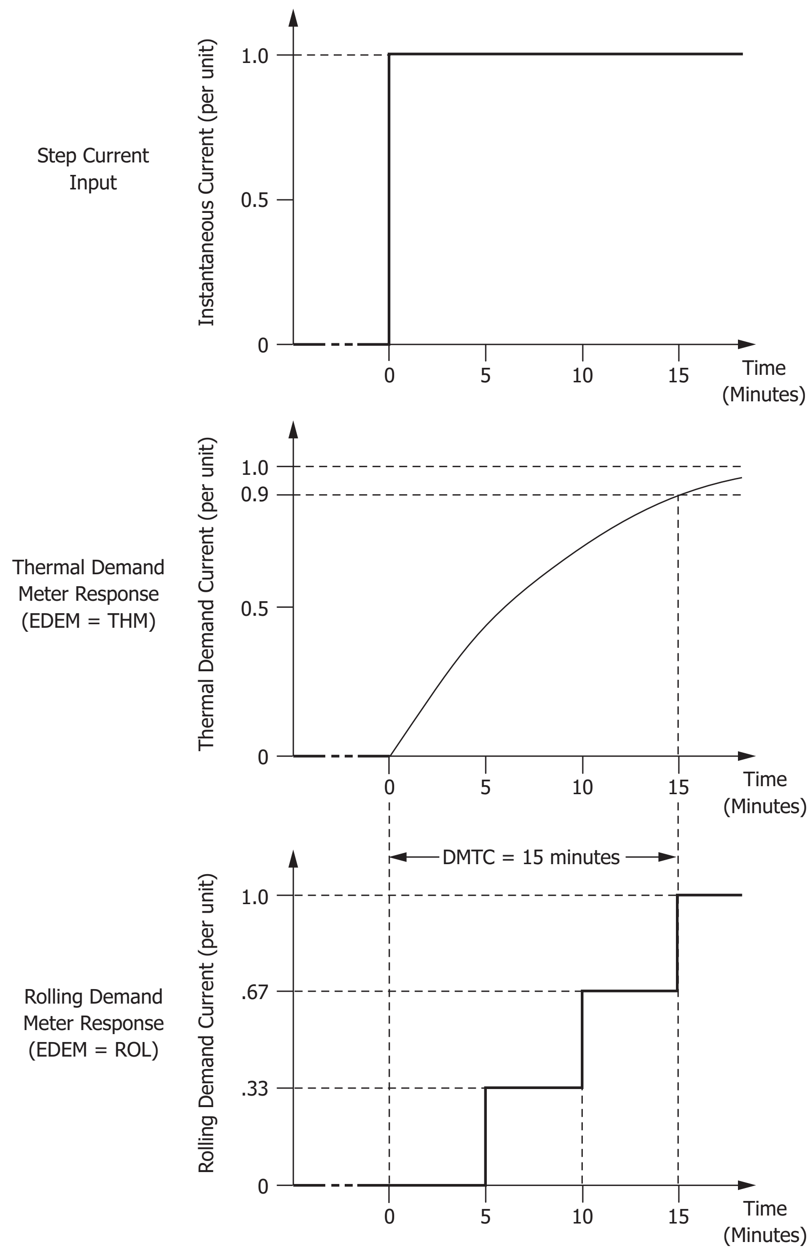


Figure 4.64 Response of Thermal and Rolling Demand Meters to a Step Input (Setting DMTC = 15 minutes)

Thermal Demand Meter Response

The response of the thermal demand meter in *Figure 4.64* (middle) to the step current input (top) is analogous to the series RC circuit in *Figure 4.65*.

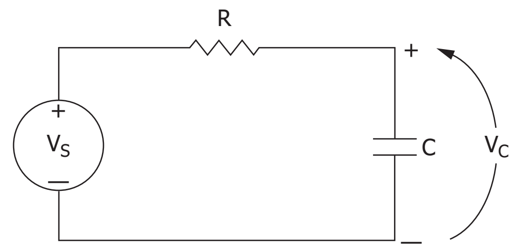


Figure 4.65 Voltage V_S Applied to Series RC Circuit

In the analogy:

> Voltage V_S in *Figure 4.65* corresponds to the step current input in *Figure 4.64* (top).
>
> Voltage V_C across the capacitor in *Figure 4.65* corresponds to the response of the thermal demand meter in *Figure 4.64* (middle).

If voltage V_S in *Figure 4.65* has been at zero (V_S = 0.0 per unit) for some time, voltage V_C across the capacitor in *Figure 4.65* 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 4.64* (middle) to the step current input (top).

In general, as voltage V_C across the capacitor in *Figure 4.65* 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 4.39*). Note in *Figure 4.64*, 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-787 updates thermal demand values approximately every second.

Rolling Demand Meter Response

The response of the rolling demand meter in *Figure 4.64* (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 4.39*). Note in *Figure 4.64*, 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 second. 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 4.64* 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 4.64* (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.

Trip/Close Logic

The trip logic and close logic for the SEL-787 operate in a similar manner. Each has a SELogic control equation setting to set or latch the logic and another SELogic control equation setting to reset or unlatch the logic. Each also has other elements or functions that unlatch the logic. The output of each logic is a Relay Word bit that can be assigned to operate output contacts or programmed as part of a SELogic control equation. Note that settings TR1–TR4 and CL1–CL4 are available in all the models. Refer to *Figure 4.66* for the trip logic and *Figure 4.67* for the close logic. The specifics of each type of logic are discussed in the following sections.

Table 4.40 Trip/Close Logic Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
MIN TRIP TIME	0.00–400.00 sec	TDURD := 0.5
CLOSE 1 FAIL DLY	0.00–400.00 sec	CFD1 := 0.5
CLOSE 2 FAIL DLY	0.00–400.00 sec	CFD2 := 0.5
CLOSE 3 FAIL DLY	0.00–400.00 sec	CFD3 := 0.5
CLOSE 4 FAIL DLY	0.00–400.00 sec	CFD4 := 0.5
TRIP 1 EQUATION	SV	TR1 := 50P11T OR 51P1T OR 51Q1T OR LT05 AND SV04T OR OC1
TRIP 2 EQUATION	SV	TR2 := 51P2T OR 51Q2T OR LT06 AND SV04T OR OC2
TRIP 3 EQUATION	SV	TR3 := 51P3T OR 51Q3T OR LT07 AND SV04T OR OC3[a] TR3 := 0[b]
TRIP 4 EQUATION	SV	TR4 := 51P4T OR 51Q4T OR LT08 AND SV04T OR OC4[c] TR4 := 0[d]
TRIP XFMR EQN	SV	TRXFMR := 87R OR 87U
REMOTE TRIP EQN	SV	REMTRIP := 0
UNLATCH TRIP 1	SV	ULTRIP1 := NOT (51P1P OR 51Q1P OR 52A1)
UNLATCH TRIP 2	SV	ULTRIP2 := NOT (51P2P OR 51Q2P OR 52A2)
UNLATCH TRIP 3	SV	ULTRIP3 := NOT (51P3P OR 51Q3P OR 52A3)[a] ULTRIP3 := 1[b]
UNLATCH TRIP 4	SV	ULTRIP4 := NOT (51P4P OR 51Q4P OR 52A4)[c] ULTRIP4 := 1[d]
UNLATCH TRP XFMR	SV	ULTRXFMR := NOT (87R OR 87U)
BRKR1 N/O CONT	SV	52A1 := IN101
BRKR1 N/C CONT	SV	52B1 := NOT 52A1
BRKR2 N/O CONT	SV	52A2 := IN102
BRKR2 N/C CONT	SV	52B2 := NOT 52A2
BRKR3 N/O CONT	SV	52A3 := 0
BRKR3 N/C CONT	SV	52B3 := NOT 52A3

Table 4.40 Trip/Close Logic Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
BRKR4 N/O CONT	SV	52A4 := 0
BRKR4 N/C CONT	SV	52B4 := NOT 52A4
CLOSE 1 EQUATION	SV	CL1 := SV03T AND LT05 OR CC1
CLOSE 2 EQUATION	SV	CL2 := SV03T AND LT06 OR CC2
CLOSE 3 EQUATION	SV	CL3 := SV03T AND LT07 OR CC3[a] CL3 := 0[b]
CLOSE 4 EQUATION	SV	CL4 := SV03T AND LT08 OR CC4[c] CL4 := 0[d]
UNLATCH CLOSE 1	SV	ULCL1 := TRIP1 OR TRIPXFMR
UNLATCH CLOSE 2	SV	ULCL2 := TRIP2 OR TRIPXFMR
UNLATCH CLOSE 3	SV	ULCL3 := TRIP3 OR TRIPXFMR
UNLATCH CLOSE 4	SV	ULCL4 := TRIP4 OR TRIPXFMR

[a] Default setting shown is applicable to the SEL-787-3E, SEL-787-3S, and SEL-787-4X models.
[b] Default setting shown is applicable to the SEL-787-21, SEL-787-2E, and SEL-787-2X models.
[c] Default setting shown is applicable to the SEL-787-4X model.
[d] Default setting shown is applicable to the SEL-787-21, SEL-787-2E, SEL-787-2X, SEL-7873E, and SEL-787-3S.

TDURD Minimum Trip Time

This timer establishes the minimum time duration for which the TRIP Relay Word bits assert. This is a rising-edge initiated timer.

Trips initiated by TR*m* (*m* = 1, 2, 3, 4, or XFMR) Relay Word bits (includes **OPEN** command from front-panel and serial ports) are maintained for at least the duration of the minimum trip duration time (TDURD) setting.

TR Trip Conditions SELOGIC Control Equations

There are five trip logic equations within the SEL-787. They are designed to operate when SELOGIC control equation trip variable setting TR*m* is asserted (*m* = 1, 2, 3, 4, or XFMR), and to unlatch when SELOGIC control equation setting ULTR*m* is asserted. TR1, TR2, TR3, and TR4 are intended for Breakers 1, 2, 3, and 4, respectively, and TRXFMR is intended for a transformer lockout relay. The output of the logic is Relay Word bit TRIP*m*.

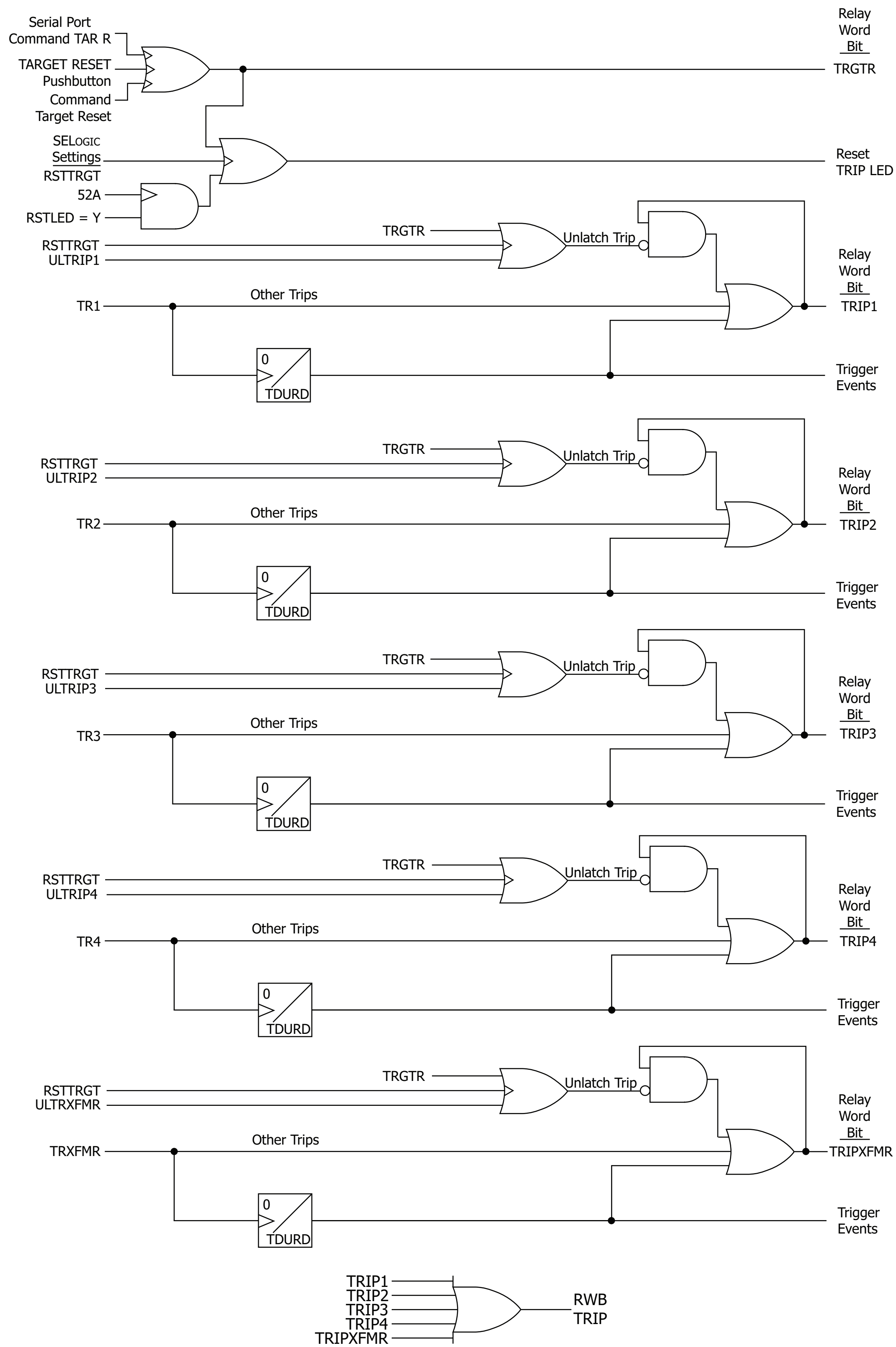


Figure 4.66 Trip Logic

The relay controls the tripping output contact(s) when the Relay Word bit TRIP*m* appears in an output contact SELOGIC control equation. Default relay settings have output **OUT103** set to TRIPXFMR (see *Table 4.49*). Assign Relay Word bits TRIP1, TRIP2, TRIP3, and TRIP4 to other available outputs as required by your application. See *Figure 2.27* for typical trip circuit connection.

Set the TR*m* SELOGIC control equations to include an OR-combination of all the Relay Word bits that you want to cause the associated trip bits to assert. The factory-default setting already includes all commonly necessary Relay Word bits.

REMTRIP Remote Trip Conditions SELOGIC Control Equation

You can map any Relay Word bit or SELOGIC control equation to the REMTRIP to trip a breaker or the transformer. For example, you can map a control input to REMTRIP and map the REMTRIP to appropriate TR*m* equation.

Unlatch Trip Logic

Each of the trip logic equations, TR*m* (*m* = 1, 2, 3, 4, or XFMR), has an associated unlatch trip SELOGIC control equation. Following a fault, the appropriate trip signal is maintained until all of the following conditions are true:

NOTE: The factory-default setting of ULTRIP provides an automatic reset of a trip when the breaker opens and selected 50/51 elements are not picked up.

- Minimum trip duration time (TDURD) passes.
- The TR*m* SELOGIC control equation result deasserts to logical 0.
- One of the following occurs:
  - Unlatch Trip SELOGIC control equation setting ULTRIP asserts to logical 1.
  - Target Reset SELOGIC control equation setting RSTTRGT asserts to logical 1.
  - Target Reset Relay Word TRGTR asserts. The TRGTR is asserted when the front-panel **TARGET RESET** pushbutton is pressed or a target reset serial port command is executed (ASCII, Modbus, or DeviceNet).

52A and 52B Breaker Status Conditions SELOGIC Control Equations

NOTE: For the disconnect settings and logic, refer to Disconnect Control Settings. For the touchscreen relay option, refer to Table 9.5 for typical disconnect symbols. For the settings related to bay control disconnect symbols, refer to Table 9.7 and the corresponding descriptions.

NOTE: For the settings related to the local/remote breaker control function, refer to Local/Remote Control on page 9.7. For breaker control via the front-panel pushbuttons, refer to Front-Panel Operator Control Pushbuttons on page 8.16. For breaker control via the two-line display, refer to Control Menu on page 8.10. For breaker control via the touchscreen, refer to Breaker/Disconnect Control Via Touchscreen on page 9.8.

Use the SELOGIC settings 52A*n* (*n* = 1, 2, 3, or 4) and 52B*n* to map the respective breaker auxiliary contacts to the relay. Because the 52B*n* contact is not always available, and to reduce the number of I/O required, the breaker status logic does not include the 52B*n* contact. The relay uses the 52A*n* Relay Word bit as the status of the breaker in conjunction with the protection elements and trip and close logic. The default 52B*n* setting is NOT 52A*n*. The factory-default setting assumes no auxiliary contact connection (i.e., 52A1 := 52A2 := 52A3 := 52A4 := 0).

If you connect the breaker auxiliary contacts to digital inputs, you must change the factory-default logic equations for 52A*n* and 52B*n*. For example, set 52A1 := IN101 and 52B1 := IN102 if you connect the 52a and 52b contacts of Breaker 1 to Inputs **IN101** and **IN102**, respectively.

The SEL-787 Relay with the touchscreen display option also provides you with the ability to design detailed single-line diagrams and display the breaker and disconnect status. Refer to *Table 9.1* for typical circuit breaker symbols available for display on the bay screens. For settings related to bay control breaker symbols, refer to *Table 9.7* and the corresponding description.

Figure 4.67 shows a close logic diagram for all four breakers.

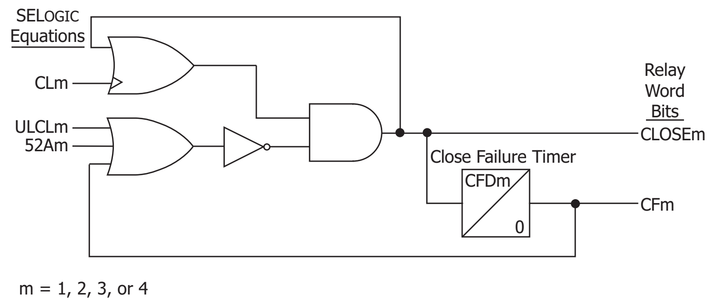


Figure 4.67 Close Logic

CL Close SELOGIC Control Equation

There are four close logic equations within the SEL-787. They are designed to operate when SELOGIC control equation close variable setting CL*m* is asserted (*m* = 1, 2, 3, 4) and to unlatch when SELOGIC control equation setting ULCL*m* is asserted. The output of the logic is Relay Word bits CLOSE*m*.

The relay controls the closing output contact(s) when the Relay Word bit CLOSE*m* appears in an output contact SELOGIC control equation. Assign the CLOSE bits to desired output relays as required by your application. See *Figure 2.27* for typical close circuit connection.

Set the CL*m* SELOGIC control equations to include an OR-combination of all Relay Word bits that you want to cause the associated close bits to assert. The factory-default setting already includes all commonly necessary Relay Word bits.

Unlatch Close Logic

Each of the four close logic equations has an associated unlatch close SELOGIC control equation. Once a CLOSE bit is asserted it is sealed-in until one of the following conditions are true:

- Unlatch Close SELOGIC control equation setting ULCL*n* asserts to logical 1.
- Relay Word 52A*n* asserts to logical 1.
- Close failure Relay Word bit asserts to logical 1.

Close Failure Logic

Each of the four close logic equations includes a close failure detection with an associated delay setting, CFD*m*. Set the close failure delay equal to the longest close time of the breaker plus a safety margin. If the breaker fails to close, the Relay Word CF*n* asserts for 1/4 cycle. Use the CF*n* bits as necessary.

Logic Settings (SET L Command)

Settings associated with latches, timers, counters, math variables, and output contacts are listed below. Note that SELOGIC control equations are processed every quarter cycle while math variable equations and analog quantities are updated every 25 ms.

SELOGIC Enables

Table 4.41 shows the enable settings for latch bits (ELAT), SELOGIC control equations (including timers) (ESV), Counters (ESC), and math variable equations (EMV). This helps limit the number of settings that you need to make. For example, if you need six timers, only enable six timers.

IMPORTANT: Upon relay initial turn on, Port 1 setting changes, or Logic setting changes, you may have to wait as long as two minutes before an additional setting change can occur. Note that the relay is functional with protection enabled, as soon as the **ENABLED** LED comes on (approximately 5–10 seconds from turn on).

Table 4.41 Enable Settings

Setting Prompt	Setting Range	Default Setting
SELOGIC Latches	N, 1–32	ELAT := 4
SV/Timers	N, 1–32	ESV := 5
SELOGIC Counters	N, 1–32	ESC := N
Math Variables[a]	N, 1–32	EMV := N

[a] If a math variable is set equal to NA (e.g., MV01 := NA), it is treated as 0.

Latch Bits

Latch control switches (latch bits are the outputs of these switches) replace traditional latching devices. Traditional latching devices maintain output contact state. The SEL-787 latch control switch also retains state even when power to the device is lost. If the latch control switch is set to a programmable output contact and power to the device is lost, the state of the latch control switch is stored in nonvolatile memory, but the device de-energizes the output contact. When power to the device is restored, the programmable output contact returns to the state of the latch control switch after device initialization. Traditional latching device output contact states are changed by pulsing the latching device inputs (see *Figure 4.68*). Pulse the set input to close (set) the latching device output contact. Pulse the reset input to open (reset) the latching device output contact. The external contacts wired to the latching device inputs are often from remote control equipment (e.g., SCADA, RTU).

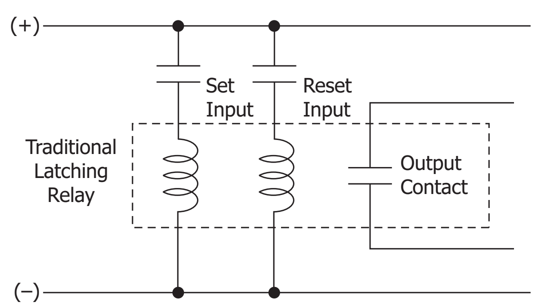


Figure 4.68 Schematic Diagram of a Traditional Latching Device

Thirty-two latch control switches in the SEL-787 provide latching device functionality. *Figure 4.69* shows the logic diagram of a latch switch. The output of the latch control switch is a Relay Word bit LT*n* (*n* = 01–32), called a latch bit.

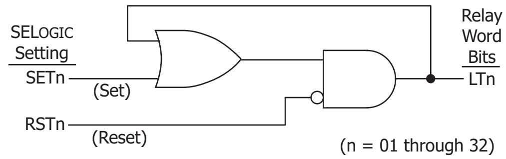


Figure 4.69 Logic Diagram of a Latch Switch

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. You can use these latch bits in SELOGIC control equations to create custom logic for your application.

The SEL-787 includes 32 latches. *Table 4.41* shows the **SET** and **RESET** default settings for Latch 1 through Latch 4. The remaining latches are all set to NA.

Table 4.42 Latch Bits Equation Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
SET01	SELOGIC	SET01 := R_TRIG SV01T AND NOT LT01
RST01	SELOGIC	RST01 := R_TRIG SV01T AND LT01
SET02	SELOGIC	SET02 := (PB02 AND R_TRIG SV02T) AND LT01 AND NOT ((52A1 AND LT05) OR (52A2 AND LT06) OR (52A3 AND LT07) OR (52A4 AND LT08)) AND (LT05 OR LT06 OR LT07 OR LT08)[a]
		SET02 := (PB02 AND R_TRIG SV02T) AND LT01 AND NOT ((52A1 AND LT05) OR (52A2 AND LT06) OR (52A3 AND LT07)) AND (LT05 OR LT06 OR LT07)[b]
		SET02 := (PB02 AND R_TRIG SV02T) AND LT01 AND NOT ((52A1 AND LT05) OR (52A2 AND LT06)) AND (LT05 OR LT06)[c]
RST02	SELOGIC	RST02 := (SV03T OR R_TRIG SV02T) AND LT02
SET03	SELOGIC	SET03 := (PB03 AND R_TRIG SV02T) AND ((52A1 AND LT05) OR (52A2 AND LT06) OR (52A3 AND LT07) OR (52A4 AND LT08)) AND (LT05 OR LT06 OR LT07 OR LT08)[a]
		SET03 := (PB03 AND R_TRIG SV02T) AND ((52A1 AND LT05) OR (52A2 AND LT06) OR (52A3 AND LT07)) AND (LT05 OR LT06 OR LT07)[b]
		SET03 := (PB03 AND R_TRIG SV02T) AND ((52A1 AND LT05) OR (52A2 AND LT06)) AND (LT05 OR LT06)[c]
RST03	SELOGIC	RST03 := (SV04T OR R_TRIG SV02T) AND LT03
SET04	SELOGIC	SET04 := NA
RST04	SELOGIC	RST04 := NA
SET05	SELOGIC	SET05 := PB05 AND R_TRIG SV02T AND NOT LT05

Table 4.42 Latch Bits Equation Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
RST05	SELOGIC	RST05 := (PB05 OR PB06 OR PB07 OR PB08) AND R_TRIG SV02T AND LT05[a]
		RST05 := (PB05 OR PB06 OR PB07) AND R_TRIG SV02T AND LT05[b]
		RST05 := (PB05 OR PB06) AND R_TRIG SV02T AND LT05[c]
SET06	SELOGIC	SET06 := PB06 AND R_TRIG SV02T AND NOT LT06
RST06	SELOGIC	RST06 := (PB05 OR PB06 OR PB07 OR PB08) AND R_TRIG SV02T AND LT06[a]
		RST06 := (PB05 OR PB06 OR PB07) AND R_TRIG SV02T AND LT06[b]
		RST06 := (PB05 OR PB06) AND R_TRIG SV02T AND LT06[c]
SET07	SELOGIC	SET07 := PB07 AND R_TRIG SV02T AND NOT LT07[d]
		SET07 := NA[c]
RST07	SELOGIC	RST07 := (PB05 OR PB06 OR PB07 OR PB08) AND R_TRIG SV02T AND LT07[a]
		RST07 := (PB05 OR PB06 OR PB07) AND R_TRIG SV02T AND LT07[b]
		RST07 := NA[c]
SET08	SELOGIC	SET08 := PB08 AND R_TRIG SV02T AND NOT LT08[a]
		SET08 := NA[e]
RST08	SELOGIC	RST08 := (PB05 OR PB06 OR PB07 OR PB08) AND R_TRIG SV02T AND LT08[a]
		RST08 := NA[e]
⋮	⋮	⋮
SET32	SELOGIC	SET32 := NA
RST32	SELOGIC	RST32 := NA

[a] Default logic applicable to the SEL-787-4X model.
[b] Default logic applicable to the SEL-787-3E and SEL-787-3S models.
[c] Default logic applicable to the SEL-787-21, SEL-787-2E, SEL-787-2X models.
[d] Default logic applicable to the SEL-787-3E, SEL-787-3S, SEL-787-4X models.
[e] Default logic applicable to the SEL-787-21, SEL-787-2E, SEL-787-2X, SEL-787-3E, and SEL-787-3S models.

Latch Bits: Nonvolatile State

Power Loss

The states of the latch bits (LT01–LT32) are retained if power to the device is lost and then restored. If a latch bit is asserted (e.g., LT02 := logical 1) when power is lost, it is asserted (LT02 := logical 1) when power is restored. If a latch bit is deasserted (e.g., LT03 := logical 0) when power is lost, it is deasserted (LT03 := logical 0) when power is restored.

Settings Change

If individual settings are changed, the states of the latch bits (Relay Word bits LT01 through LT32) are retained, as in the preceding *Power Loss on page 4.107* explanation. If the individual settings change causes a change in SELOGIC control equation settings SET*n* or RST*n* (*n* = 1 through 32), the retained states of the latch bits can be changed, subject to the newly enabled settings SET*n* or RST*n*.

Make Latch Control Switch Settings With Care

The latch bit states are stored in nonvolatile memory so they can be retained during power loss or settings 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 a flash self-test failure. *An average of 5000 cumulative latch bit state changes per day can be made for a 25-year device service life.*

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 you use any optoisolated inputs in settings SET*n* and RST*n*, the inputs each have a separate debounce timer that can help in providing the necessary time qualification.

SELOGIC Control Equation Variables/Timers

Enable the number of SELOGIC control equations necessary for your application. Only the enabled SELOGIC control equations appear for settings. Each SELOGIC control equation variable/timer has a SELOGIC control equation setting input and variable/timer outputs as shown in *Figure 4.70*. Timers SV01T through SV32T in *Figure 4.70* have a setting range of 0.00–3000.00 seconds. This timer setting range applies to both pickup and dropout times (SV*n*PU and SV*n*DO, *n* = 1 through 32).

NOTE: Any SELOGIC control equation that contains a Relay Word bit/analog quantity that gets hidden due to a setting change or a configuration change will show up as a BAD SELOGIC EQUATION.

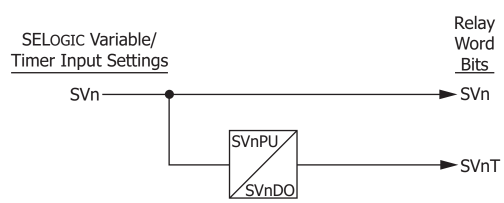


Figure 4.70 SELOGIC Control Equation Variable/Timers SV01/SV01T–SV32T

You can enter as many as 15 elements per SELOGIC control equation, including a total of 14 elements in parentheses (see *Table 4.44* for more information).

SELOGIC Control Equation Operators

Use the Boolean operators to combine values with a resulting Boolean value. Edge trigger operators provide a pulse output. Combine the operators and operands to form statements that evaluate complex logic. SELOGIC control equations are either Boolean type or math type. Because the equals sign (=) is already used as an equality comparison, both Boolean type and math type of SELOGIC control equation settings begin with an "assignment" operator (:=) instead of with an equals sign.

Boolean SELOGIC control equation settings use logic similar to Boolean algebra logic, combining Relay Word bits together with one or more of the Boolean operators listed in *Table 4.44*. Math SELOGIC control equation settings operate on numerical values, using one or more of the Mathematical operators listed in *Table 4.44*. These numerical values can be mathematical variables or actual real numbers.

The relay converts variables from decimal to integer before performing math operations, i.e., scales it by multiplying by 128 followed by rounding. After the math operations, the relay converts the result back from integer to decimal by scaling the value down by 128 before reporting the results. This effectively means that math calculations are rounded. See *Example 4.10* for an explanation on improving the accuracy of the math operations by managing the processing order.

EXAMPLE 4.10 Improving the Accuracy of Math Operations

If MV01 := (60/4160) • 100,000, the relay performs the 60/4160 calculation and scales it by 128, then rounds this up to a 2. The relay then multiplies it by 100,000 and stores it as 200,000. When the number is reported, it divides out the scale factor (128) and reports 1562.5.

Alternatively, if MV01 := (60 • 100,000)/4160, the relay multiplies (60 • 100,000) and then scales by 128 and then divides by 4160. This result is then rounded and stored as 184,615. The relay then divides 184,615 by 128 and reports 1442.3.

Example 4.10 illustrates how important it is to avoid calculations where a small number is divided by a large number followed by multiplication. It will amplify the error significantly.

NOTE: Math variables are reset to zero if the relay loses power because the math variables are stored in volatile memory.

The executed result of a math SELOGIC control equation is stored in a math variable. The storage format of the math variable is a 32-bit fixed point signed integer; 24 bits represent the integer portion, 7 bits represent the fractional portion, and 1 bit represents the sign. The smallest and largest values a math variable can represent are –16777215.99 and +16777215.99, respectively. If the executed result exceeds these limits, it will be clipped at the limit value. For example, when the MV01:= executed result is –16777219.00, MV01 will be –16777215.99. Similarly, when the MV02 := executed result is +16777238.00, MV02 will be +16777215.99. Since there are only 7 bits available for the fractional portion, the result of multiplication and division with decimals will have lower accuracy than one would expect with a floating point processor. As illustrated by the results in *Table 4.43*, the results vary from 20 percent at the smallest end of the fractional values to 0.2 percent at the largest. Using scaling factors where possible is recommended to avoid the error introduced by the fixed point processor when multiplying and dividing fractional numbers.

Table 4.43 Math Variable Fractional Multiplication Results

MV01 := 0.01 • 10	Result = 0.08	Error = 20%
MV01 := 0.05 • 10	Result = 0.47	Error = 6.0%
MV01 := 0.10 • 10	Result = 1.02	Error = 2.0%
MV01 := 0.50 • 10	Result = 5.00	Error = 0.0%
MV01 := 0.99 • 10	Result = 9.92	Error = 0.2%

Comments can be added to both Boolean and math SELOGIC control equations by inserting a # symbol. Everything following the # symbol in a SELOGIC control equation is treated as a comment. See *Table 4.45* for this and other Boolean and math operators and values.

Operator Precedence

When you combine several operators and operands within a single expression, the SEL-787 evaluates the operators from left to right, starting with the highest precedence operators and working down to the lowest precedence. This means that if you write an equation with three AND operators, for example SV01 AND SV02 AND SV03, each AND is evaluated from the left to the right. If you substitute NOT SV04 for SV03 to make SV01 AND SV02 AND NOT SV04, the device evaluates the NOT operation of SV04 first and uses the result in subsequent evaluation of the expression.

Table 4.44 SELOGIC Control Equation Operators (Listed in Operator Precedence)

Operator	Function	Function Type (Boolean and/or Mathematical)
( )	parentheses	Boolean and Mathematical (highest precedence)
–	negation	Mathematical
NOT	NOT	Boolean
R_TRIG	rising-edge trigger/detect	Boolean
F_TRIG	falling-edge trigger/detect	Boolean
*	multiply	Mathematical
/	divide	Mathematical
+	add	Mathematical
–	subtract	Mathematical
<, >, <=, >=	comparison	Boolean
=	equality	Boolean
<>	inequality	Boolean
AND	AND	Boolean
OR	OR	Boolean (lowest precedence)

Parentheses Operator ( )

You can use more than one set of parentheses in a SELOGIC control equation setting. For example, the following Boolean SELOGIC control equation setting has two sets of parentheses:

SV04 := **(SV04 OR IN102) AND (PB01_LED OR RB01)**

In the above example, the logic within the parentheses is processed first and then the two parentheses resultants are ANDed together. Use as many as 14 sets of parentheses in a single SELOGIC control equation setting. The parentheses can be “nested” (parentheses within parentheses).

Math Negation Operator (–)

The negation operator – changes the sign of a numerical value. For example:

MV01 := **RB01**

When Remote bit RB01 asserts, Math variable MV01 has a value of 1, i.e., MV01 = 1. We can change the sign on MV01 with the following expression:

MV01 := **-1 * RB01**

Now, when Remote bit RB01 asserts, Math variable MV01 has a value of –1, i.e., MV01 = –1.

Boolean NOT Operator (NOT)

Apply the NOT operator to a single Relay Word bit and to multiple elements (within parentheses).

An example of a single Relay Word bit is as follows:

SV01 := **NOT RB01**

When Remote bit RB01 asserts from logical 0 to logical 1, the Boolean NOT operator, in turn, changes the logical 1 to a logical 0. In this example, SV01 deasserts when RB01 asserts.

Following is an example of the NOT operator applied to multiple elements within parentheses.

The Boolean SELOGIC control equation OUT101 setting could be set as follows:

OUT101 := **NOT(RB01 OR SV02)**

If both RB01 and SV02 are deasserted (= logical 0), output contact OUT101 asserts, i.e., OUT101 := NOT (logical 0 OR logical 0) = NOT (logical 0) = logical 1.

In a Math SELOGIC control equation, use the NOT operator with any Relay Word bits. This allows a simple if/else type equation, as shown in the example below.

MV01 := **12 * IN101 + (MV01 + 1) * NOT IN101**

The equation above sets MV01 to 12 whenever IN101 asserts, otherwise it increments MV01 by 1 each time the equation is executed.

Boolean Rising-Edge Operator (R_TRIG)

Apply the rising-edge operator, R_TRIG, to individual Relay Word bits only; you cannot apply R_TRIG to groups of elements within parentheses. When any Relay Word bit asserts (going from logical 0 to logical 1), R_TRIG interprets this logical 0 to logical 1 transition as a “rising edge” and asserts to logical 1 for one processing interval.

For example, the Boolean SELOGIC control equation event report generation setting uses rising-edge operators:

ER := **R_TRIG IN101 OR R_TRIG IN102**

The rising-edge operators detect a logical 0 to logical 1 transition each time one of IN101 or IN102 asserts. Using these settings, the device triggers a new event report each time IN101 or IN102 asserts anew, if the device is not already recording an event report. You can use the rising-edge operator with the NOT operator as long as the NOT operator precedes the R_TRIG operator. The NOT R_TRIG combination produces a logical 0 for one processing interval when it detects a rising edge on the specified element.

Boolean Falling-Edge Operator (F_TRIG)

Apply the falling-edge operator, F_TRIG, to individual Relay Word bits only; you cannot apply F_TRIG to groups of elements within parentheses. The falling-edge operator, F_TRIG, operates similarly to the rising-edge operator, but operates on Relay Word bit deassertion (elements going from logical 1 to logical 0) instead of Relay Word bit assertion. When the Relay Word bit deasserts, F_TRIG interprets this logical 1 to logical 0 transition as a “falling edge” and asserts to logical 1 for one processing interval, as shown in *Figure 4.71*.

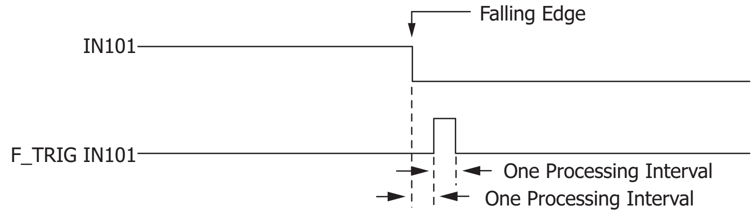


Figure 4.71 Result of Falling-Edge Operator on a Deasserting Input

You can use the falling-edge operator with the NOT operator as long as the NOT operator precedes the F_TRIG operator. The NOT F_TRIG combination produces a logical 0 for one processing interval when it detects a falling edge on the specified element.

Math Arithmetic Operators (*, /, +, and –)

If Relay Word bits (which are effectively Boolean resultants, equal to logical 1 or logical 0) are used in mathematical operations, they are treated as numerical values 0 and 1, depending on if the Relay Word bit is equal to logical 0 or logical 1, respectively.

Boolean Comparison Operators (<, >, <=, and >=)

Comparisons are mathematical operations that compare two numerical values, with the result being a logical 0 (if the comparison is not true) or logical 1 (if the comparison is true). Thus, what starts out as a mathematical comparison ends up as a Boolean resultant. For example, if the output of a math variable is above a certain value, an output contact is asserted:

OUT103 := **MV01 > 8**

If the math variable (MV01) is greater than 8 in value, output contact OUT103 asserts (OUT103 = logical 1). If the math variable (MV01) is less than or equal to 8 in value, output contact OUT103 deasserts (OUT103 = logical 0).

Boolean Equality (=) and Inequality (<>) Operators

Equality and inequality operators operate similar to the comparison operators. These are mathematical operations that compare two numerical values, with the result being a logical 0 (if the comparison is not true), or logical 1 (if the comparison is true). Thus, what starts out as a mathematical comparison, ends up as a Boolean resultant. For example, if the output of a math variable is not equal to a certain value, an output contact is asserted:

OUT102 := **MV01 <> 45**

If the math variable (MV01) is not equal to 45 in value, output contact OUT102 asserts (effectively OUT102 := logical 1). If the math variable (MV01) is equal to 45 in value, output contact OUT102 deasserts (effectively OUT102 := logical 0). *Table 4.45* shows other operators and values that you can use in writing SELOGIC control equations.

Table 4.45 Other SELOGIC Control Equation Operators/Values

Operator/ Value	Function	Function Type (Boolean and/or Mathematical)
0	Set SELOGIC control equation directly to logical 0 (*XXX* := 0)	Boolean
1	Set SELOGIC control equation directly to logical 1 (*XXX* := 1)	Boolean
#	Characters entered after the # operator are not processed and deemed as comments	Boolean and Mathematical
\	Indicates that the preceding logic should be continued on the next line ("\" is entered only at the end of a line)	Boolean and Mathematical

Timers Reset When Power Lost or Settings Changed

If the device loses power or settings change, the SELOGIC control equation variables/timers reset. Relay Word bits SV*n* and SV*n*T (*n* = 01–32) reset to logical 0 after power restoration or a settings change. *Figure 4.72* shows an effective seal-in logic circuit, created by the use of Relay Word bit SV07 (SELOGIC control equation variable SV07) in SELOGIC control equation SV07:

SV07 = **(SV07 OR OUT101) AND (OUT102 OR OUT401)**

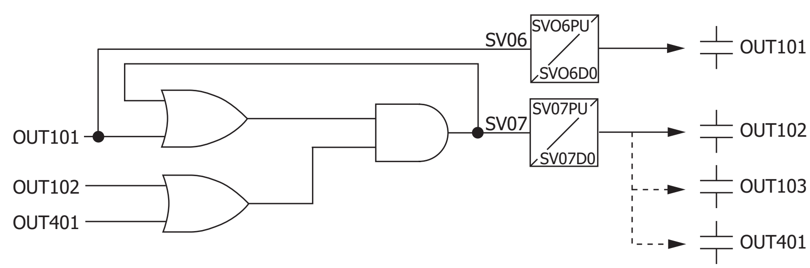


Figure 4.72 Example Use of SELOGIC Variables/Timers

SV/Timers Settings

The SEL-787 includes 32 SELOGIC variables. *Table 4.46* shows the pickup, dropout, and equation settings for SV01 through SV05. The remaining SELOGIC variables are not enabled (see *Table 4.41*).

Table 4.46 SELOGIC Variable Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Default Settings
SV TIMER PICKUP	0.00–3000.00 sec	SV01PU := 3.00
SV TIMER DROPOUT	0.00–3000.00 sec	SV01DO := 0.00
SV INPUT	SELOGIC	SV01 := PB01
SV TIMER PICKUP	0.00–3000.00 sec	SV02PU := 0.25
SV TIMER DROPOUT	0.00–3000.00 sec	SV02DO := 0.00
SV INPUT	SELOGIC	SV02 := PB01 OR PB02 OR PB03 OR PB05 OR PB06 OR PB07 OR PB08[a]
		SV02 := PB01 OR PB02 OR PB03 OR PB05 OR PB06 OR PB07[b]
		SV02 := PB01 OR PB02 OR PB03 OR PB05 or PB06[c]

Table 4.46 SELOGIC Variable Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Default Settings
SV TIMER PICKUP	0.00–3000.00 sec	SV03PU := 2.00
SV TIMER DROPOUT	0.00–3000.00 sec	SV03DO := 0.00
SV INPUT	SELOGIC	SV03 := LT02
SV TIMER PICKUP	0.00–3000.00 sec	SV04PU := 0.00
SV TIMER DROPOUT	0.00–3000.00 sec	SV04DO := 0.00
SV INPUT	SELOGIC	SV04 := LT03
SV TIMER PICKUP	0.00–3000.00 sec	SV05PU := 0.25
SV TIMER DROPOUT	0.00–3000.00 sec	SV05DO := 0.25
SV INPUT	SELOGIC	SV05 := (PB01 OR PB02 OR LT02 OR LT03) AND NOT SV05T
• • •	• • •	• • •
SV TIMER PICKUP	0.00–3000.00 sec	SV32PU := 0.00
SV TIMER DROPOUT	0.00–3000.00 sec	SV32DO := 0.00
SV INPUT	SELOGIC	SV32 := NA

[a] Default logic is applicable to the SEL-787-4X model.
[b] Default logic is applicable to the SEL-787-3E and SEL-787-3S models.
[c] Default logic is applicable to the SEL-787-21, SEL-787-2E, and SEL-787-2X models.

Counter Variables

NOTE: These counter elements conform to the standard counter function block #3 in IEC 1131-3 First Edition 1993-03 International Standard for Programmable controllers—Part 3: Programming languages.

NOTE: For device configurations that include voltage cards, the SEL-787 tracks the frequency. When tracking the frequency, the processing interval varies with the frequency.

NOTE: If setting SCnnCD is set to NA, the entire counter nn is disabled).

NOTE: SELOGIC counters are reset to zero if the relay loses power because the counters are stored in volatile memory.

NOTE: If setting SCnnCU is set to NA, the counter counts downward only.

SELOGIC counters are up- or down-counting elements, updated every processing interval. Each counter element consists of one count setting, four control inputs, two digital outputs, and one analog output. *Figure 4.73* shows Counter 01, the first of 32 counters available in the device.

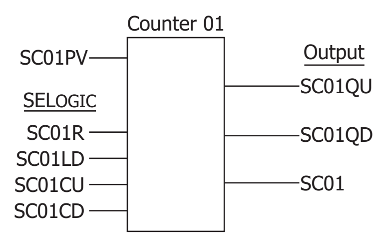


Figure 4.73 Counter 01

Digital output SC01QD asserts when the counter is at position zero, and Digital output SC01QU asserts when the counter reaches the programmable count value. Use the reset input (SC01R) to force the count to zero, and the analog output (SC*nn*) with analog comparison operators. *Table 4.47* describes the counter inputs and outputs, and *Table 4.48* shows the order of precedence of the control inputs.

Table 4.47 Counter Input/Output Description (Sheet 1 of 2)

Name	Type	Description
SC*nn*LD	Active High Input	Load counter with the preset value to assert the output (SC*nn*QU) (follows SELOGIC setting).
SC*nn*PV	Input Value	This Preset Value is loaded when SC*nn*LD pulsed. This Preset Value is the number of counts before the output (SC*nn*QU) asserts (follows SELOGIC setting).

Table 4.47 Counter Input/Output Description (Sheet 2 of 2)

Name	Type	Description
SC*nn*CU	Rising-Edge Input	Count Up increments the counter (follows SELOGIC setting).
SC*nn*CD	Rising-Edge Input	Count Down decrements the counter (follows SELOGIC setting).
SC*nn*R	Active High Input	Reset counter to zero (follows SELOGIC setting)
SC*nn*QU	Active High Output	This Q Up output asserts when the Preset Value (maximum count) is reached (SC*nn* = SC*nn*PV, *nn* = 01 to 32).
SC*nn*QD	Active High Output	This Q Down output asserts when the counter is equal to zero (SC*nn* = 0, *nn* = 01 to 32).
SC*nn*	Output Value	This counter output is an analog value that may be used with analog comparison operators in a SELOGIC control equation and viewed using the **COU** command.

Table 4.48 Order of Precedence of the Control Inputs

Order	Input
1	SC*nn*R
2	SC*nn*LD
3	SC*nn*CU
4	SC*nn*CD

Figure 4.74 shows an example of the effects of the input precedence, with SC01PV set to 7. The vertical dashed line indicates the relationship between SC01CU first being seen as a rising edge and the resultant outputs. This indicates that there is no intentional lag between the control input asserting and the count value changing. Most of the pulses in the diagram are on every second processing interval. The "one processing interval" valley is an example where the CD and CU pulses are only separated by one processing interval.

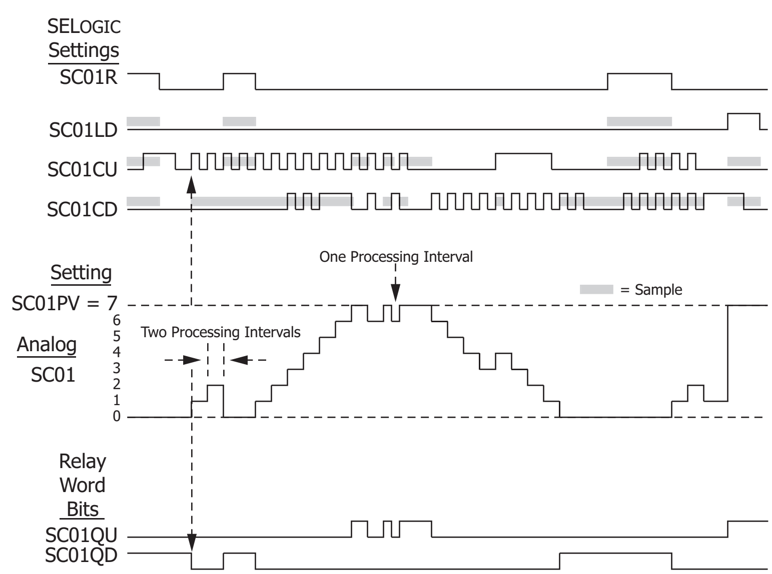


Figure 4.74 Example of the Effects of the Input Precedence

The shaded areas illustrate the precedence of the inputs:

- ➤ When SC01R is asserted, the SC01LD input is ignored.
- ➤ When SC01R or SC01LD is asserted, rising edges on the SC01CU or SC01CD inputs are ignored.
- ➤ When input SC01CU has a rising edge, a rising edge on SC01CD is ignored (unless SC01 is already at the maximum value SC01PV (= 7), in which case SC01CU is ignored, and the SC01CD is processed). An example of this exception appears in the above diagram, just before the "one processing interval" notation.

A maintained logical 1 state on the SC01CU or SC01CD inputs is ignored (after the rising edge is processed). A rising edge received on the SC01CU or SC01CD inputs is ignored when the SC01R or SC01LD inputs are asserted.

A maintained logical 1 on the SC01CU or SC01CD inputs does not get treated as a rising edge when the SC01R or SC01LD input deasserts. The same operating principles apply for all of the counters: SC01–SC*mm*, where *mm* = the number of enabled counters.

Output Contacts

NOTE: When an output contact is not used for a specific function you must set the associated SELOGIC control equation to either 0 or 1.

NOTE: Four digital outputs in Slot **D** are shown. The outputs in Slots **C** and **E** have similar settings.

Table 4.49 Control Output Equations and Contact Behavior Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
OUT101 FAIL-SAFE	Y, N	OUT101FS := Y
OUT101	SELOGIC	OUT101 := HALARM OR SALARM
OUT102 FAIL-SAFE	Y, N	OUT102FS := N
OUT102	SELOGIC	OUT102 := 0
OUT103 FAIL-SAFE	Y, N	OUT103FS := N
OUT103	SELOGIC	OUT103 := TRIPXFMR
• • •	• • •	• • •
OUT401 FAIL-SAFE	Y, N	OUT401FS := N
OUT401	SELOGIC	OUT401 := 0
OUT402 FAIL-SAFE	Y, N	OUT402FS := N
OUT402	SELOGIC	OUT402 := 0
OUT403 FAIL-SAFE	Y, N	OUT403FS := N
OUT403	SELOGIC	OUT403 := 0
OUT404 FAIL-SAFE	Y, N	OUT404FS := N
OUT404	SELOGIC	OUT404 := 0
• • •	• • •	• • •
OUT408 FAIL-SAFE	Y, N	OUT408FS := N
OUT408	SELOGIC	OUT408 := 0

The SEL-787 provides the ability to use SELOGIC control equations to map protection (trip and warning) and general-purpose control elements to the outputs. In addition, you can enable fail-safe output contact operation for relay contacts on an individual basis.

If the contact fail-safe is enabled, the relay output is held in its energized position when relay control power is applied. The output falls to its de-energized position when control power is removed. Contact positions with de-energized output relays are indicated on the relay chassis and in *Figure 2.17* and *Figure 2.18*.

When TRIP output fail-safe is enabled and the **TRIP** contact is appropriately connected (see *Figure 2.21*), the breaker is automatically tripped when relay control power fails.

MIRRORED BITS Transmit SELOGIC Control Equations

See *Appendix J: MIRRORED BITS Communications* and *SEL-787-2, -3, -4 Settings Sheets* for details.

Global Settings (SET G Command)

General Settings

Table 4.50 General Global Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
PHASE ROTATION	ABC, ACB	PHROT := ABC
RATED FREQ.	50, 60 Hz	FNOM := 60
SELECT VS VBAT	VS, VBAT	VS_BAT := VS
DATE FORMAT	MDY, YMD, DMY	DATE_F := MDY
MET CUTOFF THRES	Y, N	METHRES := Y
FAULT CONDITION	SELOGIC	FAULT := 51P1P OR 51P2P OR 51P3P OR 51G1P OR 51G2P OR 51G3P OR TRIP[a] FAULT := 51P1P OR 51P2P OR 51G1P OR 51G2P OR TRIP[b]
EVE MSG PTS ENABL	N, 1–32	EMP := N
MESSENGER POINT MP01 TRIGGER	Off, 1 Relay Word bit	MPTR01 := OFF
MESSENGER POINT MP01 AQ	None, 1 analog quantity	MPAQ01 := NONE
MESSENGER POINT MP01 TEXT	148 characters	MPTX01 := (blank)
• • •	• • •	• • •
MESSENGER POINT MP32 TRIGGER	Off, 1 Relay Word bit	MPTR32 := OFF

Table 4.50 General Global Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
MESSENGER POINT MP32 AQ	None, 1 analog quantity	MPAQ32 := NONE
MESSENGER POINT MP32 TEXT	148 characters	MPTX32 := (blank)

[a] Default logic is applicable to the SEL-787-3E, SEL-787-3S, and SEL-787-4X models.
[b] Default logic is applicable to the SEL-787-21, SEL-787-2E, and SEL-787-2X models.

The phase rotation setting tells the relay your phase labeling standard. Set PHROT equal to ABC when B-phase current lags A-phase current by 120 degrees. Set PHROT equal to ACB when B-phase current leads A-phase current by 120 degrees.

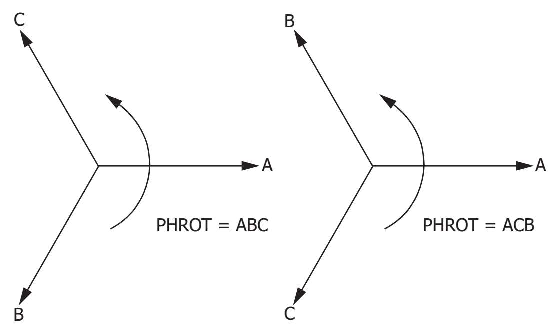


Figure 4.75 Phase Rotation Setting

Set the FNOM setting equal to your system nominal frequency. The VS_VBAT setting is only available in the SEL-787-3S model. Set VS_VBAT equal to VS if you intend to use the VS/VBAT channel for synchronism checking. Set VS_VBAT equal to VBAT if you intend to use the channel to monitor dc voltage levels of the substation battery. The DATE_F setting allows you to change the relay date presentation format to the North American standard (Month/Day/Year), the engineering standard (Year/Month/Day), or the European standard (Day/Month/Year).

The METHRES setting governs how various metering functions behave when the metered value is smaller than a fixed threshold. Refer to *Small Signal Cutoff for Metering on page 5.20* for more details.

Set the SELOGIC control equation FAULT to temporarily block *Maximum and Minimum Metering*, *Energy Metering*, and *Demand Metering*.

Event Messenger Points

The SEL-787 can be configured to automatically send ASCII message on a communications port when trigger condition is satisfied. Use the **SET P** command to set PROTO := EVMSG on the desired port to select the port. This feature is designed to send messages to the SEL-3010 Event Messenger, however, any device capable of receiving ASCII messages can be used.

Set EMP to enable the desired number of message points.

Set each of MPTR*xx* (*xx* = 01–32) to the desired Relay Word bits, the rising edge of which defines the trigger condition.

MPAQ*xx* is an optional setting and can be used to specify an Analog Quantity to be formatted into a single message as described next.

Use MPTX*xx* to construct the desired message. Note that by default the analog quantity value, if specified, is added at the end of the message, rounded to the nearest integer value (see *Example 4.11*).

EXAMPLE 4.11 Setting MPTXxx Using the Default Location of Analog Quantity

MPTX01 := THE LOAD CURRENT IS

MPAQ01 value = 157.44

Formatted message out when triggered: THE LOAD CURRENT IS 157

Location and resolution of the analog quantity value within the message can be specified by using "%.pf", where,

% defines location of the value

p defines number of digits (as many as 6, defaults to 6 if omitted)

f indicates floating point value (use %d if nearest whole number is desired)

EXAMPLE 4.12 Setting MPTXxx With a Specified Location of Analog Quantity

MPTX01 := THE LOAD CURRENT IS %.2f AMPERES

MPAQ01 value = 157.44

Formatted message out when triggered: THE LOAD CURRENT IS 157.44 AMPERES

MPTX01 := THE LOAD CURRENT IS %d AMPERES

MPAQ01 value = 157.44

Formatted message out when triggered: THE LOAD CURRENT IS 157 AMPERES

Multiple Settings Groups

SEL-787 Relays have four independent settings groups. Each settings group has complete relay settings and protection SELOGIC settings. The active settings group can be:

- Viewed on the front-panel two-line LCD using the **MAIN** > **Set/Show** > **Active Group** menus, as shown in *Figure 8.24*.
- Viewed using the SEL ASCII serial port **GROUP** command, as described in *Table 7.28*.
- Selected using the SEL ASCII serial port **GROUP *n*** command, as described in *Table 7.28*.
- Selected using SELOGIC control equation settings SS1 through SS4, as shown in *Table 4.51*.

If SELOGIC control equations SS1–SS4 are defined and evaluate to logical 1, they have priority over the **GROUP *n*** command to select the active settings group. If the SELOGIC control equations are defined but evaluate to logical 0, or if they are not defined, the **GROUP *n*** command can be used to select the active settings group.

Active Settings Group Indication

Only one settings group can be active at a time. Relay Word bits SG1 through SG4 indicate the active settings group. For example, if settings Group 3 is the active settings group, Relay Word bit SG3 is asserted to logical 1 and Relay Word bits SG1, SG2, and SG4 are deasserted to logical 0.

Active Settings Group Selection Via SELOGIC Control Equations

The Global settings class contains the SELOGIC control equation settings SS1 through SS4, as shown in *Table 4.51*.

Table 4.51 Settings Group Selection

Setting Prompt	Setting Range	Setting Name := Factory Default
GRP CHG DELAY	0–400 sec	TGR := 3
SELECT GROUP1	SELOGIC	SS1 := 1
SELECT GROUP2	SELOGIC	SS2 := 0
SELECT GROUP3	SELOGIC	SS3 := 0
SELECT GROUP4	SELOGIC	SS4 := 0

As an example of how these settings operate, assume that the active settings group is settings Group 3. The corresponding Relay Word bit, SG3, is asserted to logical 1 to indicate that settings Group 3 is the active settings group.

When settings Group 3 is the active settings group, setting SS3 has priority. If setting SS3 is asserted to logical 1, settings Group 3 remains the active settings group, regardless of the activity of settings SS1, SS2, or SS4. If settings SS1 through SS4 all deassert to logical 0, settings Group 3 remains the active settings group.

If the active settings Group 3 SELOGIC control equation SS3 deasserts to logical 0 and one of the other settings (e.g., SS1) asserts to logical 1, the relay switches the active settings group from settings Group 3 to one of the other settings groups (e.g., settings Group 1) after the qualifying time setting TGR (Global setting).

In this example, if multiple SS*n* assert after SS3 deasserts to logical 0, the order of switching follows the first SS*n* that is set in a priority order of 1 through 4.

Active Settings Group Changes

The relay is disabled for less than one second while it processes the active settings group change. Relay elements, timers, and logic are reset, unless otherwise indicated in the specific logic description. For example, local bit (LB01–LB32), remote bit, (RB01–RB32), and latch bit (LT01–LT32) states are retained during an active settings group change. The output contacts do not change state until the relay enables in the new settings group and the SELOGIC control equations are processed to determine the output contact status for the new group. After a group change, an automatic message is shown on the front panel and sent to any serial port that has setting AUTO := Y.

Active Setting: Nonvolatile State

Power Loss

The active settings group is retained if power to the relay is lost and then restored. If a settings group is active (e.g., settings Group 3) when power is lost, the same settings group is active when power is restored.

Settings Change

If individual settings are changed for the active settings group or one of the other settings groups, the active settings group is retained, much like in the preceding explanation. If individual settings are changed for a settings group other than the active settings group, there is no interruption of the active settings group, so the relay is not momentarily disabled. If the individual settings change causes a change in one or more SELOGIC control equation settings SS1–SS4, the active settings group can be changed, subject to the newly enabled SS1–SS4 settings.

LEA Correction Settings

Table 4.52 LEA Ratio and Phase Correction Settings for Phase Voltage

Setting Prompt	Setting Range	Setting Name := Factory Default
VA RATIO CORRECT	0.500–1.500	VARCF := 1.000
VB RATIO CORRECT	0.500–1.500	VBRCF := 1.000
VC RATIO CORRECT	0.500–1.500	VCRCF := 1.000
VA ANGLE CORRECT	–10.0 to 10.0 deg	VAPAC := 0.0
VB ANGLE CORRECT	–10.0 to 10.0 deg	VBPAC := 0.0
VC ANGLE CORRECT	–10.0 to 10.0 deg	VCPAC := 0.0

Table 4.53 LEA Ratio and Phase Correction Settings for Phase and Neutral Current (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
IAW1 RATIO CORRECT	0.900–1.100	IAW1RCF := 1.000
IBW1 RATIO CORRECT	0.900–1.100	IBW1RCF := 1.000
ICW1 RATIO CORRECT	0.900–1.100	ICW1RCF := 1.000
IAW1 ANGLE CORRECT	–10.0 to 10.0 deg	IAW1PAC := 0.0
IBW1 ANGLE CORRECT	–10.0 to 10.0 deg	IBW1PAC := 0.0
ICW1 ANGLE CORRECT	–10.0 to 10.0 deg	IVW1PAC := 0.0
IAW2 RATIO CORRECT	0.900–1.100	IAW2RCF := 1.000
IBW2 RATIO CORRECT	0.900–1.100	IBW2RCF := 1.000
ICW2 RATIO CORRECT	0.900–1.100	ICW2RCF := 1.000
IAW2 ANGLE CORRECT	–10.0 to 10.0 deg	IAW2PAC := 0.0
IBW2 ANGLE CORRECT	–10.0 to 10.0 deg	IBW2PAC := 0.0
ICW2 ANGLE CORRECT	–10.0 to 10.0 deg	ICW2PAC := 0.0
IAW3 RATIO CORRECT	0.900–1.100	IAW3RCF := 1.000
IBW3 RATIO CORRECT	0.900–1.100	IBW3RCF := 1.000
ICW3 RATIO CORRECT	0.900–1.100	ICW3RCF := 1.000
IAW3 ANGLE CORRECT	–10.0 to 10.0 deg	IAW3PAC := 0.0
IBW3 ANGLE CORRECT	–10.0 to 10.0 deg	IBW3PAC := 0.0
ICW3 ANGLE CORRECT	–10.0 to 10.0 deg	ICW3PAC := 0.0
IAW4 RATIO CORRECT	0.900–1.100	IAW4RCF := 1.000
IBW4 RATIO CORRECT	0.900–1.100	IBW4RCF := 1.000

Table 4.53 LEA Ratio and Phase Correction Settings for Phase and Neutral Current (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
ICW4 RATIO CORRECT	0.900–1.100	ICW4RCF := 1.000
IAW4 ANGLE CORRECT	–10.0 to 10.0 deg	IAW4PAC := 0.0
IBW4 ANGLE CORRECT	–10.0 to 10.0 deg	IBW4PAC := 0.0
ICW4 ANGLE CORRECT	–10.0 to 10.0 deg	ICW4PAC := 0.0
IN1 RATIO CORRECT	0.900–1.100	IN1RCF := 1.000
IN1 ANGLE CORRECT	–10.0 to 10.0 deg	IN1PAC := 0.0

Table 4.54 LEA Ratio and Phase Correction Settings for Synchronism-Check Voltage

Setting Prompt	Setting Range	Setting Name := Factory Default
VS RATIO CORRECT	0.500–1.500	VSRCF := 1.000
VS RATIO CORRECT	–10.0–10.0	VSPACF := 1.000

The LEA ratio correction factor (RCF) settings—VARCF, VBRCF, VCRCF, VSRCF, IAW1RCF, IBW1RCF, ICW1RCF, IAW2RCF, IBW2RCF, ICW2RCF, IAW3RCF, IBW3RCF, ICW3RCF, IAW4RCF, IBW4RCF, ICW4RCF, and IN1RCF —compensate for irregularities (on a per-phase basis) of the voltage and current LEA inputs. The LEA phase correction (PAC) settings—VAPAC, VBPAC, VCPAC, VSPAC, IAW1PAC, IBW1PAC, ICW1PAC, IAW2PAC, IBW2PAC, ICW2PAC, IAW3PAC, IBW3PAC, ICW3PAC, IAW4PAC, IBW4PAC, ICW4PAC, and IN1PAC—compensate for the phase shift on the corresponding channels bringing the voltages and currents to the SEL-787. Refer to *Ratio Correction Factors (RCF) for LEA Inputs on page 4.13* for the discussion on the RCF and PAC settings. Note that PAC does not affect synchrophasors or the related metering (MET PM), the filtered event report (CEV), or the raw event report (CEV R). For phase angle correction of the synchrophasor data, use the synchrophasor compensation factor settings VCOMP, VSCOMP, and IW*n*COMP. Refer to *Settings for Synchrophasors* for more information on synchrophasor compensation factors.

Synchrophasor Measurement

The SEL-787 relay provides Phasor Measurement Control Unit (PMCU) capabilities when connected to an IRIG-B time source. See *Appendix K: Synchrophasors* for description and *Table K.1* for the settings.

Time and Date Management Settings

The SEL-787 supports several methods of updating the relay time and date. For IRIG-B and phasor measurement unit (PMU) synchrophasor applications, refer to *Appendix K: Synchrophasors* for the description and *Table K.1* for the settings. For SNTP applications, refer to *Simple Network Time Protocol (SNTP) on page 7.17*. For PTP applications, refer to *Precision Time Protocol (PTP) on page 7.19*. For time update from a DNP Master, see *Time Synchronization on page D.9*.

Table 4.55 shows the time and date management settings that are available in the Global settings.

Table 4.55 Time and Date Management Settings

Setting Description	Setting Range	Setting Name := Factory Default
IRIG-B CONTROL BITS DEFINITION	NONE, C37.118	IRIGC := NONE
OFFSET FROM UTC	–24.00 to 24.00 hours, rounds up to nearest 0.25 hour	UTC_OFF := 0.00
MONTH TO BEGIN DST	OFF, 1–12	DST_BEGM := OFF
WEEK OF THE MONTH TO BEGIN DST	1–3, L	DST_BEGW := 2
DAY OF THE WEEK TO BEGIN DST	SUN, MON, TUE, WED, THU, FRI, SAT, SUN	DST_BEGD := SUN
LOCAL HOUR TO BEGIN DST	0–23	DST_BEGH := 2
MONTH TO END DST	1–12	DST_ENDM := 11
WEEK OF THE MONTH TO END DST	1–3, L	DST_ENDW := 1
DAY OF THE WEEK TO END DST	SUN, MON, TUE, WED, THU, FRI, SAT, SUN	DST_ENDD := SUN
LOCAL HOURS TO END DST	0–23	DST_ENDH := 2

IRIGC

IRIGC defines whether IEEE C37.118 control bit extensions are in use. Control bit extensions contain information such as leap second, UTC, daylight-saving time (DST), and time quality. When your satellite-synchronized clock provides these extensions, your relay adjusts the synchrophasor time stamp accordingly.

- IRIGC := NONE ignores bit extensions
- IRIGC := C37.118 extracts bit extensions and corrects synchrophasor time accordingly

Coordinated Universal Time (UTC) Offset Setting

The SEL-787 has a Global setting UTC_OFF, settable from –24.00 to 24.00 hours, in 0.25 hour increments.

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.

Automatic Daylight-Saving Time Settings

The SEL-787 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 will begin, while the last four settings control the month, week, day, and time that daylight-saving time will end.

Once configured, the SEL-787 changes 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-787 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 DST 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 of the daylight-saving time settings are properly configured.

Simple Network Time Protocol (SNTP)

The SEL-787 Port 1 (Ethernet Port) supports the SNTP Client protocol. See *Section 7: Communications*, *Simple Network Time Protocol (SNTP) on page 7.17* for a description and *Table 7.5* for the settings.

Precision Time Protocol (PTP)

The SEL-787 Port 1 (Ethernet Port) supports PTP. See *Precision Time Protocol (PTP) on page 7.19* for a description and *Table 7.7* for the settings.

PTP Timekeeping

Using PTP, the SEL-787 can only be synchronized by a grandmaster clock on the PTP timescale, not an arbitrary (ARB) timescale. With the ARB timescale, the epoch is set by an administrative procedure and can change at any time during normal operation. The PTP timescale uses the PTP epoch of

January 1, 1970 00:00:00 International Atomic Time (TAI), which corresponds to December 31, 1969 23:59:51.999918 UTC. The unit of time is the SI second and accounts for leap seconds. As of June 2016, TAI is 37 seconds ahead of UTC.

When the SEL-787 is synced to a PTP master and the UTC offset information from the PTP master is valid, the PTP master will tell the SEL-787 when to go into daylight-saving time (DST) and when to exit DST. The PTP master will also provide the UTC offset at this time. Otherwise, the SEL-787 will use the internal values for DST and UTC offset.

The offset between TAI and UTC is included in the PTP Announce message, along with a flag that indicates whether or not the offset is valid. The SEL-787 uses the offset sent by the Grand Master (GM) clock to determine UTC regardless of validity. Because of this, all SEL devices and other slave devices that share this behavior (that are synchronized with the GM) retain relational accuracy with each other even if, in certain cases, the GM is incorrect in relation to UTC.

The Announce message may also include the current TAI to Local offset value (required in the Power, C37.238 profile). In accordance with IEEE 1588-2008 16.3.3.4, this value must include the TAI to UTC offset to reflect local time at the node, or slave device. If the SEL-787 receives a TAI to Local offset value that does not include the TAI to UTC offset, it may incorrectly calculate UTC and Local time. Also, if the Announce message does not include the TAI to Local offset value, the SEL-787 uses its configured Time and Date Management Settings (UTC_OFF and DST_BEGM) to calculate local time. This is one reason that the SEL-787 Time and Date Management Settings must match the settings in the GM clock or, devices that are synchronized may have issues with time-alignment.

SEL-787 Relays only synchronize to clocks that serve TAI and they do not support PTP in SWITCHED NETMODE. Additionally, the maximum synchronization interval that SEL-787 relays support is 16 seconds.

PTP must be enabled in the Port 1 settings (EPTP := Y). The SEL-787 must be connected to a network containing an appropriate PTP master, and all intervening switches must be IEEE 1588-aware. For SEL-787 Relays, PTP is only available on Ethernet Ports 1A and 1B. See *Precision Time Protocol (PTP) on page 7.19* for more information on configuring the relay and the Ethernet network for PTP.

PTP Over PRP Networks

In SEL-787 Relays, PTP over PRP is based on a first-come, first-serve method. While the SEL-787 Relay monitors incoming traffic on both Port 1A and Port 1B, it will sync to the first port that it receives its first PTP message on. If incoming PTP messages stop on that synced port, then the SEL-787 waits 70 seconds and if no PTP messages appear within those 70 seconds, it will switch to the other port.

Breaker Failure Setting

Table 4.56 Breaker Failure Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
52A INTERLOCK	Y, N	52ABF := N
BRKR1 CUR DETECT	0.10–10.00 A[a]	50BFP1 := 0.1[a]
BRK1 RES CUR DET	OFF, 0.50–10.00 A[a]	50BFG1 := OFF

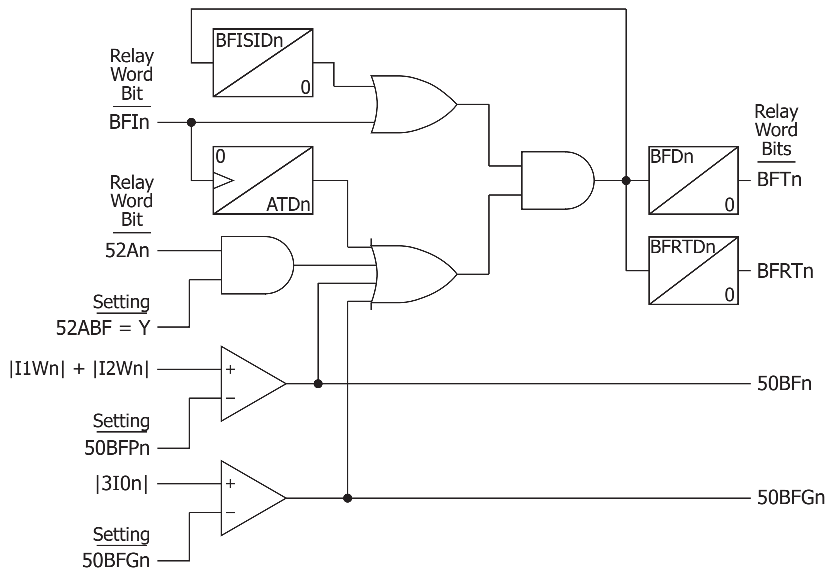
Table 4.56 Breaker Failure Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
BRKR1 FAIL DELAY	0.00–2.00 sec	BFD1 := 0.50
AUX1 TIMER DELAY	OFF, 0.00–2.00 sec	ATD1 := OFF
BRKR1 FAIL INIT	SELOGIC	BFI1 := R_TRIG TRIP1 OR R_TRIG TRIPXFMR
BRK1 SEAL-IN DLY	OFF, 0.00–2.00 sec	BFISID1 := 0.00
BRK1 RETRIP DLY	OFF, 0.00–2.00 sec	BFRTD1 := 0.05
BF1 TRIP EQN	SELOGIC	BFTR1 := 0
BF1 UNLATCH EQN	SELOGIC	BFULTR1 := 0
BRKR2 CUR DETECT	0.10–10.00 A[a]	50BFP2 := 0.1[a]
BRK2 RES CUR DET	OFF, 0.50-10.00 A[a]	50BFG2 := OFF
BRKR2 FAIL DELAY	0.00–2.00 sec	BFD2 := 0.50
AUX2 TIMER DELAY	OFF, 0.00–2.00 sec	ATD2 := OFF
BRKR2 FAIL INIT	SELOGIC	BFI2 := R_TRIG TRIP2 OR R_TRIG TRIPXFMR
BRK2 SEAL-IN DLY	OFF, 0.00–2.00 sec	BFISID2 := 0.00
BRK2 RETRIP DLY	OFF, 0.00–2.00 sec	BFRTD2 := 0.05
BF2 TRIP EQN	SELOGIC	BFTR2 := 0
BF2 UNLATCH EQN	SELOGIC	BFULTR2 := 0
BRKR3 CUR DETECT	0.10–10.00 A[a]	50BFP3 := 0.1[a]
BRK3 RES CUR DET	OFF, 0.50-10.00 A[a]	50BFG3 := OFF
BRKR3 FAIL DELAY	0.00–2.00 sec	BFD3 := 0.50
AUX3 TIMER DELAY	OFF, 0.00–2.00 sec	ATD3 := OFF
BRKR3 FAIL INIT	SELOGIC	BFI3 := R_TRIG TRIP3 OR R_TRIG TRIPXFMR
BRK3 SEAL-IN DLY	OFF, 0.00–2.00 sec	BFISID3 := 0.00
BRK3 RETRIP DLY	OFF, 0.00–2.00 sec	BFRTD3 := 0.05
BF3 TRIP EQN	SELOGIC	BFTR3 := 0
BF3 UNLATCH EQN	SELOGIC	BFULTR3 := 0
BRKR4 CUR DETECT	0.10–10.00 A[a]	50BFP4 := 0.1[a]
BRK4 RES CUR DET	OFF, 0.50-10.00 A[a]	50BFG4 := OFF
BRKR4 FAIL DELAY	0.00–2.00 sec	BFD4 := 0.50
AUX4 TIMER DELAY	OFF, 0.00–2.00 sec	ATD4 := OFF
BRKR4 FAIL INIT	SELOGIC	BFI4 := R_TRIG TRIP4 OR R_TRIG TRIPXFMR
BRK4 SEAL-IN DLY	OFF, 0.00–2.00 sec	BFISID4 := 0.00
BRK4 RETRIP DLY	OFF, 0.00–2.00 sec	BFRTD4 := 0.05
BF4 TRIP EQN	SELOGIC	BFTR4 := 0
BF4 UNLATCH EQN	SELOGIC	BFULTR4 := 0

[a] Setting ranges and default values shown are for a 5 A nominal CT rating. Divide by 5 for 1 A CTs.

The SEL-787 provides flexible breaker failure logic (see *Figure 4.76*) for as many as four breakers. In the default breaker failure logic, assertion of trip Relay Word bits associated with a breaker starts a BFD timer if the sum of positive- and negative-sequence breaker current is greater than the 50BFP setting. If the current remains above the threshold for BFD delay setting, Relay Word bit BFT asserts. Use the BFT to operate an output relay to trip appropriate backup breakers. Changing the BFI, 52ABF, ATD, 50BFP, 50BFG, BFISID, or BFRTD settings can modify the default breaker failure logic.

- Set BFI1 := R_TRIG TRIP1 OR R_TRIG TRIPXFMR AND NOT IN102 if input **IN102** is manual trip only and breaker failure initiation is not desired when the tripping is caused by this input.
- Set 52ABF := Y if you want the breaker failure logic to detect failure of breaker/contactor auxiliary contact to operate during the trip operation as defined by the BFI setting.
- Set BFISID*n* := 0 to achieve immediate seal-in, especially when breaker failure is initiated on the rising edge of the input (e.g. BFI1 := R_TRIG TRIP1). To bias your application towards security, set BFISID*n* to the desired delay or OFF with BFI*n* set to the actual input instead of the rising edge (e.g., BFI1 := TRIP1).
- Set 50BFG*n* to operate the breaker failure logic on residual ground current check, in addition to phase current checks. This can be used in applications when a weak source drives a fault.
- Aux timer (ATD*n*) can be used to start the BFD timer for dual breaker applications where the current detector may not operate on the initiation of the logic due to distribution of the fault current between the breakers. If used, the ATD*n* timer must be set longer than the normal clearing time of the adjacent breaker to allow the current to redistribute to this breaker after the adjacent breaker opens. For secure operation, set the ATD*n* timer shorter than the BFD*n* timer.
- BFRTD*n* (breaker failure retrip delay) may be set to provide a security time delay for a retrip attempt of the breaker. For added security against inadvertent breaker failure initiations (e.g., wiring or testing errors), program BFRTD*n* to a setting other than OFF. BFRTD*n* begins timing when BFI*n* and one of the supervisory elements, 50BF*n*, 50BFG*n* (if enabled), or 52A*n* (if enabled), or the aux timer (if configured) asserts. Relay Word bit BFRT*n* asserts when BFRTD*n* times out. Account for any added delay to BFRTD*n* in the BFD*n* setting. Program BFRT*n* in the associated TR SELOGIC control equation to issue a retrip to the breaker.



n = 1, 2, 3, or 4 for Breakers 52-1, 52-2, 52-3, or 52-4, respectively.

Figure 4.76 Breaker Failure Logic

The SEL-787 provides breaker failure trip logic (see *Figure 4.77*) for as many as four breakers.

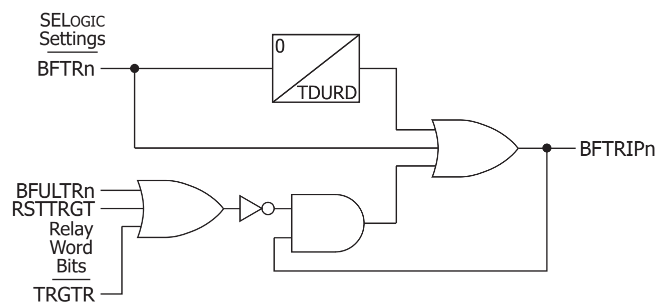


Figure 4.77 Breaker Failure Trip Logic

Include Relay Word bit BFT*n* in the SELOGIC control equation BFTR*n* (breaker failure trip equation), if you want to use the breaker failure trip logic. When BFTR*n* evaluates to logical 1, Relay Word bit BFTRIP*n* asserts and seals in. Include BFTRIP*n* in a contact output equation to trip backup breakers via an auxiliary tripping relay or use multiple contact outputs to direct trip adjacent breakers to clear the zone. For example:

OUT401 := BFTRIP1

Relay Word bit TRGTR and SELOGIC control equations BFULTR*n* and RSTTRGT reset BFTRIP*n*. The minimum trip duration of BFTRIP*n* is controlled by Group setting TDURD. See *Trip/Close Logic on page 4.100* for a description of minimum trip duration timers, trip unlatch conditions, and operation of Relay Word bit TRGTR.

Through-Fault Monitoring

The power transformers are subjected to heavy through currents for the system faults outside the transformer protection zone. The SEL-787 monitors through-fault current. See *Section 5: Metering and Monitoring* for a description and *Table 5.13* for the settings.

Analog Inputs

The SEL-787 samples the analog inputs four times per cycle. For analog inputs, set the following parameters for each input:

- ➤ Analog type
- ➤ High and low input levels
- ➤ Engineering units

Because of the flexibility to install different cards in the rear-panel slots on the device, the setting prompt adapts to the *x* and *y* variables shown in *Figure 4.78*. Variable *x* displays the slot position (**3** to **5**), and variable *y* displays the transducer (analog) input number (1 through 4).

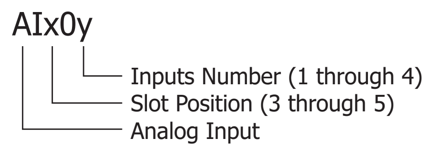


Figure 4.78 Analog Input Card Adaptive Name

Analog Input Calibration Process

In the analog input circuit, the dominant error is signal offset. To minimize the signal offset, we adjust each of the device analog input channels by a compensation factor. These compensation factors correct the signal offset errors to within ±1 µA or ±1 mV. Proceed with the following steps to calculate the signal offset compensation factor.

Step 1. Turn the SEL-787 on and allow it to warm up for a few minutes.

Step 2. Set the analog inputs for each analog channel to the desired range using the AI*xxx*TYP, AI*xxx*L, AI*xxx*H, AI*xxx*EL, and AI*xxx*EH settings (for example, ±1 mA).

Step 3. Short each analog input in turn at the device terminals using short, low resistance leads with solid connections.

Step 4. Issue the command **MET AI 10** to obtain 10 measurements for each channel.

Step 5. Record these 10 measurements, then calculate the average of the 10 measurements by adding the 10 values algebraically, and dividing the sum by 10. This is the average offset error in engineering units at zero input (for example, –0.014 mA).

Step 6. Negate this value (flip the sign) and add the result to each of the AI*xxx*EL and AI*xxx*EH quantities. For this example, the new AI*xxx*EL and AI*xxx*EH values are –0.986 mA and 1.014 mA.

Analog Input Setting Example

Assume we install an analog card in Slot **3**. On Input 1 of this analog card, we connect a 4–20 mA transducer driven from a device that measures temperature on a transformer load tap-changer mechanism. For this temperature transducer, 4 mA corresponds to –50°C, and 20 mA corresponds to 150°C. You have already installed the correct hardware jumper (see *Figure 2.3* for more information) for Input 1 to operate as a current input.

Table 4.57 summarizes the steps and describes the settings we use in this example.

Table 4.57 Summary of Steps for Setting Analog Input 1

	Step	Activity	Terse Description
General	1	SET G AI301NAM	Access settings for INPUT 1
	2	TX_TEMP	Enter a Tag name
	3	I	Select type of analog input; “I” for current
Transducer High/Low Output	4	4	Enter transducer low output (LOW IN VAL)
	5	20	Enter transducer high output (HI IN VAL)
Level	6	Degrees C	Enter Engineering unit
	7	–50	Enter Engineering unit value LOW
	8	150	Enter Engineering unit value HIGH
Low Warning/ Alarm	9	OFF	Enter LOW WARNING 1 value
	10	OFF	Enter LOW WARNING 2 value
	11	OFF	Enter LOW ALARM value
High Warning/ Alarm	12	65	Enter HIGH WARNING 1 value
	13	95	Enter HIGH WARNING 2 value
	14	105	Enter HIGH ALARM value

NOTE: The AIx0yNAM setting cannot accept the following and will issue the Invalid Element message:
- Analog Quantities
- Duplicate Names
- Other AI Names

Because the analog card is in Slot **3**, type **SET G AI301NAM <Enter>** to go directly to the setting for Slot **3**, Input 1. Although the device accepts alphanumeric characters, the name AI*x*0*y*NAM setting must begin with an alpha character (A through Z) and not a number. The device displays the following prompt:

```
AI301 TAG NAME (8 Characters)   AI301NAM:= AI301 ?
```

Use the Instrument Tag Name to give the analog quantity a more descriptive name. This tag name appears in reports (EVENT, METER, and SUMMARY) instead of the default name of AI301. SELOGIC control equations, Signal Profiles, and Fast Message Read use the default names. Use as many as eight valid tag name characters to name the analog quantity. Valid tag name characters are: 0–9, A–Z, and the underscore (_). For this example, we assign TX_TEMP as the tag name.

Because this is a 4–20 mA transducer, enter **I <Enter>** (for current driven device) at AI301TYP, the next prompt (enter **V** if this is a voltage-driven device). The next two settings define the lower level (AI301L) and the upper level (AI301H) of the transducer. In this example, the low level is 4 mA and the high level is 20 mA.

```
AI301 TYPE  (I,V)               AI301TYP:= I  ?
```

NOTE: Because the SEL-787 accepts current values ranging from –20.48 to 20.48 mA, be sure to enter the correct range values.

The next three settings define the applicable engineering unit (AI301EU), the lower level in engineering units (AI301EL) and the upper level in engineering units (AI301EH). Engineering units refer to actual measured quantities, i.e., temperature, pressure, etc. Use the 16 available characters to assign descriptive names for engineering units. Because we measure temperature in this example, enter “degrees C” (without quotation marks) as engineering units. Type **–50 <Enter>** for the lower level and **150 <Enter>** for the upper level.

With the levels defined, the next six settings provide two warning settings and one alarm setting for the low temperature values, as well as two warning settings and one alarm setting for the high temperature values. State the values in engineering units, not as the setting range of the transducer. Note the difference between low warnings and alarm functions and high warnings and alarm functions: low warnings and alarm functions assert when the measured value falls below the setting; high warnings and alarm functions assert when the measured values rise above the setting.

In this example, we measure the oil temperature of a power transformer, and we want the following three actions to take place at three different temperature values:

- At 65°C, start the cooling fans
- At 95°C, send an alarm
- At 105°C, trip the transformer

Because we are only interested in cases when the temperature values exceed their respective temperature settings (high warnings and alarm functions), we do not use the low warnings and alarm functions. Therefore, set the lower values (AI301LW1, AI301LW2, AI301LAL) to OFF, and the three higher values as shown in *Figure 4.79*. Set inputs connected to voltage driven transducers in a similar way.

```
=>>SET G AI301NAM TERSE <Enter>
Global
AI 301 Settings
AI301 TAG NAME (8 characters)
AI301NAM:= AI301
? TX_TEMP <Enter>
AI301 TYPE (I,V)                               AI301TYP:= I       ? <Enter>
AI301 LOW IN VAL (-20.480 to 20.480 mA)        AI301L  := 4.000   ? <Enter>
AI301 HI IN VAL (-20.480 to 20.480 mA)         AI301H  := 20.000  ? <Enter>
AI301 ENG UNITS (16 characters)
AI301EU := mA
? degrees C <Enter>
AI301 EU LOW (-99999.000 to 99999.000)         AI301EL := 4.000   ? -50 <Enter>
AI301 EU HI (-99999.000 to 99999.000)          AI301EH := 20.000  ? 150 <Enter>
AI301 LO WARN L1 (OFF,-99999.000 to 99999.000) AI301LW1:= OFF     ? <Enter>
AI301 LO WARN L2 (OFF,-99999.000 to 99999.000) AI301LW2:= OFF     ? <Enter>
AI301 LO ALARM (OFF,-99999.000 to 99999.000)   AI301LAL:= OFF     ? <Enter>
AI301 HI WARN L1 (OFF,-99999.000 to 99999.000) AI301HW1:= OFF     ? 65 <Enter>
AI301 HI WARN L2 (OFF,-99999.000 to 99999.000) AI301HW2:= OFF     ? 95 <Enter>
AI301 HI ALARM (OFF,-99999.000 to 99999.000)   AI301HAL:= OFF     ? 115 <Enter>
AI 302 Settings
AI302 TAG NAME (8 characters)
AI302NAM:= AI302
? END  <Enter>
Save changes (Y,N)? Y <Enter>
Settings Saved
=>>
```

Figure 4.79 Settings to Configure Input 1 as a 4–20 mA Transducer Measuring Temperatures Between –50°C and 150°C

Analog (DC Transducer) Input Board

Table 4.58 shows the setting prompt, setting range, and factory-default settings for an analog input card in Slot **3**. For the name setting (AI301NAM, for example), enter only alphanumeric and underscore characters. Characters are not case sensitive, but the device converts all lowercase characters to uppercase. Although the device accepts alphanumeric characters, the name AI301NAM setting must begin with an alpha character (A–Z) and not a number.

Table 4.58 Analog Input Card in Slot 3

Setting Prompt	Setting Range	Setting Name := Factory Default
AI301 TAG NAME	8 characters 0–9, A–Z, _	AI301NAM := AI301
AI301 TYPE	I, V	AI301TYP := I
AI301 LOW IN VAL	–20.480 to +20.480 mA	AI301L := 4.000
AI301 HI IN VAL	–20.480 to +20.480 mA	AI301H := 20.000
AI301 LOW IN VAL	–10.240 to +10.240 V	AI301L := 0.000[a]
AI301 HI IN VAL	–10.240 to +10.240 V	AI301H := 10.000[a]
AI301 ENG UNITS	16 characters	AI301EU := mA
AI301 EU LOW	–99999.000 to +99999.000	AI301EL := 4.000
AI301 EU HI	–99999.000 to +99999.000	AI301EH := 20.000
AI301 LO WARN L1	OFF, –99999.000 to +99999.000	AI301LW1 := OFF
AI301 LO WARN L2	OFF, –99999.000 to +99999.000	AI301LW1 := OFF
AI301 LO ALARM	OFF, –99999.000 to +99999.000	AI301LAL := OFF
AI301 HI WARN L1	OFF, –99999.000 to +99999.000	AI301HW1 := OFF
AI301 HI WARN L2	OFF, –99999.000 to +99999.000	AI301HW2 := OFF
AI301 HI ALARM	OFF, –99999.000 to +99999.000	AI301HAL := OFF

[a] Voltage setting range for a voltage transducer, i.e., when AI301TYP := V.

Analog Outputs

If an SEL-787 configuration includes the four analog inputs and four analog outputs (4 AI/4 AO) card, the analog outputs are allocated to output numbers 1-4. *Figure 4.80* shows the *x* and *y* variable allocation for the analog output card.

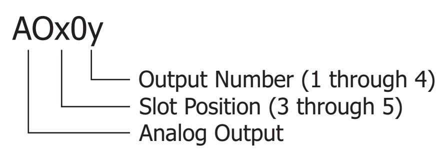


Figure 4.80 Analog Output Number Allocation

For an analog input/output card in Slot **3**, setting AO301AQ identifies the analog quantity we assign to Analog Output 1 (when set to OFF, the device hides all associated AO*x*0*y* settings and no value appears on the output). You can assign any of the analog quantities listed in *Appendix M: Analog Quantities*.

Table 4.59 shows the setting prompt, setting range, and factory-default settings for an analog card in Slot **3**.

NOTE: The SEL-787 hides the following settings with default values when you use a 3 DI/4 DO/1 AO card:
AOxx1TYP := I
AOxx1L := 4.000
AOxx1H := 20.000

Table 4.59 Output Setting for a Card in Slot 3 (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
AO301 ANALOG QTY	Off, 1 analog quantity	AO301AQ := OFF
AO301 TYPE	I, V	AO301TYP := I
AO301 AQTY LO	–2147483647.000 to +2147483647.000	AO301AQL := 4.000

Table 4.59 Output Setting for a Card in Slot 3 (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
AO301 AQTY HI	–2147483647.000 to +2147483647.000	AO301AQH := 20.000
AO301 LO OUT VAL	–20.480 to +20.480 mA	AO301L := 4.000
AO301 HI OUT VAL	–20.480 to +20.480 mA	AO301H := 20.000
AO301 LO OUT VAL	–10.240 to +10.240 V	AO301L := 0.000[a]
AO301 HI OUT VAL	–10.240 to +10.240 V	AO301H := 10.000[a]

[a] Voltage setting range for a voltage transducer, i.e., when AO301TYP := V.

Example to Set Analog Output

In this example, assume we want to display in the station control room the analog quantity (refer to *Appendix M: Analog Quantities*) IAW1_MAG, Phase A Current Magnitude in Primary Amps (0 to 3000 Amps range) using a –20 to +20 mA Analog Output channel. We install an analog input/output card in slot C (SELECT 4 AI/ 4 AO) and set the card channel AO301 as shown in *Figure 4.80* below. Note that the AO301 channel has to be configured as a "current analog output" channel (refer to *Figure 2.5*).

The display instrument expects –20 mA when the IAW1_MAG current is 0 amperes primary and +20 mA when it is 3000 amperes primary.

```
=>>SET G AO301AQ TERSE <Enter>
Global
AO 301 Settings
AO301 ANALOG QTY (OFF, 1 analog quantity)
AO301AQ := OFF
? IAW1_MAG <Enter>
AO301 TYPE (I,V)                              AO301TYP:= I        ? <Enter>
AO301 AQTY LO (-2147483647.000 to 2147483647.000)
                                              AO301AQL:= 4.000    ? 0 <Enter>
AO301 AQTY HI (-2147483647.000 to 2147483647.000)
                                              AO301AQH:= 20.000   ? 3000 <Enter>
AO301 LO OUT VAL (-20.480 to 20.480 mA)       AO301L  := 4.000    ? –20 <Enter>
AO301 HI OUT VAL (-20.480 to 20.480 mA)       AO301H  := 20.000   ? 20 <Enter>
AO 302 Settings
AO302 ANALOG QTY (OFF, 1 analog quantity)
AO302AQ := OFF
? END <Enter>
Save changes (Y,N)? Y <Enter>
Settings Saved
=>>
```

Figure 4.81 Analog Output Settings

Station DC Battery Monitor

The station dc battery monitor in the SEL-787 alarms for under- or overvoltage dc battery conditions and displays how much the station dc battery voltage dips when tripping, closing, and other dc control functions take place. Refer to *Station DC Battery Monitor on page 5.21* for a detailed description and *Table 5.10* for settings.

Breaker Monitor

The breaker monitor in the SEL-787 helps in scheduling circuit breaker maintenance. Refer to *Breaker Monitor on page 5.25* for a detailed description and *Table 5.12* for settings.

Digital Input Debounce

To comply with different control voltages, the SEL-787 offers dc debounce as well as ac debounce modes. Therefore, if the control voltage is dc, select the dc mode of operation, and if the control voltage is ac, select the ac mode of operation. In general, debounce refers to a qualifying time delay before processing the change of state of a digital input. Normally, this delay applies to both the processing of the debounced input when used in device logic, as well as to the time stamping in the SER. Following is a description of the two modes.

DC Mode Processing (DC Control Voltage)

Figure 4.82 shows the logic for the dc debounce mode of operation. To select the dc mode of debounce, set IN101D to any number between 0 and 65000 ms. In the figure, Input IN101 becomes IN101R (internal variable), after analog-to-digital conversion. On assertion, IN101R starts the debounce timer, producing Relay Word bit IN101 after the debounce time delay. The debounce timer is a pickup/dropout combination timer, with debounce setting IN101D applying to both pickup (pu) and dropout (do) timers, i.e., you cannot set any timer individually. For example, a setting of IN101D := 20 ms delays processing of the input signal by 20 ms (pu) and maintains the output of the timer (do) for 20 ms. Relay Word bit IN101 is the output of the debounce timer. If you do not want to debounce a particular input, still use Relay Word bit IN101 in logic programming, but set the debounce time delay to 0 (IN101D := 0).

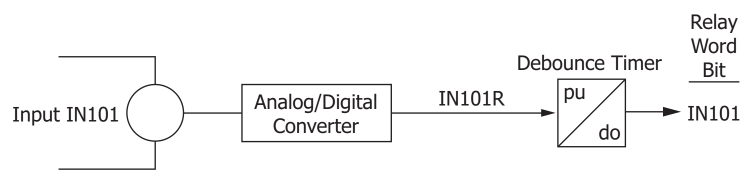


Figure 4.82 DC Mode Processing

AC Mode Processing (AC Control Voltage)

Figure 4.83 shows IN101R from Input IN101 applied to a pickup/dropout timer. Different from the dc mode, there are no time settings for the debounce timer in the ac mode: the pickup time delay is fixed at 2 ms, and the dropout time is fixed at 16 ms. Relay Word bit IN101 is the output of the debounce timer. To select the ac mode of debounce, set IN101D := AC.

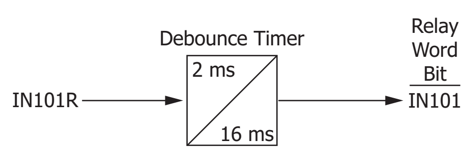


Figure 4.83 AC Mode Processing

Figure 4.84 shows a timing diagram for the ac mode of operation. On the rising edge of IN101R, the pickup timer starts timing (points marked 1). If IN101R deasserts (points marked 2) before expiration of the pickup time setting, Relay Word bit IN101 does not assert, and remains at logical 0. If, however, IN101R remains asserted for a period longer than the pickup timer setting, then Relay Word bit IN101 asserts to a logical 1.

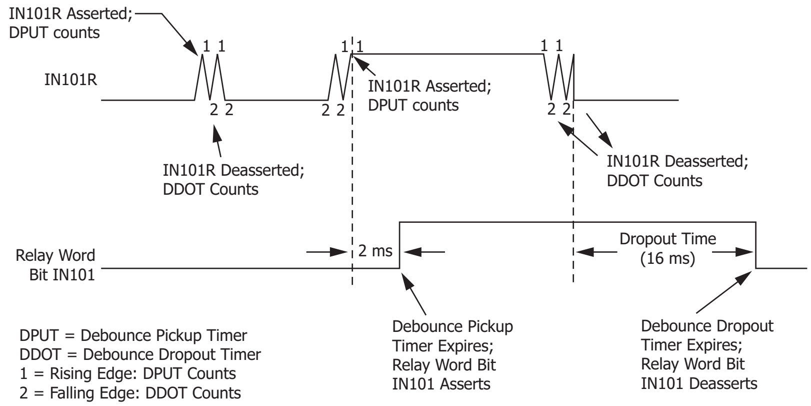


Figure 4.84 Timing Diagram for Debounce Timer Operation in AC Mode

Deassertion follows the same logic. On the falling edge of IN101R, the dropout timer starts timing. If IN101R remains deasserted for a period longer than the dropout timer setting, then Relay Word bit IN101 deasserts to a logical 0.

Table 4.60 shows the settings prompt, setting range, and factory-default settings for an 8 DI card in Slot **C**. See the *SEL-787-2, -3, -4 Settings Sheets* for a complete list of input debounce settings.

Table 4.60 Slot C Input Debounce Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
IN301 DEBOUNCE	AC, 0–65000 ms	IN301D := 10
IN302 DEBOUNCE	AC, 0–65000 ms	IN302D := 10
IN303 DEBOUNCE	AC, 0–65000 ms	IN303D := 10
IN304 DEBOUNCE	AC, 0–65000 ms	IN304D := 10
IN305 DEBOUNCE	AC, 0–65000 ms	IN305D := 10
IN306 DEBOUNCE	AC, 0–65000 ms	IN306D := 10
IN307 DEBOUNCE	AC, 0–65000 ms	IN307D := 10
IN308 DEBOUNCE	AC, 0–65000 ms	IN308D := 10

Data Reset

Table 4.61 Data Reset Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
RESET TARGETS	SELOGIC	RSTTRGT := 0
RESET ENERGY	SELOGIC	RSTENRGY := 0
RESET MAX/MIN	SELOGIC	RSTMXMN := 0
RESET DEMAND	SELOGIC	RSTDEM := 0
RESET PK DEMAND	SELOGIC	RSTPKDEM := 0

The RSTTRGT setting resets the trip output and front-panel **TRIP** LED, provided there is no trip condition present. See *Figure 4.66* for more details. The RSTENRGY and RSTMXMN settings reset the Energy and Max/Min Metering values, respectively. You should assign a contact input (for example, RSTTRGT := IN401) to each of these settings if you want remote reset. The RSTDEM and RSTPKDEM settings reset demand and peak-demand. See *Figure 4.63* for the demand current logic diagram.

Access Control

NOTE: DISABLSET does not disable the setting changes from the serial or Ethernet ports.

NOTE: Do not set the maximum access level setting MAXACC := ACC on all ports at the same time when you are using the DSABLSET setting. This locks you out from editing settings.

The DSABLSET setting defines conditions for disabling all setting changes from the front-panel interface. To disable setting changes from the front-panel interface, assign, for example, a contact input (e.g., DSABLSET := IN402) to the DSABLSET setting. When Relay Word bit DSABLSET asserts, you can view the device settings from the front-panel interface, but you can only change settings using serial port commands. *Table 4.62* shows the settings prompt, setting range, and factory-default settings.

Table 4.62 Setting Change Disable Setting

Setting Prompt	Setting Range	Setting Name := Factory Default
DISABLE SETTINGS	SELOGIC	DSABLSET := 0

Time-Synchronization Source

The SEL-787 accepts a demodulated IRIG-B time signal. *Table 4.63* shows the setting to identify the input for the signal. Set TIME_SRC := IRIG1 when you use relay terminals B01/B02 or EIA-232 serial Port 3 for the time signal input. When you use fiber-optic Port 2 for the signal, set the TIME_SRC := IRIG2. Refer to *IRIG-B Time-Code Input on page 2.31* and *IRIG-B on page 7.8* for additional information.

Table 4.63 Time Synchronization Source Setting

Setting Prompt	Setting Range	Setting Name := Factory Default
IRIG TIME SOURCE	IRIG1, IRIG2	TIME_SRC := IRIG1

Disconnect Control Settings

The SEL-787 supports control of as many as sixteen two-position and two three-position disconnects. For the disconnect settings and logic, refer to *Disconnect Control Settings on page 9.2*. The SEL-787 relay with the touchscreen display also provides you with the ability to design detailed single-line diagrams and display the breaker and disconnect statuses. Refer to *Table 9.5* for typical disconnect symbols available for display on the bay screens. For the settings related to bay control disconnect symbols, refer to *Table 9.7* and the corresponding description.

Local/Remote Control

The SEL-787 supports local/remote control of breakers and disconnects. For the settings related to the local/remote control function, refer to *Local/Remote Control on page 9.7*. For breaker control via the front-panel pushbuttons, refer to *Front-Panel Operator Control Pushbuttons on page 8.16*. For breaker control via the two-line display, refer to *Control Menu on page 8.10*. The touchscreen allows you to control the breaker through two applications, **Bay Screens** and **Breaker Control**. For breaker control via the touchscreen display, refer to *Breaker/Disconnect Control Via Touchscreen on page 9.8*.

Port Settings (SET P Command)

The SEL-787 provides settings that allow you to configure the parameters for the communications ports. See *Section 2: Installation* for a detailed description of port connections. On the base unit: PORT F (front panel) is an EIA-232 port; PORT 1 is an optional Ethernet port(s); PORT 2 is a fiber-optic serial port; and PORT 3 (rear) is optionally an EIA-232 or EIA-485 port. On the optional communications card, you can select PORT 4 as either EIA-485 or EIA-232 (not both) with the COMMINF setting. See *Table 4.64* through *Table 4.69* for the serial port settings. See the appropriate appendix for additional information on the protocols (DNP3, Modbus, EtherNet/IP, IEC 61850, IEC 60870-5-103, DeviceNet, MIRRORED BITS, and synchrophasors) of interest.

The EPORT and MAXACC settings provide you with access controls for the corresponding port. Setting EPORT to N disables the port and hides the remaining port settings. The MAXACC setting selects the highest access level for the port.

PORT F

Table 4.64 Front-Panel Serial Port Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE PORT	Y, N	EPORT := Y
PROTOCOL	SEL, MOD, EVMSG[a], PMU	PROTO := SEL
MAXIMUM ACCESS LEVEL	1, 2, C	MAXACC := 2
SPEED	300–38400 bps	SPEED := 9600
DATA BITS	7, 8 bits	BITS := 8
PARITY	O, E, N	PARITY := N
STOP BITS	1, 2 bits	STOP := 1
PORT TIME-OUT	0–30 min	T_OUT := 5
HDWR HANDSHAKING	Y, N	RTSCTS := N
LANGUAGE	ENGLISH, SPANISH	LANG := ENGLISH
SEND AUTOMESSAGE	Y, N	AUTO := N
MODBUS SLAVE ID	1–247	SLAVEID := 1

[a] When PROTO := EVMSG, the relay uses the settings BITS = 8, PARITY = N, and STOP = 1, regardless of any user-entered settings.

PORT 1

Table 4.65 Ethernet Port Settings (Sheet 1 of 3)

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE PORT	Y, N	EPORT := Y
ENABLE ETHERNET FIRMWARE UPGRADE	Y, N	EETHFWU := N
IP ADDRESS	zzz.yyy.xxx.www	IPADDR := 192.168.1.2
SUBNET MASK	15 characters	SUBNETM := 255.255.255.0
DEFAULT ROUTER	15 characters	DEFRTR := 192.168.1.1
ENABLE TCP KEEP-ALIVE	Y, N	ETCPKA := Y
TCP KEEP-ALIVE IDLE RANGE	1–20 sec	KAIDLE := 10
TCP KEEP-ALIVE INTERVAL RANGE	1–20 sec	KAINTV := 1
TCP KEEP-ALIVE COUNT RANGE	1–20 sec	KACNT := 6
OPERATING MODE	FIXED, FAILOVER, SWITCHED, PRP	NETMODE := FAILOVER

IMPORTANT: Upon relay initial turn on, Port 1 setting changes, or Logic setting changes, you may have to wait as long as two minutes before an additional setting change can occur. Note that the relay is functional with protection enabled, as soon as the ENABLED LED comes ON (about 5–10 seconds from turn on).

NOTE: The Telnet LANG setting also applies to the web server interface.

Table 4.65 Ethernet Port Settings (Sheet 2 of 3)

Setting Prompt	Setting Range	Setting Name := Factory Default
FAILOVER TIMEOUT	OFF, 0.10–65.00 sec	FTIME := 1.00
PRIMARY NETPORT	A, B	NETPORT := A
PRP ENTRY TIMEOUT	400–10000 msec	PRPTOUT := 500
PRP DESTINATION ADDR LSB	0–255	PRPADDR := 0
PRP SUPERVISION TX INTERVAL	1–10 sec	PRPINTV := 2
NETWRK PORTA SPD	AUTO, 10, 100 Mbps	NETASPD := AUTO
NETWRK PORTB SPD	AUTO, 10, 100 Mbps	NETBSPD := AUTO
ENABLE TELNET	Y, N	ETELNET := Y
MAXIMUM ACCESS LEVEL	1, 2, C	MAXACC := 2
LANGUAGE	ENGLISH, SPANISH	LANG := ENGLISH
TELNET PORT	23, 1025–65534	TPORT := 23
TELNET CONNECT BANNER	254 characters	TCBAN := TERMINAL SERVER
TELNET TIMEOUT	1–30 min	TIDLE := 15
FAST OP MESSAGES	Y, N	FASTOP := N
ENABLE FTP	Y, N	EFTPSERV := Y
FTP MAXIMUM ACCESS	1, 2, C	FTPACC := 2
FTP USER NAME	20 characters	FTPUSER := FTPUSER
FTP CONNECT BANNER	254 characters	FTPBAN := FTP
FTP IDLE TIMEOUT	5–255 min	FTPIDLE := 5
ENABLE IEC 61850 PROTOCOL	Y, N	E61850 := N
ENABLE IEC 61850 GSE	Y, N	EGSE := N
ENABLE MMS FILE SERVICES	Y, N	EMMSFS := N
ENABLE 61850 MODE/BEHAVIOR CONTROL	Y, N	E850MBC := N
ENABLE GOOSE TX IN OFF MODE	Y, N	EOFFMTX := N
ENABLE MODBUS SESSIONS	0–2	EMOD := 0
MODBUS MASTER IP ADDRESS	zzz.yyy.xxx.www[a]	MODIP1 := 0.0.0.0
MODBUS MASTER IP ADDRESS	zzz.yyy.xxx.www[a]	MODIP2 := 0.0.0.0
MODBUS TCP PORT 1	(1–65534)	MODNUM1 := 502
MODBUS TCP PORT 2	(1–65534)	MODNUM2 := 502
MODBUS TIMEOUT 1	(15–900 sec)	MTIMEO1 := 15
MODBUS TIMEOUT 2	(15–900 sec)	MTIMEO2 := 15
ENABLE HTTP SERVER	Y, N	EHTTP := Y

NOTE: The FAST OP MESSAGES setting only functions when using SEL Fast Operate protocol to operate/set/pulse breaker bits and remote bits. This setting has no effect on other protocols.

Table 4.65 Ethernet Port Settings (Sheet 3 of 3)

Setting Prompt	Setting Range	Setting Name := Factory Default
HTTP MAXIMUM ACCESS LEVEL	1, 2	HTTPACC := 2
TCP/IP PORT	1–65535	HTTPPORT := 80
HTTP CONNECT BANNER	254 ASCII printable characters	HTTPBAN := This system is for the use of authorized personnel only.
HTTP WEB SERVER TIMEOUT	1–60 min	HTTPIDLE := 10
ENABLE RSTP	Y, N	ERSTP := N
BRIDGE PRIORITY[b]	0–61440	BRDGPRI := 49152
PORTA PRIORITY[b]	0–240	PORTAPRI := 128
PORTB PRIORITY[b]	0–240	PORTBPRI := 128
ENABLE PMU PROCESSING[c]	0–2	EPMIP := 0
ENABLE DNP SESSIONS[d]	0–5	EDNP := 0
ENABLE SNTP CLIENT[e]	OFF, UNICAST, MANYCAST, BROADCAST	ESNTP := OFF
ENABLE PTP[f]	Y, N	EPTP := N
ENABLE ETHERNET/IP[g]	Y, N	EEIP := N

[a] MODIP1 and MODIP2 cannot share an address and must be unique (except when 0.0.0.0, which effectively disables security and allows any master to communicate).
[b] The bridge priority and port priority settings should be in increments of 4096 and 16, respectively.
[c] See Appendix K: Synchrophasors for a complete list of synchrophasor settings and their descriptions.
[d] See Table D.7 for a complete list of the DNP3 session settings.
[e] See Table 7.5 for a complete list of SNTP settings and their descriptions.
[f] See Table 7.7 for a complete list of PTP settings and their descriptions.
[g] See Table F.22 for a complete list of EtherNet/IP settings and their descriptions.

Port Number Settings Must be Unique

When making the SEL-787 Port 1 settings, port number settings cannot be used for more than one protocol. The relay checks all of the settings shown in *Table 4.66* before saving changes. If a port number is used more than once, or if it matches any of the fixed port numbers (20, 21, 23, 102, 502), the relay displays an error message and returns to the first setting that is in error or contains a duplicate value.

Table 4.66 Port Number Settings That Must be Unique (Sheet 1 of 2)

Setting	Name	Setting Required When
TPORT	Telnet Port	Always
MODNUM1[a]	Modbus TCP Port 1	EMOD > 0
MODNUM2[a]	Modbus TCP Port 2	EMOD > 1
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
DNPNUM	DNPTCP and UDP Port	EDNP > 0
SNTPPORT	SNTPIP (Local) Port Number	ESNTP ≠ OFF

Table 4.66 Port Number Settings That Must be Unique (Sheet 2 of 2)

Setting	Name	Setting Required When
EPTP	Enable PTP	PTPPRO = DEFAULT and PTPTR = UDP (Ports 319 and 320 are reserved)
EEIP	Enable EtherNet/IP	EEIP ≠ N (Ports 2222 and 44818 are reserved)

[a] MODNUM1 and MODNUM2 can have the same port number. The relay displays an error message if this number matches with the port numbers of the other protocols.

PORT 2

Table 4.67 Fiber-Optic Serial Port Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE PORT	Y, N	EPORT := Y
PROTOCOL	SEL, DNP, MOD, EVMSG[a], PMU, MBA, MBB, MB8A, MB8B, MBTA, MBTB, 103	PROTO := SEL
MAXIMUM ACCESS LEVEL	1, 2, C	MAXACC := 2
SPEED	300–38400 bps	SPEED := 9600
DATA BITS	7, 8 bits	BITS := 8
PARITY	O, E, N	PARITY := N
STOP BITS	1, 2 bits	STOP := 1
PORT TIMEOUT	0–30 min	T_OUT := 5
LANGUAGE	ENGLISH, SPANISH	LANG := ENGLISH
SEND AUTOMESSAGE	Y, N	AUTO := N
FAST OP MESSAGES	Y, N	FASTOP := N
MODBUS SLAVE ID	1–247	SLAVEID := 1

[a] When PROTO := EVMSG, the relay uses the settings BITS = 8, PARITY = N, and STOP = 1, regardless of any user-entered settings.

NOTE: For additional settings when PROTO := MBxx, see Table J.5 as well as MIRRORED BITS Transmit SELOGIC Equations.

For additional settings when PROTO := DNP, see Table D.7 for a complete list of the DNP3 session settings.

Refer to Appendix H: IEC 60870-5-103 Communications for more information on IEC 60870-5-103.

PORT 3

Table 4.68 Rear-Panel Serial Port Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE PORT	Y, N	EPORT := Y
PROTOCOL	SEL, DNP, MOD, EVMSG[a], PMU, MBA, MBB, MB8A, MB8B, MBTA, MBTB, 103	PROTO := SEL
MAXIMUM ACCESS LEVEL	1, 2, C	MAXACC := 2
SPEED	300–38400 bps	SPEED := 9600
DATA BITS	7, 8 bits	BITS := 8
PARITY	O, E, N	PARITY := N
STOP BITS	1, 2 bits	STOP := 1
PORT TIMEOUT	0–30 min	T_OUT := 5
HDWR HANDSHAKING	Y, N	RTSCTS := N
LANGUAGE	ENGLISH, SPANISH	LANG := ENGLISH

NOTE: For additional settings when PROTO := MBxx, see Table J.5 as well as MIRRORED BITS Transmit SELOGIC Equations.

For additional settings when PROTO := DNP, see Table D.7 for a complete list of the DNP3 session settings.

Refer to Appendix H: IEC 60870-5-103 Communications for more information on IEC 60870-5-103.

Table 4.68 Rear-Panel Serial Port Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
SEND AUTOMESSAGE	Y, N	AUTO := N
FAST OP MESSAGES	Y, N	FASTOP := N
MODBUS SLAVE ID	1–247	SLAVEID := 1

[a] When PROTO := EVMSG, the relay uses the settings BITS = 8, PARITY = N, and STOP = 1, regardless of any user-entered settings.

PORT 4

Table 4.69 Rear-Panel Serial Port (EIA-232/EIA-485) Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE PORT	Y, N	EPORT := Y
PROTOCOL	SEL, MOD, DNET, DNP, EVMSG[a], PMU, MBA, MBB, MB8A, MB8B, MBTA, MBTB, 103	PROTO := SEL
MAXIMUM ACCESS LEVEL	1, 2, C	MAXACC := 2
COMM INTERFACE	232, 485	COMMINF := 232
SPEED	300–38400 bps	SPEED := 9600
DATA BITS	7, 8 bits	BITS := 8
PARITY	O, E, N	PARITY := N
STOP BITS	1, 2 bits	STOP := 1
PORT TIMEOUT	0–30 min	T_OUT := 5
HDWR HANDSHAKING	Y, N	RTSCTS := N
LANGUAGE	ENGLISH, SPANISH	LANG := ENGLISH
SEND AUTOMESSAGE	Y, N	AUTO := N
FAST OP MESSAGES	Y, N	FASTOP := N
MODBUS SLAVE ID	1–247	SLAVEID := 1

[a] When PROTO := EVMSG, the relay uses the settings BITS = 8, PARITY = N, and STOP = 1, regardless of any user-entered settings.

NOTE: For additional settings when PROTO := MBxx, see Table J.5 as well as MIRRORED BITS Transmit SELOGIC Equations.

For additional settings when PROTO := DNP, see Table D.7 for a complete list of the DNP3 session settings.

Refer to Appendix H: IEC 60870-5-103 Communications for more information on IEC 60870-5-103.

Set the speed, data bits, parity, and stop bits settings to match the serial port configuration of the equipment that is communicating with the serial port.

After Port Timeout minutes of inactivity on a serial port at Access Level 2, the port automatically returns to Access Level 0. This security feature helps prevent unauthorized access to the relay settings if the relay is accidentally left in Access Level 2. If you do not want the port to time out, set Port Timeout equal to 0 minutes.

For detailed information on communications protocols, refer to *Appendix C: SEL Communications Processors*, *Appendix D: DNP3 Communications*, *Appendix E: Modbus Communications*, *Appendix F: EtherNet/IP Communications*, *Appendix G: IEC 61850 Communications*, *Appendix H: IEC 60870-5-103 Communications*, *Appendix I: DeviceNet Communications*, *Appendix J: MIRRORED BITS Communications*, and *Appendix K: Synchrophasors*.

Use the MBT option if you are using a Pulsar MBT9600 baud modem (see *Appendix J: Mirrored Bits Communications* for more information). With this option set, the relay transmits a message every second processing interval and the device deasserts the RTS signal on the EIA-232 connector. Also, the device monitors the CTS signal on the EIA-232 connector, which the modem deasserts if the channel has too many errors. The modem uses the device RTS signal to determine whether the MB or MB8 Mirrored Bits protocol is in use.

The relay EIA-232 serial ports support software (XON/XOFF) flow control. To enable support for hardware (RTS/CTS) flow control, set the RTSCTS setting equal to Y.

On Ports F, 2, 3, and 4, when PROTO := SEL, use the LANG setting to communicate with the relay in English or Spanish. On Port 1, when ETELNET := Y, use the LANG setting to communicate with the relay in English or Spanish. Refer to the *SEL-787-2, -3, -4 Relay Command Summary* for commands in both languages.

Set the AUTO := Y to allow automatic messages at a serial port.

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 C: SEL Communications Processors* for the description of the SEL-787 Fast Operate commands.

Set PROTO := DNET to establish communications when the DeviceNet card is used. *Table 4.70* shows the additional settings, which can be set only at the rear on the DeviceNet card. Once the relay detects the DeviceNet card, all **Port 4** settings are hidden. Refer to *Appendix I: DeviceNet Communications* for details on DeviceNet.

Table 4.70 Rear-Panel DeviceNet Port Settings

Setting Name	Setting Range
MAC_ID	0–63
ASA	8 Hex characters assigned by factory
DN_RATE	125, 250, 500 kbps

Front-Panel Settings (SET F Command)

The SEL-787 supports various front-panel options (see *Table 1.3*). This section covers all of the front-panel related settings, except for the touchscreen display settings. Refer to *Table 9.7* for the touchscreen display settings. The touchscreen display settings are not settable via the **SET F** command.

General Settings

Local bits provide control from the front panel (local bits), and display points display selected information on the LCD display. However, you need to first enable the appropriate number of local bits and display points necessary for your application. When your SEL-787 arrives, four display points are already enabled, but no local bits are enabled. If more display points are necessary for your application, use the EDP setting to enable as many as 32 display points. Use the ELB setting to enable as many as 32 local bits. The EDP settings and the corresponding display point settings are not available for the touchscreen display model. The touchscreen display model provides you with the ability to configure bay screens with analog and digital labels, similar to the display point functionality in the two-line display model. Refer to *Section 9: Bay Control* for the procedure to create configurable bay screens.

Table 4.71 Display Point and Local Bit Default Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
DISPLAY PTS ENABL	N, 1–32	EDP := 4
LOCAL BITS ENABL	N, 1–32	ELB := N

To optimize the time you spend on setting the device, only the number of enabled display points and enabled local bits become available for use. Use the front-panel LCD timeout setting FP_TO as a security measure. If the display is within an Access Level 2 function when a timeout occurs, such as the device setting entry, the function is automatically terminated (without saving changes) after inactivity for this length of time. After terminating the function, the front-panel display returns to the default display. The FP_TO setting is not available in the touchscreen display model. Refer to *Section 9: Bay Control* for the touchscreen display settings. If you prefer to disable the front-panel timeout function during device testing, set the LCD timeout equal to OFF.

Use the front-panel LCD contrast setting FP_CONT to adjust the contrast of the LCD. The FP_CONT setting is not available in the touchscreen display model.

Use the front-panel automessage setting FP_AUTO to define the display of Trip/Warning messages. Set FP_AUTO either to OVERRIDE or ROTATING for when the relay triggers a Trip/Warning message. Choosing OVERRIDE will have the Trip/Warning message override the rotating display, while choosing ROTATING will add the Trip/Warning message to the rotating display. Refer to *Table 9.7* for the equivalent touchscreen display settings. Note that the FP_AUTO setting is not available in the touchscreen display model. The touchscreen display provides settings that allow you to choose from a wide range of screens, including custom screens, to display as part of the rotating display. The touchscreen automatically flashes a screen that overrides the rotating display in the case of trip or diagnostic failures. Refer to *Section 8: Front-Panel Operations* for more information on trip and diagnostic messages.

Set RSTLED := Y to automatically reset the latched LEDs when the breaker or contactor closes.

The MAXACC setting (under Front-Panel Settings) selects the highest access level for the front-panel HMI. If MAXACC is set to 1, the front-panel HMI only allows metering and read access to the settings. If MAXACC is set to 2, the front-panel HMI allows breaker control and read/write access to the settings.

NOTE: All target LED settings can be found in Table 4.80.

Table 4.72 LCD Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
LCD TIMEOUT[a]	OFF, 1–30 min	FP_TO := 15
LCD CONTRAST[a]	1–16	FP_CONT := 5
FP AUTOMESSAGES[a]	OVERRIDE, ROTATING	FP_AUTO := OVERRIDE

Table 4.72 LCD Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
CLOSE RESET LEDS	Y, N	RSTLED := Y
MAXIMUM ACCESS LEVEL[a]	1, 2	MAXACC := 2

[a] These settings are not supported in the touchscreen display model.

Display Points

NOTE: The rotating display is updated approximately every two (2) seconds.

Use display points to view either the state of internal relay elements (Boolean information) or analog information on the LCD display. Although the LCD displays a maximum of 16 characters at a time, you can enter as many as 60 valid characters. Valid characters are 0–9, A–Z, -, /, ", {, }, space. For text exceeding 16 characters, the LCD displays the first 16 characters, then scrolls through the remaining text not initially displayed on the screen.

Table 4.73 Front-Panel Display Point Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
DISPLAY POINT DP01	60 characters	DP01 := RID,"{16}"
DISPLAY POINT DP02	60 characters	DP02 := TID,"{16}"
DISPLAY POINT DP03	60 characters	DP03 := I1W1_MAG,"W1POS I {5} A"
DISPLAY POINT DP04	60 characters	DP04 := I1W2_MAG,"W2POS I {5} A"
DISPLAY POINT DP05	60 characters	DP05 :=
• • •	• • •	• • •
DISPLAY POINT DP32	60 characters	DP32 :=

Boolean Display Point Entry Composition

Boolean information is the status of Relay Word bits (see *Appendix L: Relay Word Bits*). In general, the legal syntax for Boolean display points consists of the following four fields or strings, separated by commas:

Relay Word Bit Name, “Alias”, “Set String”, “Clear String”.

where:

Name = Relay Word bit name (IN101, for example). All binary quantities occupy one line on the front-panel display (all analog quantities occupy two lines).

Alias = A more descriptive name for the Relay Word bit (such as TRANSFORMER 3), or the analog quantity (such as TEMPERATURE).

Set String = State what should be displayed on the LCD when the Relay Word bit is asserted (CLOSED, for example)

Clear String = State what should be displayed on the LCD when the Relay Word bit is deasserted (OPEN, for example)

Any or all of Alias, Set String, or Clear String can be empty. Although the relay accepts an empty setting Name as valid, a display point with an empty

Name setting is always hidden (see *Table 4.74*). Commas are significant in identifying and separating the four strings. Use quotation marks only if the text you enter for Alias, Set String, or Clear String contains commas or spaces. For example, DP01 = Name,Text is valid, but Name, Alias 3 is not valid (contains a space). Correct the Alias name by using the quotation marks: Name, "Text 3". You can customize the data display format by entering data in selected strings only. *Table 4.74* shows the various display appearances resulting from entering data in selected strings.

Hidden (No Display)

The relay allows you to program the display points such that they are always hidden, never hidden, or conditionally hidden. *Table 4.74* shows examples of settings that always, never, or conditionally hide a display point.

Table 4.74 Settings That Always, Never, or Conditionally Hide a Display Point

Programmable Automation Controller Setting	Name	Alias	Set String	Clear String	Comment
DP01 := IN101,TRFR1,CLOSED,OPEN	IN101	TRFR1	CLOSED	OPEN	Never hidden
DP01 := IN101,TRFR1	IN101	TRFR1	—	—	Never hidden
DP01 := NA	—	—	—	—	Always hidden
DP01 := IN101,,,	IN101	—	—	—	Always hidden
DP01 := IN101,TRFR1,,	IN101	TRFR1	—	—	Always hidden
DP01 := IN101,TRFR1,CLOSED,	IN101	TRFR1	CLOSED	—	Hidden when IN101 is deasserted
DP01 := IN101,"TRFR 1",,OPEN	IN101	TRFR 1	—	OPEN	Hidden when IN101 is asserted
DP01 := 1,{}	1	{}	—	—	Empty line
DP01 := 1,"Fixed Text"	1	Fixed Text	—	—	Displays the fixed text
DP01 := 0	0	—	—	—	Hides the display point

Following are examples of selected display point settings, showing the resulting front-panel displays. For example, at a certain station we want to display the status of both HV and LV circuit breakers of Transformer 1. When the HV circuit breaker is open, we want the LCD display to show: `TRFR 1 HV BRKR: OPEN`, and when the HV circuit breaker is closed, we want the display to show: `TRFR 1 HV BRKR: CLOSED`. We also want similar displays for the LV breaker.

After connecting a form a (normally open) auxiliary contact from the HV circuit breaker to Input **IN101** and a similar contact from the LV circuit breaker to Input **IN102** of the SEL-787, we are ready to program the display points, using the following information for the HV breaker (LV breaker similar):

- ➤ Relay Word bit—IN101
- ➤ Alias—TRFR 1 HV BRKR:
- ➤ Set String—CLOSED (the Form A [normally open] contact asserts or sets Relay Word bit IN101 when the circuit breaker is closed)
- ➤ Clear String—OPEN (the Form A [normally open] contact deasserts or clears Relay Word bit IN101 when the circuit breaker is open)

Name, Alias, Set String, and Clear String

When all four strings have entries, the relay reports all states.

Table 4.75 Entries for the Four Strings

Name	Alias	Set String	Clear String
IN101	TRFR 1 HV BRKR:	CLOSED	OPEN

Figure 4.85 shows the settings for the example, using the **SET F** command. Use the **>** character to move to the next settings category.

```
=>>SET F TERSE <Enter>
Front Panel
General Settings
DISPLY PTS ENABL (N,1-32)                      EDP     := 4         ? > <Enter>
.
.
.
Target LED Set
TRIP LATCH T_LED (Y,N)                         T01LEDL := Y         ? > <Enter>
Display Point Settings (maximum 60 characters):
(Boolean): Relay Word Bit Name, "Alias", "Set String", "Clear String"
(Analog) : Analog Quantity Name, "User Text and Formatting"
DISPLAY POINT DP01 (60 characters)
DP01    := RID,"{16}"
? IN101,"TRFR 1 HV BRKR:",CLOSED,OPEN <Enter>
DISPLAY POINT DP02 (60 characters)
DP02    := TID,"{16}"
? IN102,"TRFR 1 LV BRKR:",CLOSED,OPEN <Enter>
DISPLAY POINT DP03 (60 characters)
DP03    := IAV, "IAV CURR {5} A"
? END <Enter>
Save changes (Y,N)? Y <Enter>
Settings Saved
=>>
```

Figure 4.85 Display Point Settings

Figure 4.86 shows the display when both HV and LV breakers are open (both IN101 and IN102 deasserted). *Figure 4.87* shows the display when the HV breaker is closed, and the LV breaker is open (IN101 asserted, but IN102 still deasserted).

Figure 4.86 Front-Panel Display—Both HV and LV Breakers Open

Figure 4.87 Front-Panel Display—HV Breaker Closed, LV Breaker Open

Name String, Alias String, and Either Set String or Clear String Only

The following discusses omission of the Clear String; omission of the Set String gives similar results. Omitting the Clear String causes the relay to only show display points in the set state, using the **SET F** command as follows:

```
DP01    := RID, “{16}”
 ? IN101,"TRFR 1 HV BRKR:",CLOSED <Enter>
```

When the Relay Word bit IN101 deasserts, the relay removes the complete line with the omitted Clear String (TRFR 1 HV BRKR). When both breakers are closed, the relay has the set state information for both HV and LV breakers, and the relay displays the information as shown in *Figure 4.88*. When the HV breaker opens (LV breaker is still closed), the relay removes the line containing the HV breaker information because the Clear String information was omitted. Because the line containing the HV breaker information is removed, the relay now displays the LV breaker information on the top line, as shown in *Figure 4.89*.

Figure 4.88 Front-Panel Display—Both HV and LV Breakers Closed

Figure 4.89 Front-Panel Display—HV Breaker Open, LV Breaker Closed

If you want the relay to display a blank state when IN101 deasserts instead of removing the line altogether, use the curly brackets {} for the Clear String, as follows:

```
DP01    := RID, “{16}”
 ? IN101,"TRFR 1 HV BRKR:",CLOSED,{} <Enter>
```

When Input IN101 now deasserts, the relay still displays the line with the HV breaker information, but the state is left blank, as shown in *Figure 4.90*.

Figure 4.90 Front-Panel Display—HV Breaker Open, LV Breaker Closed

Name Only

Table 4.76 shows an entry in the Name String only (leaving the Alias string, Set String, and Clear String void), using the **SET F** command as follows:

```
DP01    := RID, “{16}”
 ? IN101 <Enter>
```

Table 4.76 Binary Entry in the Name String Only

Name	Alias	Set String	Clear String
IN101	—	—	—

Figure 4.91 shows the front-panel display for the entry in *Table 4.76*. Input IN101 is deasserted in this display (`IN101=0`), but changes to `IN101=1` when Input IN101 asserts.

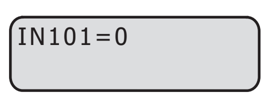


Figure 4.91 Front-Panel Display for a Binary Entry in the Name String Only

Analog Display Point Entry Composition

In general, the legal syntax for analog display points consists of the following two fields or strings:

Name, "User Text and Formatting."

where:

Name	=	Analog quantity name (AI301 for example). All analog quantities occupy two lines on the front-panel display (all binary quantities occupy one line on the display).
User text and numerical formatting	=	Display the user text, replacing the numerical formatting {width.dec,scale} with the value of Name, scaled by "scale", formatted with total width "width" and "dec" decimal places. Name can be either an analog quantity or a Relay Word bit. The width value includes the decimal point and sign character, if applicable. The "scale" value is optional; if omitted, the scale factor is 1. If the numeric value is smaller than the string size requested, the string is padded with spaces to the left of the number. If the numeric value does not fit within the string width given, the string grows (to the left of the decimal point) to accommodate the number.

Unlike binary quantities, the relay displays analog quantities on both display lines. *Table 4.77* shows an entry in the Name string only (leaving the User Text and Formatting string void) with the following syntax:

Table 4.77 Analog Entry in the Name String Only

Name	Alias	Set String	Clear String
AI301	—	—	—

Figure 4.92 shows the front-panel display for the entry in *Table 4.77*, using the **SET F** command as follows:

```
DP01    := RID, "{16}"
 ? AI301 <Enter>
```

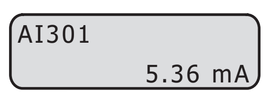


Figure 4.92 Front-Panel Display for an Analog Entry in the Name String Only

Name and Alias

For a more descriptive name of the Relay Word bit, enter the Relay Word bit in the Name String, and an alias name in User Text and Formatting String. *Table 4.78* shows a Boolean entry in the Name and Alias Strings (DP01) and an entry in the Name and User Text and Formatting Strings (DP02), using the **SET F** command as follows:

```
DP01    := RID, "{16}"
 ? IN101,"INPUT IN101:" <Enter>
DP02    := TID, "{16}"
 ? AI301,TEMPERATURE: <Enter>
```

Table 4.78 Entry in the Name String and the Alias Strings

Name	Alias	Set String	Clear String
IN101	INPUT IN101	—	—
AI301	TEMPERATURE	—	—

Figure 4.93 shows the front-panel display for the entry in *Table 4.78*. Input IN101 is deasserted in this display (0), and the display changes to `INPUT IN101=1` when Input IN101 asserts.

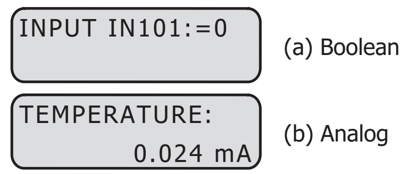


Figure 4.93 Front-Panel Display for an Entry in (a) Boolean Name and Alias Strings and (b) Analog Name and User Text and Formatting Strings

If the engineering units are set, then the front-panel display shows the engineering units. For example, in the Group setting example, we set AI301EU to degrees C. With this setting, the front-panel display looks as shown in *Figure 4.94*.

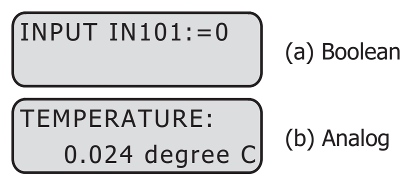


Figure 4.94 Front-Panel Display for an Entry in (a) Boolean Name and Alias Strings and (b) Analog Name, User Text and Formatting Strings, and Engineering Units

For fixed text, enter a 1 in the Name String, then enter the fixed text as the alias text. For example, to display the word DEFAULT and SETTINGS on two different lines, use a display point for each word, i.e., DP01 = 1,“DEFAULT” and DP02 = 1,“SETTINGS.” *Table 4.79* shows other options and front-panel displays for the User Text and Formatting settings.

Table 4.79 Example Settings and Displays

Example Display Point Setting Value	Example Display
AI301,"TEMP {4}deg C"	TEMP 1234 deg C
AI301,"TEMP = {4.1}"	TEMP = 1234.0
AI301,"TEMP = {4.2,0.001} C"	TEMP = 1.23 C
AI301,"TEMP HV HS1 = {4,1000}"	TEMP HV HS1 = 12340000
1,{}	Empty line
1,"Fixed Text"	Fixed Text
0	Hides the display point

Following is an example of an application of analog settings. Assume we also want to know the hot-spot temperature, oil temperature, and winding temperature of the transformer at a certain installation. To measure these temperatures, we have installed an analog card in relay Slot **C**, and connected

4–20 mA transducers inputs to analog inputs AI301 (hot-spot temperature), AI302 (oil temperature), and AI303 (winding temperature).

First enable enough display points for the analog measurements (e.g., EDP = 5). *Figure 4.95* shows the settings to add the three transducer measurements. (Use the > character to move to the next settings category.)

```
=>>SET F TERSE <Enter>
Front Panel
General Settings
DISPLY PTS ENABL (N,1-32)                    EDP     := 4         ? 5 <Enter>
LOCAL BITS ENABL (N,1-32)                    ELB     := 1         ? > <Enter>
.
.
.
Target LED Set
TRIP LATCH T_LED (Y,N)                       T01LEDL := Y         ? > <Enter>
Display Point Settings (maximum 60 characters):
(Boolean): Relay Word Bit Name, "Alias", "Set String", "Clear String"
(Analog) : Analog Quantity Name, "User Text and Formatting"
DISPLAY POINT DP01 (60 characters)
DP01    := IN101,"TRFR 1 HV BRKR:",CLOSED,OPEN
? <Enter>
DISPLAY POINT DP02 (60 characters)
DP02    := IN102,"TRFR 1 LV BRKR:",CLOSED,OPEN
? <Enter>
DISPLAY POINT DP03 (60 characters)
DP03    := IAV, "IAV CURR {5} A"
? AI301,"HOT SPOT TEMP" <Enter>
DISPLAY POINT DP04 (60 characters)
DP04    := IG_MAG, "GND CURR {5} %"
? AI302,"OIL TEMPERATURE" <Enter>
DISPLAY POINT DP05 (60 characters)
DP05    := IA_MAG, "IA {7.1} A pri"
? AI303,"WINDING TEMP" <Enter>
Save changes (Y,N)? Y <Enter>
Settings Saved
=>>
```

Figure 4.95 Adding Temperature Measurement Display Points

Rotating Display

With more than two display points enabled, the relay scrolls through all enabled display points, thereby forming a rotating display, as shown in *Figure 4.96*.

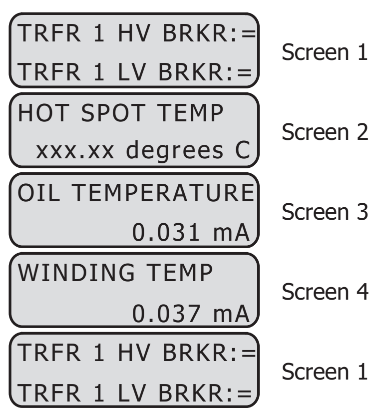


Figure 4.96 Rotating Display

To change the temperature units to more descriptive engineering units, enter the desired units with the AI*xxx*EU (e.g., AI302EU) setting.

Local Bits

Local bits are variables (LB*nn*, where *nn* means 01 through 32) that are controlled from front-panel pushbuttons. Use local bits to replace traditional panel switches. The state of the local bits is stored in nonvolatile memory every second. When power to the device is restored, the local bits revert to their states after the device initialization.

Each local bit requires three of the following four settings, using a maximum of 14 valid characters for the NLB*nn* setting, and a maximum seven valid characters (0–9, A–Z, -, /, ., space) for the remainder:

- NLB*nn*: Names the switch (normally the function that the switch performs, such as SUPERV SW) that appears on the LCD display.
- CLB*nn*: Clear local bit. Enter the text that describes the intended operation of the switch (this text appears on the display) when LB*nn* deasserts (OPEN, for example).
- SLB*nn*: Set local bit. Enter the text that describes the intended operation of the switch (this text appears on the display) when LB*nn* asserts (CLOSE, for example).
- PLB*nn*: Pulse local bit. When selecting the pulse operation, LB*nn* asserts for only one processing interval before deasserting again. Enter the text that describes the intended operation when LB*nn* asserts (START, for example).
- Omit either SLB*nn* or PLB*nn* (never CLB*nn*) by setting the omitted setting to NA.

For the transformer in our example, configure two local bits: one to replace a supervisory switch, and the other to start a fan motor. Local bit 1 replaces a supervisory switch (SUPERV SW) and we use the clear/set combination. Local bit 2 starts a fan motor (START) that only needs a short pulse to seal itself in, and we use the clear/pulse combination. *Figure 4.97* shows the settings to program the two local bits.

```
=>>SET F TERSE <Enter>
Front Panel
General Settings
DISPLY PTS ENABL (N,1-32)                       EDP     := 5        ? <Enter>
LOCAL BITS ENABL (N,1-32)                       ELB     := N        ? 2 <Enter>
LCD TIMEOUT (OFF,1-30 min)                      FP_TO   := 15       ? > <Enter>
  .
  .
  .
Target LED Set
TRIP LATCH T_LED (Y,N)                          T01LEDL := Y        ? > <Enter>
Display Point Settings (maximum 60 characters):
(Boolean): Relay Word Bit Name, "Alias", "Set String", "Clear String"
(Analog) : Analog Quantity Name, "User Text and Formatting"
DISPLAY POINT DP01 (60 characters)
DP01    := IN101,"TRFR 1 HV BRKR:",CLOSED,OPEN
? > <Enter>
Local Bits Labels:
LB_ NAME (14 characters; Enter NA to null)
NLB01   :=
? SPERV SW <Enter>
CLEAR LB_ LABEL (7 characters; Enter NA to null)
CLB01   :=
? OPEN <Enter>
SET LB_ LABEL (7 characters; Enter NA to null)
SLB01   :=
? CLOSE <Enter>
PULSE LB_ LABEL (7 characters; Enter NA to null)
PLB01   :=
? NA <Enter>
LB_ NAME (14 characters; Enter NA to null)
NLB02   :=
? FAN START <Enter>
CLEAR LB_ LABEL (7 characters; Enter NA to null)
CLB02   :=
? OFF <Enter>
SET LB_ LABEL (7 characters; Enter NA to null)
SLB02   :=
? NA <Enter>
```

Figure 4.97 Adding Two Local Bits

```
PULSE LB_ LABEL (7 characters; Enter NA to null)
PLB02   :=
? START <Enter>
Save changes (Y,N)? Y <Enter>
Settings Saved
=>>
```

Figure 4.97 Adding Two Local Bits (Continued)

Target LED Settings

The SEL-787 offers the following two types of LEDs. See *Figure 8.5* and *Figure 8.29* for the programmable LED locations:

- ➤ One **ENABLED** and one **TRIP** tricolored target LED
- ➤ Six tricolored programmable target LEDs
- ➤ Sixteen tricolored programmable pushbutton LEDs

You can program all 22 LEDs using SELOGIC control equations, the only difference being that the Target LEDs also include a latch function.

Target LEDs

NOTE: If the LED latch setting (TnLEDL) is set to Y, and TRIP asserts, the LED latches to the state at TRIP assertion. The latched LED targets can be reset with TARGET RESET if the target conditions are absent.

NOTE: Relay Word bits TLED_01–TLED_06 are not accessible to the user in the SYNCHROWAVE Event file.

The **ENABLED** and **TRIP** LEDs are not programmable. Except for choosing the LED illuminated color (LEDENAC or LEDTRPC), they are fixed-function LEDs. The **ENABLED** LED illuminates when the SEL-787 is powered correctly, is functional, and has no self-test failures. The **TRIP** LED illuminates and latches in at the rising-edge of any trip that comes from the trip logic. The LEDENAC setting is not supported in the touchscreen display models. For touchscreen display relays, the illuminated color of the **ENABLED** LED is fixed at green.

Settings T*n*LEDL (*n* = 01 through 06) and T*n*_LED (*n* = 01 through 06) control the six front-panel LEDs. If the T*n*_LEDL is set to Y, the LED will assert if a trip condition occurs and the T0*n*_LED equation asserts within 1.5 cycles of the trip assertion. At this point, the LED is latched. To reset these latched LEDs, the trip condition should no longer exist and one of the following takes place:

- ➤ Pressing **TARGET RESET** on the front panel.
- ➤ Issuing the serial port command **TAR R**.
- ➤ The assertion of the SELOGIC control equation RSTTRGT.

With T*n*LEDL settings set to N, the LEDs do not latch and directly follow the state of the associated SELOGIC control equation setting.

Enter any of the Relay Word bits (or combinations of Relay Word bits) as conditions in the T*n*_LED SELOGIC control equation settings. When these Relay Word bits assert, the corresponding LED also asserts.

Table 4.80 shows the target LED settings. The factory-default settings shown match the as-shipped front-panel overlay (see *Figure 8.2* through *Figure 8.5*). You can change the settings to suit your application. See *Section 8: Front-Panel Operations* for slide-in labels for custom LED designations.

Table 4.80 Target LED Settings (Sheet 1 of 2)

Setting Prompt	Setting Range[a]	Setting Name := Factory Default
CLOSE RESET LEDS	Y, N	RSTLED := Y
ENA_LED COLOR[b]	R, G, A	LEDENAC := G

Table 4.80 Target LED Settings (Sheet 2 of 2)

Setting Prompt	Setting Range[a]	Setting Name := Factory Default
TRIP_LED COLOR	R, G, A	LEDTRPC := R
TRIP LATCH T_LED	Y, N	T01LEDL := Y
TARGET T_LED ASSERTED COLOR	R, G, A	T01LEDC := R
LED1 EQUATION	SELOGIC	T01_LED := 87U OR 87R
TRIP LATCH T_LED	Y, N	T02LEDL := Y
TARGET T_LED ASSERTED COLOR	R, G, A	T02LEDC := R
LED2 EQUATION	SELOGIC	T02_LED := ORED50T
TRIP LATCH T_LED	Y, N	T03LEDL := Y
TARGET T_LED ASSERTED COLOR	R, G, A	T03LEDC := R
LED3 EQUATION	SELOGIC	T03_LED := ORED51T
TRIP LATCH T_LED	Y, N	T04LEDL := Y
TARGET T_LED ASSERTED COLOR	R, G, A	T04LEDC := R
LED4 EQUATION	SELOGIC	T04_LED := 27P1T OR 27P2T OR 59P1T OR 59P2T OR 59Q1T OR 59Q2T[c] T04_LED := 87HR1 OR 87R1 AND NOT 87BL1[d]
TRIP LATCH T_LED	Y, N	T05LEDL := Y
TARGET T_LED ASSERTED COLOR	R, G, A	T05LEDC := R
LED5 EQUATION	SELOGIC	T05_LED := 81D1T OR 81D2T OR 81D3T OR 81D4T[b] T05_LED := 87HR2 OR 87R2 AND NOT 87BL2[d]
TRIP LATCH T_LED	Y, N	T06LEDL := Y
TARGET T_LED ASSERTED COLOR	R, G, A	T06LEDC := R
LED6 EQUATION	SELOGIC	T06_LED := 24D1T OR 24C2T[b] T06_LED := 87HR3 OR 87R3 AND NOT 87BL3[d]

[a] R = Red, G = Green, and A = Amber
[b] The setting LEDENAC is not supported in the touchscreen display model.
[c] These settings are applicable to the SEL-787-2E, SEL-787-3E, and SEL-787-3S models.
[d] These settings are applicable to the SEL-787-21, SEL-787-2X, and SEL-787-4X models.

Pushbutton LEDs

Enter any of the Relay Word bits (or combinations of Relay Word bits) as conditions in the PB*p*_LED (*p* = 1A, 1B,…8A, 8B) SELOGIC control equation settings. When these Relay Word bits assert, the corresponding LED turns on. *Table 4.81* shows the setting prompts, settings ranges, and default settings for the LEDs.

The factory-default settings shown match the as-shipped front-panel overlay. (see *Figure 8.2* through *Figure 8.5*). You can change the settings to suit your application. See *Section 8: Front-Panel Operations* for slide-in labels for custom LED designations.

Table 4.81 Pushbutton LED Settings (Sheet 1 of 2)

Setting Prompt	Setting Range[a]	Setting Name := Factory Default
PB_LED ASSERTED/ DEASSRTED COLORS	AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO	PB1ALEDC := AO
PB1A_LED EQUATION	SELOGIC	PB1A_LED := NOT LT01 OR SV01 AND NOT SV01T AND SV05T
PB_LED ASSERTED/ DEASSRTED COLORS	AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO	PB1BLEDC := AO
PB1B_LED EQUATION	SELOGIC	PB1B_LED := LT01 OR SV01 AND NOT SV01T AND SV05T
PB_LED ASSERTED/ DEASSRTED COLORS	AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO	PB2ALEDC := AO
PB2A_LED EQUATION	SELOGIC	PB2A_LED := SV03 AND NOT SV03T AND SV05T
PB_LED ASSERTED/ DEASSRTED COLORS	AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO	PB2BLEDC := AO
PB2B_LED EQUATION	SELOGIC	PB2B_LED := 0
PB_LED ASSERTED/ DEASSRTED COLORS	AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO	PB3ALEDC := AO
PB3A_LED EQUATION	SELOGIC	PB3A_LED := SV04 AND NOT SV04T AND SV05T
PB_LED ASSERTED/ DEASSRTED COLORS	AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO	PB3BLEDC := AO
PB3B_LED EQUATION	SELOGIC	PB3B_LED := 0
PB_LED ASSERTED/ DEASSRTED COLORS	AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO	PB4ALEDC := AO
PB4A_LED EQUATION	SELOGIC	PB4A_LED := 0
PB_LED ASSERTED/ DEASSRTED COLORS	AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO	PB4BLEDC := AO
PB4B_LED EQUATION	SELOGIC	PB4B_LED := 0
PB_LED ASSERTED/ DEASSRTED COLORS	AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO	PB5ALEDC := AO
PB5A_LED EQUATION	SELOGIC	PB5A_LED := LT05
PB_LED ASSERTED/ DEASSRTED COLORS	AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO	PB5BLEDC := RG
PB5B_LED EQUATION	SELOGIC	PB5B_LED := 52A1
PB_LED ASSERTED/ DEASSRTED COLORS	AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO	PB6ALEDC := AO
PB6A_LED EQUATION	SELOGIC	PB6A_LED := LT06
PB_LED ASSERTED/ DEASSRTED COLORS	AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO	PB6BLEDC := RG

Table 4.81 Pushbutton LED Settings (Sheet 2 of 2)

Setting Prompt	Setting Range[a]	Setting Name := Factory Default
PB6B_LED EQUATION	SELOGIC	PB6B_LED := 52A2
PB_LED ASSERTED/ DEASSRTED COLORS	AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO	PB7ALEDC := AO
PB7A_LED EQUATION	SELOGIC	PB7A_LED := LT07[b]
		PB7A_LED := 0[c]
PB_LED ASSERTED/ DEASSRTED COLORS	AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO	PB7BLEDC := RG[b]
		PB7BLEDC := AO[c]
PB7B_LED EQUATION	SELOGIC	PB7B_LED := 52A3[b]
		PB7B_LED := 0[c]
PB_LED ASSERTED/ DEASSRTED COLORS	AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO	PB8ALEDC := AO
PB8A_LED EQUATION	SELOGIC	PB8A_LED := LT08[d]
		PB8A_LED := 0[e]
PB_LED ASSERTED/ DEASSRTED COLORS	AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO	PB8BLEDC := RG[d]
		PB8BLEDC := AO[e]
PB8B_LED EQUATION	SELOGIC	PB8B_LED := 52A4[d]
		PB8B_LED := 0[e]

[a] Setting is a two-letter combination of the letters R, G, A, and O, where asserted/deasserted color choices: R = Red, G = Green, A = Amber, and O = OFF.
[b] These settings are applicable to the SEL-787-3E, SEL-787-3S, and SEL-787-4X models.
[c] These settings are applicable to the SEL-787-21, SEL-787-2E, and SEL-787-2X models.
[d] These settings are applicable to the SEL-787-4X model.
[e] These settings are applicable to the SEL-787-21, SEL-787-2E, SEL-787-2X, SEL-787-3E, SEL-787-3S models.

Report Settings (SET R Command)

The report settings use Relay Word bits for the SER trigger as shown in *Table 4.83* (see *Appendix L: Relay Word Bits* for more information).

SER Chatter Criteria

The SER includes an automatic deletion and reinsertion function to prevent overfilling of the SER buffer with chattering information. Each processing interval the relay checks the Relay Word bits in the four SER reports for any changes of state (except the Relay Word bits corresponding to the digital inputs that have 1/16 of the power system cycle SER-accurate time-stamps). When detecting a change of state, the relay adds a record to the SER report containing the Relay Word bit(s), new state, time stamp, and checksum (see *Section 10: Analyzing Events* for more information).

When detecting oscillating SER items, the relay automatically deletes these oscillating items from SER recording. *Table 4.82* shows the auto-removal settings.

Table 4.82 Auto-Removal Settings

Settings Prompt	Setting Range	Setting Name := Factory Default
Auto-Removal Enable	Y, N	ESERDEL := N
Number of Counts	2–20 counts	SRDLCNT := 5
Removal Time	0.1–90.0 seconds	SRDLTIM := 1.0

To use the automatic deletion and reinsertion function, proceed with the following steps:

Step 1. Set Report setting ESERDEL (Enable SER Delete) to Y to enable this function.

Step 2. Select values for the setting SRDLCNT (SER Delete Count) and the setting SRDLTIM (SER Delete Time) that mask the chattering SER element.

Setting SRDLTIM declares a time interval during which the relay qualifies an input by comparing the changes of state of each input against the SRDLCNT setting. When an item changes state more than SRDLCNT times in an SRDLTIM interval, the relay automatically removes these Relay Word bits from SER recording. Once deleted from recording, the item(s) are ignored for the next nine intervals. At the ninth interval, the chatter criteria are again checked and, if the point does not exceed the criteria, it is automatically reinserted into recording at the starting of the tenth interval. You can enable or disable the auto-deletion function via the SER settings. Any auto-deletion notice entry is lost during changes of settings. The deleted items can be viewed in the SER Delete Report (Command **SER D**—refer to *Section 7: Communications* for additional information).

SER Trigger Lists

To capture element state changes in the SER report, enter the Relay Word bit into one of the four SER (SER1 through SER4) trigger equations. Each of the four programmable trigger equations allows entry of as many as 24 Relay Word bits separated by spaces or commas; the SER report accepts a total of 96 Relay Word bits. *Table 4.83* shows the settings prompt and default settings for the four SER trigger equations.

Table 4.83 SER Trigger Settings

Setting Prompt	Setting Name := Factory Default[a]
SER1	SER1 := IN101 IN102 PB01 PB02 PB03 52A1 52A2 TRIP1 TRIP2 TRIP TRIPXFMR
SER2	SER2 := ORED51T ORED50T 87U 87R REF3AF REF3BF RTDT[b]
	SER2 := ORED51T ORED50T 87U 87R RTDT[c]
SER3	SER3 := NA
SER4	SER4 := SALARM

[a] Use as many as 24 Relay Word elements separated by spaces or commas for each setting.
[b] These settings are applicable to the SEL-787-3E, SEL-787-3S, and SEL-787-4X models.
[c] These settings are applicable to the SEL-787-21, SEL-787-2E, and SEL-787-2X models.

Relay Word Bit Aliases

Table 4.84 Enable Alias Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
Enable ALIAS Settings (N, 1–32)	N, 1–32	EALIAS := 4

To simplify your review of the information displayed in the SER record, the relay provides the Alias setting function. Using the Alias settings, you can change the way relay elements listed in the SER settings are displayed in the SER report. In addition, the Alias settings allow you to change the text displayed when a particular element is asserted and deasserted. The relay permits as many as 32 unique aliases, as defined by the Enable Alias Settings (EALIAS) setting. Factory-default alias settings are shown in *Table 4.85*.

Define the enabled alias settings by entering the Relay Word bit name, a space, the desired alias, a space, the text to display when the condition asserts, a space, and the text to display when the condition deasserts.

```
ALIAS1 = PB01 FP_AUX1 PICKUP DROPOUT
```

See *Table L.1* for the complete list of Relay Word bits. Use as many as 15 characters to define the alias, asserted text, and deasserted text strings. You can use capital letters (A–Z), numbers (0–9), and the underscore character (_) within each string. Do not attempt to use a space within a string because the relay interprets a space as the break between two strings. If you wish to clear a string, simply type **NA**.

Table 4.85 Factory-Default Alias Settings

Setting Prompt	Relay Word Bit	Alias	Asserted Text	Deasserted Text
ALIAS1 :=	PB01	FP_LOCK	PICKUP	DROPOUT
ALIAS2 :=	PB02	FP_BRKR_SELECT	PICKUP	DROPOUT
ALIAS3 :=	PB03	FP_CLOSE	PICKUP	DROPOUT
ALIAS4 :=	PB04	FP_TRIP	PICKUP	DROPOUT
ALIAS5–ALIAS32	NA			

Event Report Settings

Table 4.86 Event Report Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
EVENT TRIGGER	SELOGIC	ER := 0
EVENT LENGTH	15, 64, 180 cyc	LER := 15
PREFAULT LENGTH	OFF, 1-(LER-5) cyc	PRE := 5

NOTE: Event report data stored in the relay are lost when you change the LER setting. You must save the data before changing the setting.

Event reports can be 15, 64, or 180 cycles in length as determined by the LER setting. For LER of 15, 64, or 180 cycles, the prefault length, PRE, must be in the range 1–10, 1–59, or 1–175 cycles, respectively. The relay can hold at least fifty 15-cycle event reports, eighteen 64-cycle event reports, or five 180-cycle event reports.

Fast Message Remote Analogs Settings

NOTE: When Type is set to Float, you cannot write the maximum value of 99999.99 to a remote analog. Instead, use 99999.98 as the maximum number. Similarly, use –99999.98 instead of –99999.99.

Remote devices are able to write analog quantities into the SEL-787 using protocols such as Modbus, EtherNet/IP, DNP3, IEC 61850 (RA001 through RA128), and SEL Fast Message (RA01 through RA32). These analog quantities are available for use in math variable equations. If the SEL Fast Message protocol is used, then the data type must be declared for each analog quantity (RA01TYPE through RA32TYPE). Choose from the analog quantities in *Appendix M: Analog Quantities*.

Load Profile Settings

Use the LDLIST setting to declare the analog quantities you want included in the Load Profile Report. Enter as many as 17 analog quantities, separated by spaces or commas, into LDLIST setting. See *Appendix M: Analog Quantities* for a list of the available analog quantities. Also set the LDAR to the desired acquisition rate for the report.

IMPORTANT: All stored load data are lost when changing the LDLIST.

Table 4.87 Load Profile Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
LDP LIST	NA, as many as 17 analog quantities	LDLIST := NA
LDP ACQ RATE	5, 10, 15, 30, 60 min	LDAR := 15

DNP Map Settings (SET D Command)

Table 4.88 shows the available settings. See *Appendix D: DNP3 Communications* for additional details.

Table 4.88 DNP Map Settings[a] (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
DNP Binary Input Label Name	10 characters	BI_00 := ENABLED
DNP Binary Input Label Name	10 characters	BI_01 := TRIPXFMR
DNP Binary Input Label Name	10 characters	BI_02 := TRIP1
DNP Binary Input Label Name	10 characters	BI_03 := TRIP2
• • •	• • •	• • •
DNP Binary Input Label Name	10 characters	BI_99 := NA
DNP Binary Output Label Name	10 characters	BO_00 := RB01
• • •	• • •	• • •
DNP Binary Output Label Name	10 characters	BO_31 := RB32
DNP Analog Input Label Name	24 characters	AI_00 := IAW1_MAG
DNP Analog Input Label Name	24 characters	AI_01 := IBW1_MAG
• • •	• • •	• • •
DNP Analog Input Label Name	24 characters	AI_99 := NA

Table 4.88 DNP Map Settings[a] (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
DNP Analog Output Label Name	6 characters	AO_00 := NA
•	•	•
•	•	•
•	•	•
DNP Analog Output Label Name	6 characters	AO_31 := NA
DNP Counter Label Name	11 characters	CO_00 := NA
•	•	•
•	•	•
•	•	•
DNP Counter Label Name	11 characters	CO_31 := NA

[a] See Appendix D: DNP3 Communications for complete list of the DNP Map Labels and factory-default settings.

Modbus Map Settings (SET M Command)

Modbus User Map

Table 4.89 shows the available user map register settings. See *Appendix E: Modbus Communications* for additional details.

Table 4.89 User Map Register Settings[a]

Setting Prompt	Setting Range	Setting Name := Factory Default
USER REG#001	NA, 1 Modbus Register Label	MOD_001 := IAW1_MAG
•	•	•
•	•	•
•	•	•
USER REG#125	NA, 1 Modbus Register Label	MOD_125 := NA

[a] See Appendix E: Modbus Communications for a complete list of the Modbus Register Labels and factory-default settings.

EtherNet/IP Assembly Map Settings (SET E Command)

Table 4.90 shows the available assembly map settings. See *Appendix F: EtherNet/IP Communications* for additional details.

Table 4.90 EtherNet/IP Assembly Map (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
Input Assembly (IA) Binary		
EIP Input Assembly Binary Label Name	10 characters	IAB_00 := NA
•	•	•
•	•	•
•	•	•
EIP Input Assembly Binary Label Name	10 characters	IAB_99 := NA

Table 4.90 EtherNet/IP Assembly Map (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
Input Assembly (IA) Analog		
EIP Input Assembly Analog Label Name	10 characters	IAA_00 := NOOP
EIP Input Assembly Analog Label Name	10 characters	IAA_01 := NA
• • •	• • •	• • •
EIP Input Assembly Analog Label Name	10 characters	IAA_99 := NA
Output Assembly (OA) Binary		
EIP Output Assembly Binary Label Name	10 characters	OAB_00 := NA
• • •	• • •	• • •
EIP Output Assembly Binary Label Name	10 characters	OAB_31 := NA
Output Assembly (OA) Analog		
EIP Output Assembly Analog Label Name	10 characters	OAA_00 := NOOP
EIP Output Assembly Analog Label Name	10 characters	OAA_01 := NA
• • •	• • •	• • •
EIP Output Assembly Analog Label Name	10 characters	OAA_31 := NA

Touchscreen Settings

The touchscreen settings apply to relays that support the color touchscreen display and are discussed in *Section 9: Bay Control* (see *Table 9.7*).

Section 5

Metering and Monitoring

Overview

The SEL-787 Transformer Protection Relay includes metering functions to display the present values of current, voltage (if included), analog inputs (if included), and RTD measurements (with the external SEL-2600 RTD Module or an internal RTD card).

The relay provides the following methods to read the present meter values:

- Front-panel rotating display
- Front-panel menu
- Web server via Ethernet port
- EIA-232 serial ports (using SEL ASCII text commands or ACSELERATOR QuickSet SEL-5030 Software)
- Telnet via Ethernet port
- Modbus via EIA-232 port or EIA-485 port
- Modbus TCP via Ethernet port
- EtherNet/IP via Ethernet port
- DNP3 Serial via EIA-232 port or EIA-485 port
- DNP3 LAN/WAN via Ethernet port
- DeviceNet port
- Analog outputs
- IEC 61850 Edition 2 via Ethernet port
- IEC 60870-5-103 via EIA-232 or EIA-485
- IEEE C37.118 Synchrophasor Protocol via serial port or Ethernet port

Load monitoring and trending are possible using the Load Profile function. The relay automatically configures itself to save as many as 17 quantities (selected from the Analog Quantities) every 5, 10, 15, 30, or 60 minutes. The data are stored in nonvolatile memory. As many as 9800 time samples are stored.

The SEL-787 has a through-fault event monitoring function that gathers current level, duration and date/time for each through fault experienced by the transformer. The function calculates and tracks accumulated I^2t through fault and alarms excess I^2t over time. This monitor function can be used to schedule proactive transformer bank maintenance.

Power Measurement Conventions

The SEL-787 uses the IEEE convention for power measurement. The implications of this convention are depicted in *Figure 5.1*.

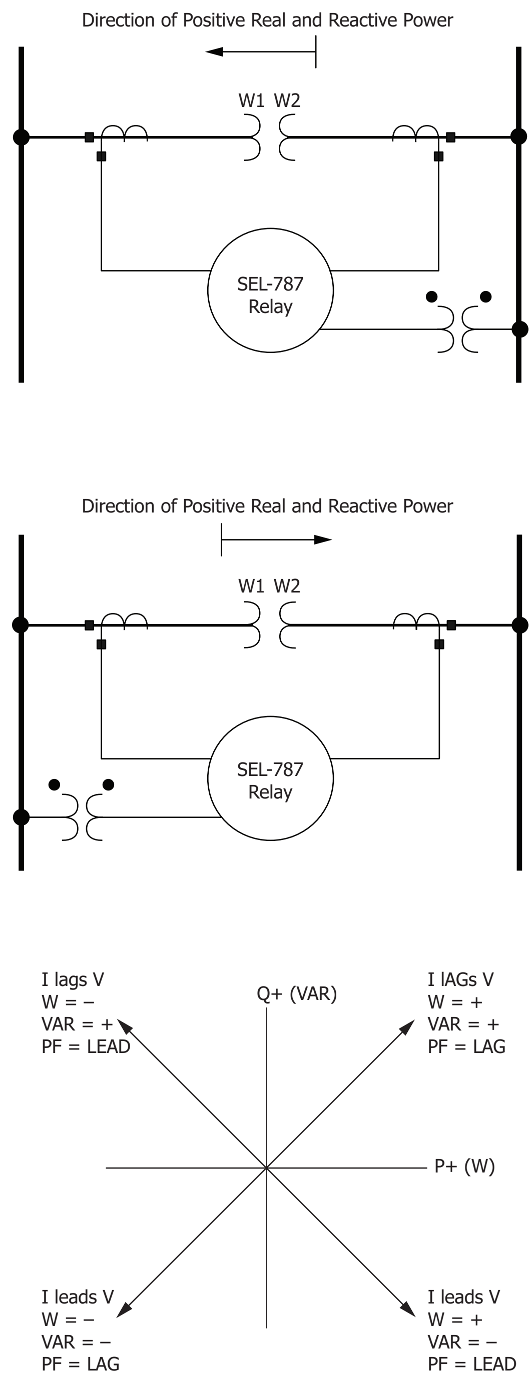


Figure 5.1 Complex Power Measurement Conventions

Delta-Connected CTs

The relay displays currents, voltages, and power in primary values as part of most metering and monitoring reports. If the winding phase CTs are wye connected, the relay can accurately derive the primary currents from the secondary values through multiplying them by the corresponding CT ratio.

Delta-connected CTs, in general, remove zero-sequence current and introduce a phase shift. They also increase magnitude by $\sqrt{3}$ under balanced system conditions and as high as two times under unbalanced conditions. As a result, the relay cannot derive the primary currents/quantities accurately. The relay performs the following under all system conditions in the case of delta-connected CTs. The primary currents displayed are derived from the secondary values through multiplying them by the corresponding CT ratio and dividing them by $\sqrt{3}$. The phase angles are not compensated and reflect the same values as measured on the secondary.

Metering

The SEL-787 meter data fall into the following categories:

- Fundamental metering
- Differential metering
- Thermal metering: RTD metering (with the external SEL-2600 RTD Module or an internal RTD option)
- Energy metering
- Maximum and minimum metering
- Math variable metering
- RMS metering
- Analog transducer input metering
- Demand and peak demand metering
- Harmonic metering
- Synchrophasor metering
- Remote analog metering

Fundamental Metering

Table 5.1 details each of the fundamental meter data types in the SEL-787. *Section 8: Front-Panel Operations* and *Section 7: Communications* describe how to access the various types of meter data using the relay front panel and communications ports.

NOTE: Calculated phase-to-phase voltages for wye-connected PTs are available in the analog quantities and can be selected as display points. See Appendix M: Analog Quantities.

If the winding phase CTs are delta connected, the primary currents displayed are derived from the secondary values by multiplying them with CTR (CT ratio) and dividing them by $\sqrt{3}$. The phase angles shown are the same as the secondary values. If the CT connection type is known (DAB or DAC), you can correct the phase angles. The MET response is meant to show steady-state primary values. During unbalanced conditions the primary line currents cannot be reproduced accurately because the delta-connected CTs filter out the zero-sequence component of the line current. Wye-connected CTs do not have any such issue.

Table 5.1 Measured Fundamental Meter Values (Sheet 1 of 3)

Relay Option	Meter Values
All Models	Line Currents: IAW1, IBW1, ICW1 and IAW2, IBW2, ICW2 magnitude (A primary) and phase angle (deg) for Windings 1 and 2 IGW1, IGW2 (Residual Ground Fault Current) magnitude (A primary) and phase angle (deg) for Windings 1 and 2 I1W1, I2W2 (Positive-Sequence Current) magnitude (A primary) and angle (deg) for Windings 1 and 2 3I2W1, 3I2W2 (Negative-Sequence Current) magnitude (A primary) and angle (deg) for Windings 1 and 2 System Frequency (Hz)
Models With Empty or I/O Card in Slot E (SEL-787-2X)	Includes meter values shown for all models
Models With 1 ACI Card in Slot E (SEL-787-21)	Includes meter values shown for all models Neutral Current IN magnitude (A primary) and phase angle (deg)
Models With 1 ACI/ 3 AVI Card in Slot E (SEL-787-2E)	Includes meter values shown for all models Neutral Current IN magnitude (A primary) and phase angle (deg) VAB, VBC, VCA (DELTA-connected PTs) or VAN, VBN, VCN, VG (WYE-connected PTs) magnitude (V primary) and phase angle (deg) Positive-Sequence Voltage V1 magnitude (V primary) and phase angle (deg) Negative-Sequence Voltage 3V2 magnitude (V primary) and phase angle (deg) Real Power (kW)[a] Reactive Power (kVAR)[a] Apparent Power (kVA)[a] Power Factor[a] Volts/Hertz (%)

Table 5.1 Measured Fundamental Meter Values (Sheet 2 of 3)

Relay Option	Meter Values
Models With 4 ACI/ 3 AVI Card in Slot E (SEL-787-3E)	Includes meter values shown for all models
	Neutral Current IN magnitude (A primary) and phase angle (deg)
	Line Currents: IAW3, IBW3, ICW3 magnitude (A primary) and phase angle (deg) for Winding 3
	IGW3 (Residual Ground Fault Current) magnitude (A primary) and phase angle (deg) for Winding 3
	I1W3 (Positive-Sequence Current) magnitude (A primary) for Winding 3
	3I2W3 (Negative-Sequence Current) magnitude (A primary) for Winding 3
	VAB, VBC, VCA (DELTA-connected PTs) or VAN, VBN, VCN, VG (WYE-connected PTs) magnitude (V primary) and phase angle (deg)
	Positive-Sequence Voltage V1 magnitude (V primary) and phase angle (deg)
	Negative-Sequence Voltage 3V2 magnitude (V primary) and phase angle (deg)
	Real Power (kW)[a]
	Reactive Power (kVAR)[a]
	Apparent Power (kVA)[a]
	Power Factor[a]
	Volts/Hertz (%)

Table 5.1 Measured Fundamental Meter Values (Sheet 3 of 3)

Relay Option	Meter Values
Models With 3 ACI/ 4 AVI Card in Slot E (SEL-787-3S)	Includes meter values shown for all models Line Currents: IAW3, IBW3, ICW3 magnitude (A primary) and phase angle (deg) for Winding 3 IGW3 (Residual Ground Fault Current) magnitude (A primary) and phase angle (deg) for Winding 3 I1W3 (Positive-Sequence Current) magnitude (A primary) for Winding 3 3I2W3 (Negative-Sequence Current) magnitude (A primary) for Winding 3 VAB, VBC, VCA or VAN, VBN, VCN, VG magnitude (V primary) and phase angle (deg) Positive-Sequence Voltage V1 magnitude (V primary) and phase angle (deg) Negative-Sequence Voltage 3V2 magnitude (V primary) and phase angle (deg) Real Power (kW)[a] Reactive Power (kVAR)[a] Apparent Power (kVA)[a] Power Factor[a] Volts/Hertz (%) If setting VS_VBAT = VBAT: station battery VDC magnitude in Vdc If setting VS_VBAT = VS: synchronism-check voltage VS magnitude (V primary) and phase angle (deg) VS frequency FREQS (Hz)
Models With 6 ACI Card in Slot E (SEL-787-4X)	Includes meter values shown for all models Line Currents: IAW3, IBW3, ICW3, and IAW4, IBW4, ICW4 magnitude (A primary) and phase angle (deg) for Windings 3 and 4 IGW3, IGW4 (Residual Ground Fault Current) magnitude (A primary) and phase angle (deg) for Windings 3 and 4 I1W3, I1W4 (Positive-Sequence Current) magnitude (A primary) for Windings 3 and 4 3I2W3, 3I2W4 (Negative-Sequence Current) magnitude (A primary) for Windings 3 and 4 NOTE: If combined current settings CCW12, CCW23, or CCW34 are set to Y, then the meter report also shows the combined quantities.

[a] Single-phase measurements are available when DELTA_Y := WYE and WnCT = WYE.

All angles are displayed between –180 and +180 degrees. The angles are referenced to VAB or VAN (for delta- or wye-connected PTs, respectively) or IAW1. If the voltage channels are not supported, or if VAB < 13 V (for delta-connected PTs) or VAN < 13 V (for wye-connected PTs), the angles are referenced to IAW1 current. *Figure 5.2* and *Figure 5.3* show examples of the METER command report.

```
==>>MET <Enter>

SEL-787-4X                              Date: 08/22/2014 Time: 05:44:04.017
TRNSFRMR RELAY                          Time Source: Internal

                    IAW1     IBW1     ICW1     IGW1     I1W1     3I2W1
Wdg1 Mag (A pri.)      9.9      9.8     10.1      0.3      9.9      0.1
Wdg1 Angle (deg)       0.0   -121.2    119.5    105.4     -0.6    -24.8

                    IAW2     IBW2     ICW2     IGW2     I1W2     3I2W2
Wdg2 Mag (A pri.)     10.0     10.0     10.1      0.3     10.0      0.3
Wdg2 Angle (deg)      -1.4   -121.8    119.9    178.7     -1.1    -38.6

                    IAW3     IBW3     ICW3     IGW3     I1W3     3I2W3
Wdg3 Mag (A pri.)      9.9      9.9     10.0      0.6      9.9      0.4
Wdg3 Angle (deg)       0.7   -121.2    117.6     72.7     -1.0    120.4

                    IAW4     IBW4     ICW4     IGW4     I1W4     3I2W4
Wdg4 Mag (A pri.)      9.8     10.0      9.9      0.1      9.9      0.2
Wdg4 Angle (deg)       0.7   -118.9    120.7   -118.6      0.8    173.5

                     IAW12    IBW12    ICW12    IGW12    I1W12   3I2W12
Wdg12 Mag (A pri.)    19.9     19.8     20.1      0.5     19.9      0.4
Wdg12 Angle (deg)     -0.7   -121.5    119.7    137.6     -0.8    -34.9

                     IAW34    IBW34    ICW34    IGW34    I1W34   3I2W34
Wdg34 Mag (A pri.)    19.7     19.8     19.9      0.5     19.8      0.5
Wdg34 Angle (deg)      0.7   -120.1    119.2     75.4     -0.1    135.4

                FREQ
Frequency (Hz)  60.00

==>>
```

Figure 5.2 METER Command Report for SEL-787-4X Model

```
=>>MET <Enter>

SEL-787-3E                              Date: 02/04/2018   Time: 09:42:14.163
TRNSFRMR RELAY                          Time Source: Internal

                IAW1       IBW1       ICW1       IGW1       I1W1       3I2W1
Mag (A pri.)       99.9       99.9      100.1        0.1       99.9        0.2
Angle (deg)        -0.0     -120.0      120.0       74.2       -0.0     -129.4

                IAW2       IBW2       ICW2       IGW2       I1W2       3I2W2
Mag (A pri.)      999.2      999.5      998.4        1.2      999.0        0.8
Angle (deg)         0.1     -119.9      120.1      -80.2        0.1       70.6

                IAW3       IBW3       ICW3       IGW3       I1W3       3I2W3
Mag (A pri.)       10.0       10.1       10.0        0.1       10.0        0.1
Angle (deg)         0.1     -120.0      120.1     -102.1        0.1       72.1

                 IN
Mag (A pri.)        0.0
Angle (deg)         0.0

                 VAB        VBC        VCA        VA         VB         VC
Mag (V pri.)     2599.4     2599.9     2599.3     1501.1     1500.9     1500.6
Angle (deg)        30.0      -90.0      150.0        0.0     -120.0      120.0

                 VG         V1         3V2
Mag (V pri.)        1.3     1500.8        0.6
Angle (deg)       -21.3        0.0      169.1

                          A              B              C             3P
Real Pwr (kW)             1500           1500           1498          4498
Reactive Pwr (kVAR)         -2             -1             -3            -6
Apparent Pwr (kVA)        1500           1500           1498          4498
Pwr Factor                   1.00           1.00           1.00          1.00
                           LEAD           LEAD           LEAD          LEAD

                FREQ
Frequency (Hz)  59.99

V/Hz (%)  13.0
```

Figure 5.3 METER Command Report for SEL-787-3E Models

```
=>>MET <Enter>

SEL-787-21                              Date: 08/15/2017   Time: 11:26:03.389
TRNSFRMR RELAY                          Time Source: Internal

                IAW1       IBW1       ICW1       IGW1       I1W1       3I2W1
Mag (A pri.)     698.9      700.2      694.5        0.0      699.3        2.7
Angle (deg)        0.0     -120.1      120.5        0.0      -30.1      146.8

                IAW2       IBW2       ICW2       IGW2       I1W2       3I2W2
Mag (A pri.)    1207.0     1203.1     1210.0        9.7     1206.7       20.8
Angle (deg)        0.9     -118.6      121.7     -126.2        1.3      -69.7

                 IN
Mag (A pri.)       0.8
Angle (deg)      164.6

                FREQ
Frequency (Hz)  60.00

=>>
```

Figure 5.4 METER Command Report for SEL-787-21 Models

Differential Metering

The differential metering function in the SEL-787 reports the fundamental frequency operate and restraint currents for each differential element (87) in multiples of TAP. *Table 5.2* shows the value reported. *Figure 5.5* shows an example of the **METER DIF** (differential) command report. The differential report is processed only if the setting E87W*n* := Y (*n* = 1, 2, 3, or 4) for at least two windings.

Table 5.2 Measured Differential Meter Values

Relay Option	Differential Values
All Models	Operate currents IOP1, IOP2, IOP3, IOPQ in pu of TAP value for elements 87-1, 87-2, and 87-3, respectively (IOPQ is common to the elements) Restraint currents IRT1, IRT2, IRT3, IRTQ in pu of TAP value for elements 87-1, 87-2, and 87-3, respectively (IRTQ is common to the elements) IOP1F2, IOP2F2, and IOP3F2 are 2nd harmonic currents as a percentage of IOP1, IOP2, and IOP3, respectively IOP1F4, IOP2F4, IOP3F4 are 4th harmonic currents as a percentage of IOP1, IOP2, and IOP3, respectively IOP1F5, IOP2F5, and IOP3F5 are 5th harmonic currents as a percentage of IOP1, IOP2, and IOP3, respectively

```
=>>MET DIF <Enter>

SEL-787-4X                              Date: 08/20/2014 Time: 07:05:22.232
TRNSFRMR RELAY                          Time Source: Internal

                     IOP1    IOP2    IOP3    IOPQ
Operate      (pu)    6.53    6.53    6.55    0.00

                     IRT1    IRT2    IRT3    IRTQ
Restraint    (pu)    7.20    7.18    7.21    0.00

                   IOP1F2  IOP2F2  IOP3F2
2nd Harmonic (%)     0.00    0.00    0.01

                   IOP1F4  IOP2F4  IOP3F4
4th Harmonic (%)     0.00    0.01    0.01

                   IOP1F5  IOP2F5  IOP3F5
5th Harmonic (%)     0.03    0.01    0.07

=>>
```

Figure 5.5 METER DIF (Differential) Command Report

Thermal Metering

The thermal metering function reports the RTD meter values (see *Table 5.3* for details) and also reports the state of connected RTDs if any have failed (see *Table 5.4* for details).

Table 5.3 Thermal Meter Values

Relay Option	Thermal Values
Models With External SEL-2600 RTD Module or Internal RTD Option	All RTD Temperatures

Table 5.4 RTD Input Status Messages

Message	Status
Open	RTD leads open
Short	RTD leads shorted
Comm Fail	Fiber-optic communication to SEL-2600 RTD Module has failed
Stat Fail	SEL-2600 RTD Module self-test status failure

Figure 5.6 provides an example of the **METER T** command report.

```
=>>MET T <Enter>

SEL-787-4X                                 Date: 08/14/2014 Time: 12:34:14
TRNSFRMR RELAY                             Time Source: Internal

Ambient RTD       70 C
Max Other RTD    95 C

 RTD2  AMB        70 C
 RTD3  TEST3     -30 C
 RTD5  TEST5      75 C
 RTD6  TEST6      90 C
 RTD8  TEST8     -10 C
RTD10  TEST10     95 C
RTD11  TEST11     65 C
RTD12  TEST12     open

=>>
```

Figure 5.6 METER T Command Report With RTDs

Energy Metering

The SEL-787 with the voltage option includes energy metering. Use this form of metering to quantify real and reactive energy supplied by the transformer. Refer to *Figure 5.1* for the definitions of positive real power, negative real power, positive reactive power, and negative reactive power. Below are the energy meter values:

- MWhP—Positive real 3-phase energy
- MWhN—Negative real 3-phase energy
- MVARhP—Positive reactive 3-phase energy
- MVARhN—Negative reactive 3-phase energy
- Last date and time energy meter quantities were reset

NOTE: Energy values roll over after 99,999.999 MVAh and reset to 0.

Figure 5.7 shows the device response to the **METER E** command.

```
=>MET E <Enter>

SEL-787-4X                                Date: 08/23/2014 Time: 13:48:27
TRNSFRMR RELAY                            Time Source: Internal

Energy
Positive MWH (MWh)           5.300
Negative MWH (MWh)           0.000
Positive MVARH (MVArh)       0.000
Negative MVARH (MVArh)       0.411

LAST RESET = 08/20/2014 10:55:52
=>
```

Figure 5.7 METER E Command Report

To reset energy meter values, issue the **MET RE** command, as shown in *Figure 5.8*.

```
=>>MET RE <Enter>
Reset Metering Quantities (Y,N)? Y <Enter>
Reset Complete
=>>
```

Figure 5.8 METER RE Command Report

Energy metering values are stored to nonvolatile memory four times per day and within one minute of the energy metering values being reset.

Maximum and Minimum Metering

Maximum and minimum metering allows you to determine maximum and minimum operating quantities such as currents, voltages, power, analog input quantities, RTD quantities and frequency. *Table 5.5* lists the max/min metering quantities.

Table 5.5 Maximum and Minimum Meter Values (Sheet 1 of 2)

Relay Option	Max/Min Meter Values
All Models	Maximum and minimum line current magnitude IAW1, IBW1, ICW1, IAW2, IBW2, ICW2 (A primary) Maximum and minimum IG (residual ground fault current) magnitude (A primary) Maximum and minimum system frequency (Hz)
Models With Empty or I/O Card in Slot E (SEL-787-2X)	Includes the maximum and minimum meter values shown for all models (A primary)
Models With 1 ACI Card in Slot E (SEL-787-21)	Includes the maximum and minimum meter values shown for all models and the maximum and minimum neutral current IN magnitude (A primary)
Models With 1 ACI/3 AVI Card in Slot E (SEL-787-2E)	Includes the maximum and minimum meter values shown for all models and the maximum and minimum neutral current IN magnitude (A primary) Maximum and minimum VAB, VBC, VCA, or VAN, VBN, VCN, VG magnitudes (V primary) Maximum and minimum real, reactive, and apparent 3-phase power (kW, kVAR, kVA)

Table 5.5 Maximum and Minimum Meter Values (Sheet 2 of 2)

Relay Option	Max/Min Meter Values
Models With 4 ACI/3 AVI Card in Slot E (SEL-787-3E)	Includes the maximum and minimum meter values shown for all models and the maximum and minimum neutral current IN magnitude (A primary) Maximum and minimum line current magnitude IAW3, IBW3, ICW3 (A primary) Maximum and minimum IGW3 (Residual Ground Fault Current) magnitude (A primary) Maximum and minimum VAB, VBC, VCA, or VAN, VBN, VCN, VG magnitudes (V primary) Maximum and minimum real, reactive, and apparent 3-phase power (kW, kVAR, kVA)
Models With 3 ACI/4 AVI Card in Slot E (SEL-787-3S)	Includes the maximum and minimum meter values shown for all models and the maximum and minimum line current magnitude IAW3, IBW3, ICW3 (A primary) Maximum and minimum IGW3 (Residual Ground Fault Current) magnitude (A primary) Maximum and minimum VAB, VBC, VCA or VAN, VBN, VCN, VG magnitude (V primary) Maximum and minimum real, reactive and apparent 3-phase power (kW, kVAR, kVA)
Models With 6 ACI Current Card in Slot E (SEL-787-4X)	Includes the maximum and minimum meter values shown for all models Maximum and minimum line current magnitude IAW3, IBW3, ICW3, IAW4, IBW4, ICW4 (A primary) Maximum and minimum IGW3, IGW4 (Residual Ground Fault Current) magnitude (A primary)
Models With RTD Option or SEL-2600 RTD Module	Maximum and minimum RTD temperatures (°C)
Models With Analog Input Option	Maximum and minimum analog input values (engineering units)

All maximum and minimum metering values will have the date and time on which they occurred. The analog quantities in *Table 5.5* are checked approximately every second and, if a new maximum or minimum value occurs, this value is saved along with the date and time that the maximum or minimum value occurred. Maximum and minimum values are only checked if relay element FAULT is deasserted (no fault condition exists) for at least one second. Additionally, the following minimum thresholds must also be met:

- ➤ Current magnitudes of IAW*n*, IBW*n*, and ICW*n*: 3% of the nominal current (I_{NOM} • CTR*n*) (*n* = 1, 2, 3, or 4 depending on the winding)
- ➤ Current magnitude of IGW*n*: IAW*n*, IBW*n*, and ICW*n* all must be above their thresholds (*n* =1, 2, 3, or 4 depending on the winding)
- ➤ Current magnitude of IN: 3% of the nominal IN rating (I_{NOM} • CTRN)

➤ Voltage values (phase-to-neutral and phase-to-phase): 7.5 • PTR V and 13 • PTR V, respectively

➤ Power values (real, reactive, and apparent): All three currents (IAW*n*, IBW*n*, ICW*n*) and all three voltages (VA, VB, VC or VAB, VBC, VCA) must be above their thresholds

Figure 5.9 shows an example device response to the **METER M** command.

```
=>>MET M <Enter>

SEL-787-4X                                  Date: 09/17/2014   Time: 13:09:09.718
TRNSFRMR RELAY                              Time Source: Internal

              MAX        DATE       TIME       MIN        DATE       TIME
IAW1 (A)     14163     09/17/2014  13:07:51     14151     09/17/2014  13:07:23
IBW1 (A)     15198     09/17/2014  13:07:34     15189     09/17/2014  13:07:14
ICW1 (A)     15170     09/17/2014  13:08:53     15159     09/17/2014  13:07:41
IGW1 (A)      1032.1   09/17/2014  13:08:50      1011.7   09/17/2014  13:07:54
IAW2 (A)     12265     09/17/2014  13:08:30     12257     09/17/2014  13:09:00
IBW2 (A)     13192     09/17/2014  13:07:32     13176     09/17/2014  13:07:11
ICW2 (A)     13200     09/17/2014  13:07:15     13182     09/17/2014  13:07:37
IGW2 (A)       963.4   09/17/2014  13:07:26       932.7   09/17/2014  13:07:07
IAW3 (A)     17203     09/17/2014  13:07:02     17189     09/17/2014  13:07:24
IBW3 (A)     18213     09/17/2014  13:06:53     18199     09/17/2014  13:07:59
ICW3 (A)     18244     09/17/2014  13:07:16     18222     09/17/2014  13:06:54
IGW3 (A)      1052.7   09/17/2014  13:08:42      1016.6   09/17/2014  13:07:47
IAW4 (A)     19236     09/17/2014  13:07:49     19220     09/17/2014  13:07:20
IBW4 (A)     20203     09/17/2014  13:07:36     20190     09/17/2014  13:07:15
ICW4 (A)     20151     09/17/2014  13:07:18     20140     09/17/2014  13:07:49
IGW4 (A)       959.1   09/17/2014  13:06:47       937.1   09/17/2014  13:07:50

LAST RESET = 09/17/2014 13:00:08

=>>
```

Figure 5.9 METER M Command Report for the SEL-787-4X

```
=>>MET M <Enter>

SEL-787-3S                                  Date: 09/17/2014   Time: 15:13:28.969
TRNSFRMR RELAY                              Time Source: Internal

                    MAX        DATE       TIME       MIN        DATE       TIME
IAW1 (A)          6062.7    09/17/2014  15:13:24     4041.0    09/17/2014  15:13:07
IBW1 (A)          6083.2    09/17/2014  15:13:20     4055.7    09/17/2014  15:13:00
ICW1 (A)          6080.1    09/17/2014  15:13:25     4055.8    09/17/2014  15:13:14
IGW1 (A)            21.7    09/17/2014  15:13:27       17.4    09/17/2014  15:13:13
IAW2 (A)          7141.3    09/17/2014  15:13:24     5099.3    09/17/2014  15:13:16
IBW2 (A)          7108.7    09/17/2014  15:13:26     5067.8    09/17/2014  15:12:57
ICW2 (A)          7100.7    09/17/2014  15:13:18     5062.2    09/17/2014  15:12:55
IGW2 (A)            55.3    09/17/2014  15:13:20       46.9    09/17/2014  15:13:17
IAW3 (A)          8015.4    09/17/2014  15:13:24     6012.7    09/17/2014  15:13:13
IBW3 (A)          7967.1    09/17/2014  15:13:20     5969.8    09/17/2014  15:13:01
ICW3 (A)          7958.4    09/17/2014  15:13:19     5963.7    09/17/2014  15:12:57
IGW3 (A)            64.2    09/17/2014  15:13:22       55.5    09/17/2014  15:13:16
VA (V)           11658      09/17/2014  15:12:55    11656      09/17/2014  15:13:13
VB (V)           11661      09/17/2014  15:13:27    11658      09/17/2014  15:12:58
VC (V)           12043      09/17/2014  15:13:10    12040      09/17/2014  15:13:27
KW3P (kW)       432865      09/17/2014  15:13:26   300485      09/17/2014  15:13:08
KVAR3P (kVAR)   -83766      09/17/2014  15:12:56  -125600      09/17/2014  15:13:22
KVA3P (kVA)     450716      09/17/2014  15:13:25   311952      09/17/2014  15:13:07
FREQ (Hz)           60.0    09/17/2014  15:13:09       60.0    09/17/2014  15:13:02

LAST RESET = 09/17/2014 15:12:54

=>>
```

Figure 5.10 METER M Command Report for the SEL-787-3S

```
=>>MET M <Enter>

SEL-787-2E                                Date: 01/04/2000   Time: 08:09:41.209
TRNSFRMR RELAY                            Time Source: Internal

                  MAX        DATE       TIME       MIN         DATE       TIME
IAW1 (A)          605.4   01/04/2000  08:09:36      503.8   01/04/2000  08:01:51
IBW1 (A)          701.6   01/04/2000  08:09:36      501.9   01/04/2000  08:01:52
ICW1 (A)          802.4   01/04/2000  08:09:36      501.1   01/04/2000  08:01:48
IGW1 (A)          171.5   01/04/2000  08:09:35        5.2   01/04/2000  08:09:33
IAW2 (A)          598.3   01/04/2000  08:09:35      497.5   01/04/2000  08:01:48
IBW2 (A)          707.5   01/04/2000  08:09:36      505.3   01/04/2000  08:01:51
ICW2 (A)          803.2   01/04/2000  08:09:35      501.9   01/04/2000  08:01:51
IGW2 (A)          179.4   01/04/2000  08:09:35       10.9   01/04/2000  08:09:32
IN (A)            932.3   01/04/2000  08:09:35      517.7   01/04/2000  08:01:50
VA (V)           6785.2   01/04/2000  08:09:35     6493.9   01/04/2000  08:09:33
VB (V)           7756.2   01/04/2000  08:09:35     6489.4   01/04/2000  08:01:47
VC (V)           9030.4   01/04/2000  08:09:36     6720.2   01/04/2000  08:01:51
KW3P (kW)       14194     01/04/2000  08:09:35     8395.2   01/04/2000  08:01:51
KVAR3P (kVAR)   -5198.4   01/04/2000  08:01:50    -8958.2   01/04/2000  08:09:36
KVA3P (kVA)     16785     01/04/2000  08:09:36     9873.9   01/04/2000  08:01:48
FREQ (Hz)          60.0   01/04/2000  08:07:58       60.0   01/04/2000  08:01:50

LAST RESET = 01/04/2000 07:22:32
=>>
```

Figure 5.11 METER M Command Report for the SEL-787-2E

To reset maximum and minimum meter values, issue the **MET RM** command as shown in *Figure 5.12*. The max/min meter values can be reset from the serial port, the front panel, or the assertion of the RSTMXMN relay element. The date and time of the reset are preserved and shown in the max/min meter report.

```
=>MET RM <Enter>
Reset Metering Quantities (Y,N)? Y <Enter>
Reset Complete
=>
```

Figure 5.12 METER RM Command Response

All maximum and minimum metering values are stored to nonvolatile memory four times per day and within one minute of the maximum and minimum metering values being reset.

Math Variable Metering

The SEL-787 includes 32 math variables (MV). When you receive your SEL-787, no math variables are enabled. To use math variables, enable the number of math variables (between 1 and 32) you require, using the EMV setting in the Logic setting category. *Figure 5.13* shows the device response to the **METER MV** command with 8 of the 32 math variables enabled.

```
=>>MET MV <Enter>

SEL-787-4X                                 Date: 08/11/2014    Time: 12:32:10
TRNSFRMR RELAY                             Time Source: Internal

MV01       1.00
MV02   -32767.00
MV03      -1.00
MV04       0.00
MV05    1000.59
MV06   -1000.61
MV07    2411.01
MV08    2410.99

=>>
```

Figure 5.13 MET MV Command Report

RMS Metering

The SEL-787 includes root-mean-square (rms) metering. Use rms metering to measure the entire signal (including harmonics). You can measure the rms quantities shown in *Table 5.6*.

Table 5.6 RMS Meter Values

Relay Option	RMS Meter Values
All Models	RMS current IAW1, IBW1, ICW1, IAW2, IBW2, and ICW2 magnitudes (A primary)
Models With Empty or I/O Card in Slot E (SEL-787-2X)	Includes the maximum and minimum meter values shown for all models.
Models With 1 ACI Card in Slot E (SEL-787-21)	Includes the maximum and minimum meter values shown for all models and the maximum and minimum neutral current IN magnitude (A primary)
Models With 1 ACI/ 3 AVI Card in Slot E (SEL-787-2E)	Includes the maximum and minimum meter values shown for all models and the maximum and minimum neutral current IN magnitude (A primary) Maximum and minimum VAB, VBC, VCA, or VAN, VBN, VCN, VG magnitudes (V primary)
Models With 4 ACI/ 3 AVI Card in Slot E (SEL-787-3E)	Includes the rms meter values shown for all models and rms current IAW3, IBW3, ICW3, and IN magnitudes (A primary) VAB, VBC, VCA or VAN, VBN, VCN rms magnitudes (V primary)
Models With 3 ACI/ 4 AVI Card in Slot E (SEL-787-3S)	Includes the rms meter values shown for all models and rms current IAW3, IBW3, ICW3 (A primary) VAB, VBC, VCA or VAN, VBN, VCN, and VS rms magnitudes (V primary)
Models With 6 ACI Current Card in Slot E (SEL-787-4X)	Includes the rms meter values shown for all models and rms current IAW3, IBW3, ICW3, IAW4, IBW4, and ICW4 magnitudes (A primary)

RMS quantities contain the total signal, including harmonics. This differs from the fundamental meter (**METER** command) in that the fundamental meter quantities only contain the fundamental frequency (60 Hz for a 60-Hz system). *Figure 5.14* shows the METER RMS command report.

```
=>MET RMS <Enter>

SEL-787-4X                                Date: 09/10/2014   Time: 15:44:30.139
TRNSFRMR RELAY                            Time Source: Internal

               IAW1     IBW1     ICW1
RMS (A pri.)    403.0    498.0    600.5

               IAW2     IBW2     ICW2
RMS (A pri.)   5005.0   5990.0   4000.0

               IAW3     IBW3     ICW3
RMS (A pri.)  30800.0  20450.0  25775.0

               IAW4     IBW4     ICW4
RMS (A pri.)  60500.0  50250.0  40450.0

=>
```

Figure 5.14 METER RMS Command Report

Analog Input Metering

The SEL-787 can monitor analog (transducer) quantities that it is measuring if equipped with optional analog inputs. Analog input metering shows transducer values from standard voltage and current transducers. You can use these values for automation and control applications within an industrial plant.

Through the global settings, you can set each type of analog input to the type of transducer that drives that analog input. You also set the range of the transducer output. Analog inputs can accept both current and voltage transducer outputs. Ranges for the current transducers are ±20 mA and ranges for the voltage transducers are ±10 V. You also set the corresponding output of the analog inputs in engineering units. See *Section 4: Protection and Logic Functions* for an explanation of how to set up analog inputs for reading transducers. *Figure 5.15* shows an example of analog input metering.

```
=>MET AI <Enter>

SEL-787-4X                                  Date: 08/23/2014   Time: 13:44:44
TRNSFRMR RELAY                              Time Source: Internal

Input Card 3
AI301 (mA)   -0.008
AI302 (mA)   -0.007
AI303 (mA)   -0.001
AI304 (mA)   -0.006

=>
```

Figure 5.15 METER AI Command Report

Demand Metering

The SEL-787 offers the choice between two types of demand metering, settable with the enable setting:

EDEM := THM (Thermal Demand Metering)
or

EDEM := ROL (Rolling Demand Metering)

The relay provides demand (**METER DE** command) and peak demand (**METER PE** command) metering for the winding selected (Winding 1 or Winding 2). *Table 5.7* shows the values reported. *Figure 5.16* provides an example of the METER DE (demand) command report and *Figure 5.17* provides an example of the METER PE (peak demand) command report. Refer to *Demand Metering on page 4.95* for detailed descriptions and settings selection.

Table 5.7 Demand Values

Relay Option	Demand/Peak Demand Values
All Models	Demand/Peak Demand values of line currents IAW*n*, IBW*n*, and ICW*n* magnitudes (A primary) Demand/Peak Demand value of IGW*n* (residual ground fault current) magnitude (A primary) Demand/peak demand value of negative-sequence current (3I2W*n*) magnitude (A primary), where *n* = 1, 2, 3, or 4, depending on the winding selected.

```
=>MET DEM <Enter>

SEL-787-4X                              Date: 08/23/2014   Time: 13:46:56
TRNSFRMR RELAY                          Time Source: Internal

                  IAD      IBD      ICD      IGD     3I2D
DEMAND (A pri.)     53.9     55.9     54.8      2.1      1.4

LAST RESET = 07/23/2014 13:45:38
=>
```

Figure 5.16 METER DEM Command Report

```
=>MET P <Enter>

SEL-787-4X                              Date: 08/23/2014   Time: 13:47:00
TRNSFRMR RELAY                          Time Source: Internal

                 IAPD     IBPD     ICPD     IGPD     3I2PD
DEMAND (A pri.)     55.8     57.8     56.7      2.1      1.4

LAST RESET = 07/23/2014 13:45:37
=>
```

Figure 5.17 METER P Command Report

Peak demand metering values are stored to nonvolatile memory four times per day and within one minute of the peak demand metering values being reset. Demand metering is stored in volatile memory only, and the data are lost when power to the relay is removed.

Harmonic Metering

The harmonic metering function in the SEL-787 reports the current and voltage harmonics through the fifth harmonic and the total harmonic distortion percentage (THD %). *Table 5.8* shows the harmonic values reported. *Figure 5.18* provides an example of the METER H (harmonic) command report.

Table 5.8 Measured Harmonic Meter Values (Sheet 1 of 2)

Relay Option	Harmonic Values
All Models	Fundamental magnitude (secondary A) and 2nd-, 3rd-, 4th-, 5th-harmonic % values and THD % of line currents IAW1, IBW1, ICW1, IAW2, IBW2, and ICW2
Models With Empty or I/O Card in Slot E (SEL-787-2X)	Includes the harmonic meter values shown for all models and fundamental magnitude (secondary A)
Models With 1 ACI Card in Slot E (SEL-787-21)	Includes the harmonic meter values shown for all models and fundamental magnitude, 2nd-, 3rd-, 4th, and 5th-harmonic % values, THD % of neutral current IN (secondary A)
Models With 1 ACI/ 3 AVI Card in Slot E (SEL-787-2E)	Includes the harmonic meter values shown for all models and fundamental magnitude (secondary A or V), 2nd-, 3rd-, 4th-, 5th-harmonic % values, THD % of neutral current IN, and voltages VAB, VBC, VCA or VAN, VBN, VCN
Models With 4 ACI/ 3 AVI Card in Slot E (SEL-787-3E)	Includes the harmonic meter values shown for all models and fundamental magnitude (secondary A or V), 2nd-, 3rd-, 4th-, 5th-harmonic % values, THD % of neutral current IN, line currents IAW3, IBW3, ICW3, and voltages VAB, VBC, VCA or VAN, VBN, VCN

Table 5.8 Measured Harmonic Meter Values (Sheet 2 of 2)

Relay Option	Harmonic Values
Models With 3 ACI/ 4 AVI Card in Slot E (SEL-787-3S)	Includes the harmonic meter values shown for all models and fundamental magnitude (secondary A or V), 2nd-, 3rd-, 4th-, and 5th-harmonic % values, THD % of voltages VAB, VBC, VCA or VAN, VBN, VCN, and line currents IAW3, IBW3, ICW3
Models With 6 ACI Current Card in Slot E (SEL-787-4X)	Includes the harmonic meter values shown for all models and fundamental magnitude (secondary A) and 2nd-, 3rd-, 4th-, 5th-harmonic % values and THD % of line currents IAW3, IBW3, ICW3, IAW4, IBW4, and ICW4

```
=>>MET H <Enter>

SEL-787-4X                                 Date: 09/24/2014   Time: 15:23:41.940
TRNSFRMR RELAY                             Time Source: Internal

             IAW1   IBW1   ICW1   IAW2   IBW2   ICW2
Fund (sec)    1.0    1.0    1.0    2.0    2.0    2.0
2nd (%)       0.3    0.4    0.5    0.2    0.3    0.3
3rd (%)       0.5    0.6    0.6    0.2    0.3    0.2
4th (%)       0.4    0.4    0.5    0.2    0.2    0.3
5th (%)       0.6    0.6    0.9    0.3    0.3    0.2
THD (%)       0.9    1.0    1.2    0.5    0.5    0.5

             IAW3   IBW3   ICW3   IAW4   IBW4   ICW4
Fund (sec)    1.0    1.0    1.0    2.0    2.0    2.0
2nd (%)       0.3    0.4    0.5    0.2    0.3    0.3
3rd (%)       0.5    0.6    0.6    0.2    0.3    0.2
4th (%)       0.4    0.4    0.5    0.2    0.2    0.3
5th (%)       0.6    0.6    0.9    0.3    0.3    0.2
THD (%)       0.9    1.0    1.2    0.5    0.5    0.5

=>>
```

Figure 5.18 METER H Command Report for the SEL-787-4X Model

```
=>>MET H <Enter>

SEL-787-3S                                 Date: 08/28/2017   Time: 14:37:36.650
TRNSFRMR RELAY                             Time Source: Internal

             IAW1   IBW1   ICW1   IAW2   IBW2   ICW2
Fund (sec)    0.6    0.7    0.8    0.6    0.7    0.8
2nd (%)       7.5   11.3    3.9    7.3   11.2    3.9
3rd (%)       9.0    9.0    5.1    9.0    9.0    5.1
4th (%)       9.6    6.3    5.9    9.2    6.6    5.8
5th (%)      10.6    3.7    6.7   10.5    3.7    6.8
THD (%)      18.2   16.0   10.9   17.9   16.0   10.9

             IAW3   IBW3   ICW3    VA     VB     VC
Fund (sec)    0.6    0.7    0.8    2.0    3.0    4.0
2nd (%)       7.2   11.2    4.2    0.0    0.0    0.0
3rd (%)       9.1    9.1    5.3    0.0    0.0    0.0
4th (%)       9.4    6.5    6.0    0.0    0.0    0.0
5th (%)      11.0    4.1    6.8    0.0    0.0    0.0
THD (%)      18.2   16.1   11.2    0.0    0.0    0.0

=>>
```

Figure 5.19 METER H Command Report for the SEL-787-3S Model

```
=>>MET H <Enter>

SEL-787-2X                                    Date: 08/17/2017   Time: 13:36:44.254
TRNSFRMR RELAY                                Time Source: Internal

             IAW1    IBW1    ICW1    IAW2    IBW2    ICW2
Fund (sec)    14.0    15.0    16.0    14.0    15.0    16.0
2nd (%)       11.0     4.0     8.0    11.0     4.0     8.0
3rd (%)        9.0     5.0     9.0     9.1     5.0     9.0
4th (%)        6.0     6.0    10.0     6.0     6.0    10.0
5th (%)        4.0     7.0    11.0     4.0     7.0    11.0
THD (%)       15.7    11.2    18.8    15.8    11.2    18.8

=>>
```

Figure 5.20 METER H Command Report for the SEL-787-2X Model

Synchrophasor Metering

NOTE: To have the MET PM xx:yy:zzz response transmitted from a serial port, the corresponding port must have the AUTO settings set to Y (YES).

The **MET PM** serial port ASCII command may be used to view the SEL-787 synchrophasor measurements. 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, to compare it with similar data captured in other phasor measurement unit(s) at the same time.
- ➤ As a method of periodically gathering synchrophasor data through a communications processor.

The **MET PM** command displays the same set of analog synchrophasor information, regardless of the Global settings PHDATAV, PHDATAI, and PHCURR. The **MET PM** command can function even when no serial ports are sending synchrophasor data.

The **MET PM** command only operates when the SEL-787 is in the IRIG timekeeping mode, as indicated by Relay Word bit TSOK = logical 1. *Table 5.9* shows the measured values for the **MET PM** command. *Figure K.7* in *Appendix K: Synchrophasors*, shows a sample **MET PM** command response. The **MET PM** ***xx:yy:zzz*** command can be used to direct the SEL-787 to display the synchrophasor for an exact specified time, in 24-hour format. For example, entering the command **MET PM** 14:14:12 results in a response similar to *Figure K.7*, occurring just after 14:14:12, with the time stamp 14:14:12.000. Refer to *Appendix K: Synchrophasors*, for further details on synchrophasor measurements, settings, IEEE C37.118 Protocol, etc.

Table 5.9 Synchrophasor Measured Values (Sheet 1 of 2)

Relay Option	Meter Values
All Models	Currents: IAW1, IBW1, ICW1, I1W1 (Winding 1 positive-sequence current), IAW2, IBW2, ICW2, I1W2 (Winding 2 positive-sequence current), magnitude (A primary) and phase angle (deg) TSOK and SV17–SV32 Relay Word bit status MV29–MV32 Math Variables[a] System frequency (Hz) = 50 or 60 Hz
Models With Empty or I/O Card in Slot E (SEL-787-2X)	Includes synchrophasor meter values shown for all models. Rate-of-change of frequency = 0
Models With 1 ACI Card in Slot E (SEL-787-21)	Includes synchrophasor meter values shown for all models and IN magnitude (A primary) and phase angle (deg) Rate-of-change of frequency = 0

Table 5.9 Synchrophasor Measured Values (Sheet 2 of 2)

Relay Option	Meter Values
Models With 1 ACI/ 3 AVI Card in Slot E (SEL-787-2E)	Includes synchrophasor meter values shown for all models and IN magnitude (A primary) and phase angle (deg) Voltage phasors: VAB, VBC, VCA or VAN, VBN, VCN, and V1 (positive-sequence voltage), magnitude (V or kV), and phase angle (deg) Rate-of-change of frequency (Hz/s)
Models With 4 ACI/ 3 AVI Card in Slot E (SEL-787-3E)	Includes synchrophasor meter values shown for all models and IAW3, IBW3, ICW3, I1W3 (Winding 3 positive-sequence current) Voltage phasors: VAB, VBC, VCA or VAN, VBN, VCN, and V1 (positive-sequence voltage), magnitude (V or kV), and phase angle (deg) Rate-of-change-of-frequency (Hz/s)
Models With 3 ACI/ 4 AVI Card in Slot E (SEL-787-3S)	Includes synchrophasor meter values shown for all models and IAW3, IBW3, ICW3, I1W3 (Winding 3 positive-sequence current) Voltage phasors: VAB, VBC, VCA or VAN, VBN, VCN, VS, and V1 (positive-sequence voltage), magnitude (V or kV), and phase angle (deg) Rate-of-change-of-frequency (Hz/s)
Models With 6 ACI Current Card in Slot E (SEL-787-4X)	Includes the synchrophasor meter values shown for all models and IAW3, IBW3, ICW3, I1W3 (Winding 3 positive-sequence current), IAW4, IBW4, ICW4, I1W4 (Winding 4 positive-sequence current) Rate-of-change-of-frequency = 0

[a] These data are calculated every 25 ms. Only the data that occur at the top of the second are used for MET PM responses.

Remote Analog Metering

Use remote analog metering to verify the values received from an external device. The SEL-787 includes 128 remote analog variables. In *Appendix C: SEL Communications Processors*, we show how to enter remote analog settings in an SEL communications processor and the SEL-787. *Figure 5.21* shows an example of the METER RA command report for the settings in *Appendix C: SEL Communications Processors*.

```
=>>MET RA <Enter>
SEL-787-3E                              Date: 05/03/2018   Time: 10:15:10.223
TRNSFRMR RELAY                          Time Source: Internal

RA001        1.00
RA002  -32767.00
RA003       -1.00
RA004        0.00
RA005     1000.59
RA006    -1000.61
RA007     2411.01
RA008     2410.99
RA009    98303.00
RA010  -98303.00
RA011  -38400.00
RA012  -65536.00
RA013        0.00
RA014        0.00
RA015        0.00
. .
. .
. .
RA126        0.00
RA127        0.00
RA128        0.00
=>>
```

Figure 5.21 MET RA Command Report

Small Signal Cutoff for Metering

The relay applies a threshold to the secondary voltage and current magnitude metering quantities to force a reading to zero when the measurement is near zero. The threshold for fundamental metering current values is 0.01 • I_{NOM} A (secondary) and for voltage values is 0.1 V (secondary). The threshold for rms metering current values is 0.03 • I_{NOM} A (secondary) and for voltage values is 0.3 V (secondary).

The Global setting METHRES (as shown in *Table 4.50*) controls how these metering functions work when the metered value is smaller than the previously stated threshold.

METHRES := Y

Set METHRES := Y to force the fundamental and rms metering values of currents and voltages to zero when the corresponding applied signals fall below the previously stated thresholds.

METHRES := N

Set METHRES := N to bypass the meter threshold checks and disable the metering cutoff.

Load Profiling

The SEL-787 includes a load profiling function. The relay automatically records as many as 17 selected quantities into nonvolatile memory every 5, 10, 15, 30, or 60 minutes, depending on the LDAR load profile report setting (see *Load Profile Settings on page 4.158*). Choose which analog quantities you want to monitor from the analog quantities listed in *Appendix M: Analog Quantities*. Set these quantities into the LDLIST load profile list report setting.

The relay memory can hold data for 9800 time-stamped entries. For example, if you chose to monitor 10 values at a rate of every 15 minutes, you could store 102 days worth of data.

Download the load rate profile data using the serial port **LDP** command described in *LDP Command (Load Profile Report) on page 7.54*. *Figure 5.22* shows an example LDP report.

```
=>LDP <Enter>

SEL-787-4X                              Date: 2014/01/17 Time: 18:07:05
TRNSFRMR RELAY                            Time Source: Internal

#    DATE      TIME        IAW1_MAG IAW1_ANG IBW1_MAG IBW1_ANG ICW1_MAG ICW1_ANG
23 2014/01/14 16:16:40.992    0.099 0.000     0.225    -52.125    0.344 -108.435
22 2014/01/14 16:21:40.270 124.580 0.000   124.853   -119.627  123.668  120.426
21 2014/01/14 16:26:40.157 124.346 0.000   124.902   -119.358  123.626  120.711
20 2014/01/14 16:31:40.019 124.309 0.000   124.886   -119.598  123.973  120.577
19 2014/01/14 16:36:40.024 124.293 0.000   124.836   -119.361  123.403  120.631
18 2014/01/14 16:41:40.056 124.559 0.000   124.813   -119.709  123.970  120.493
17 2014/01/14 16:46:40.275 124.249 0.000   124.774   -119.646  123.907  120.574
16 2014/01/14 16:51:40.333 124.589 0.000   124.671   -119.569  123.603  120.483
15 2014/01/14 16:56:40.908   0.088 0.000     0.188     45.000    0.395  -26.565
14 2014/01/15 17:01:40.934 124.293 0.000   124.842   -119.504  123.485  120.619
13 2014/01/15 17:06:40.972 124.490 0.000   124.758   -119.463  123.546  120.518
12 2014/01/15 17:11:40.038 124.341 0.000   124.741   -119.297  123.424  120.779
11 2014/01/16 17:16:40.045 124.320 0.000   125.130   -119.517  123.630  120.623
10 2014/01/16 17:21:40.295 124.476 0.000   124.687   -119.537  123.518  120.455
9  2014/01/16 17:26:40.070 124.284 0.000   124.874   -119.413  123.649  120.818
8  2014/01/16 17:31:40.168   0.129 0.000     0.182    106.928    0.210   49.399
7  2014/01/17 17:36:40.215 124.313 0.000   125.154   -119.530  123.752  120.662
6  2014/01/17 17:41:40.803 124.383 0.000   124.992   -119.613  123.796  120.550
5  2014/01/17 17:46:40.282 124.446 0.000   124.799   -119.464  123.600  120.444
4  2014/01/17 17:51:40.077 124.432 0.000   124.710   -119.774  123.728  120.379
3  2014/01/17 17:56:40.114 124.288 0.000   125.274   -119.590  123.905  120.605
2  2014/01/17 18:01:41.047 124.392 0.000   124.730   -119.483  123.404  120.576
1  2014/01/17 18:06:41.020   0.210 0.000     0.099     -8.130    0.182  -57.529

=>
```

Figure 5.22 LDP Command Report

LDP data are also available as a read-only file that can be retrieved through the use of Ethernet File Transfer Protocol (FTP) or Manufacturing Message Specification (MMS). MMS is only available in models that support IEC 61850 and only when IEC 61850 and MMS file transfer are enabled (E61850 = Y, EMMSFS := Y). See *File Transfer Protocol (FTP) and MMS File Transfer on page 7.15*, *Virtual File Interface on page 7.73*, and *MMS on page G.5* for additional information.

Station DC Battery Monitor

NOTE: DC battery monitor settings are available in the SEL-787-3S model and when VS_VBAT := VBAT.

The station dc battery monitor in the SEL-787 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 function is available with the 3 ACI/4 AVI card option in Slot E of the relay. The monitor measures the station dc battery voltage applied to the rear-panel terminals labeled E07 (VBAT+) and E08 (VBAT–). The station dc battery monitor settings (DCLOP and DCHIP) are available via the **SET G** command (see *Table 5.10* and *Global Settings (SET G Command) on page SET.45*).

DC Under- and Overvoltage Elements

Table 5.10 Station DC Battery Monitor Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
DC UNDER VOLT PU	OFF, 20.00–300.00 Vdc	DCLOP := OFF
DC OVER VOLT PU	OFF, 20.00–300.00 Vdc	DCHIP := OFF

Refer to *Figure 5.23*. 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, 0.01Vdc increments

This range allows the SEL-787 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-787 outside of its power supply limits. See *Specifications: General on page 1.12* for the various power supply specifications. The power supply rating is located on the serial number sticker on the relay side panel.

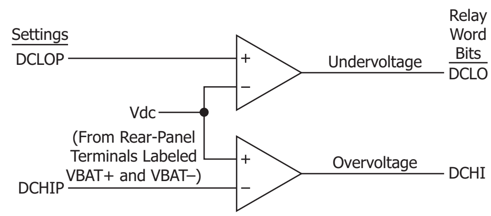


Figure 5.23 DC Under- and Overvoltage Elements

Logic outputs DCLO and DCHI in *Figure 5.23* operate as follows:

DCLO = 1 (logical 1), if Vdc ≤ pickup setting DCLOP
= 0 (logical 0), if Vdc > pickup setting DCLOP

DCHI = 1 (logical 1), if Vdc ≥ pickup setting DCHIP
= 0 (logical 0), if Vdc < 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 5.24 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 SV*n*T and then routed to output contact OUT*xxx* for alarm purposes.

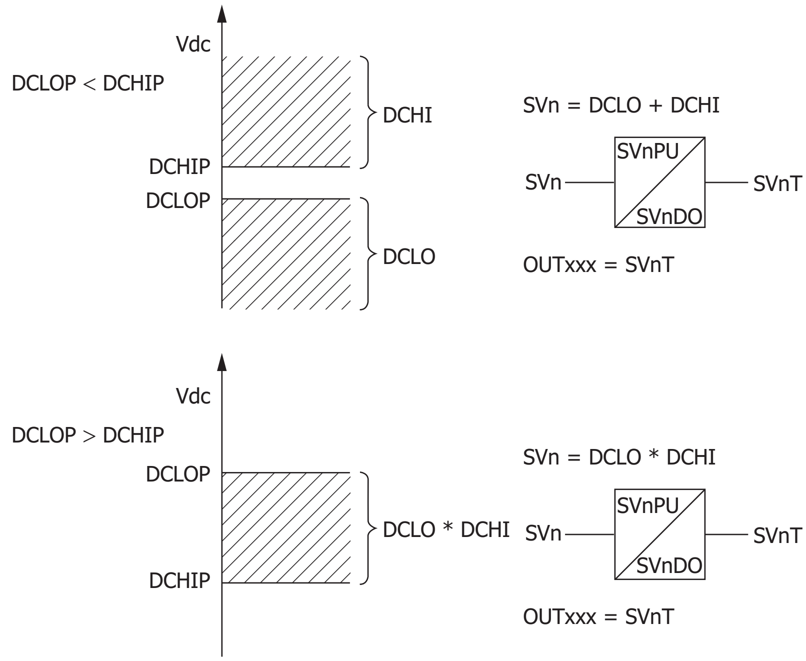


Figure 5.24 Create DC Voltage Elements With SELOGIC Control Equations

DCLO < DCHI (Top of Figure 5.24)

Output contact OUT*xxx* asserts when:

Vdc ≤ DCLOP or Vdc ≥ DCHIP

Pickup settings DCLOP and DCHIP are set such that output contact OUT*xxx* asserts when dc battery voltage goes below or above allowable limits.

If the relay loses power entirely (Vdc = 0 V)

Vdc ≤ DCLOP

then output contact OUT*xxx* should logically assert (according to top of *Figure 5.24*), 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 5.24* would be a better choice—see the following discussion.

DCLO > DCHI (Bottom of Figure 5.24)

Output contact OUT*xxx* asserts when:

DCHIP ≤ Vdc ≤ DCLOP

Pickup settings DCLOP and DCHIP are set such that output contact OUT*xxx* asserts when dc battery voltage stays between allowable limits.

If the relay loses power entirely (Vdc = 0 V)

Vdc ≤ DCHIP

then output contact OUT*xxx* should logically deassert (according to bottom of *Figure 5.24*), and this is surely what happens for a total loss of power (all output contacts deassert on total loss of power).

View Station DC Battery Voltage

Via Serial Port

The **METER** command displays the station dc battery voltage (labeled VDC).

Via Front Panel

The information available via the previously discussed **METER** serial port command is also available via the front-panel Meter Menu. See *Figure 8.10*.

Analyze Station DC Battery Voltage

The station dc battery voltage is displayed in column Vdc in the example event report in *Figure 10.3*. 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 10: Analyzing Events*.

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 4.66*). For example, output contact OUT103 is set to trip:

OUT103 = **TRIP**

Anytime output contact OUT103 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, program an optoisolated input IN*xyz* (monitoring the trip bus) in the SELOGIC control equation event report generation setting:

ER = **R_TRIG(INxyz) OR...**

Anytime 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-787 closes the circuit breaker, make the SELOGIC control equation event report generation setting:

ER = **R_TRIG(OUT102) OR...**

In this example, output contact OUT102 is set to close:

OUT102 = **CLOSE** (CLOSE is the logic output of *Figure 4.67*)

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 = R_TRIG(OUT102) OR ...) 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 = **F_TRIG(SVnT) OR ...**

Timer output SV*n*T is an example dc voltage element from the bottom of *Figure 5.24*. 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.

Breaker Monitor

The breaker monitor in the SEL-787 helps in scheduling circuit breaker maintenance. The breaker monitor on each breaker can be enabled independently with the corresponding enable setting:

EBMON*n* = **Y**, where *n* = 1, 2, 3, or 4

The breaker monitor settings in *Table 5.12* are available via the **SET G** commands (see *Table 6.3*). Also refer to *BRE n Command (Monitor Breaker n Data, where n = 1, 2, 3, or 4) on page 7.35* and *BRE n W or R Command (Preload/Reset Breaker Wear, where n = 1, 2, 3, or 4) on page 7.35*.

The breaker 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. Breaker 1 is considered in this example and the same approach can be applied to the rest. The breaker maintenance information in *Table 5.11* is plotted in *Figure 5.25*.

Table 5.11 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.

Connect the plotted points in *Figure 5.25* for a breaker maintenance curve. To estimate this breaker maintenance curve in the SEL-787 breaker monitor, three set points are entered:

Set Point 1 COSP11	**maximum** number of close/open operations with corresponding current interruption level
Set Point 2 COSP12	number of close/open operations that correspond to some **midpoint** current interruption level
Set Point 3 COSP13	number of close/open operations that correspond to the **maximum** current interruption level

These three points are entered with the settings in *Table 5.12*.

Table 5.12 Breaker Monitor Settings[a]

Setting Prompt	Setting Range	Setting Name := Factory Default
BRK *n* MONITOR	Y, N	EBMON*n* := Y
CL/OPN OPS SETPT *n*1	0–65000	COSP*n*1 := 10000[b]
CL/OPN OPS SETPT *n*2	0–65000	COSP*n*2 := 150[c, d]
CL/OPN OPS SETPT *n*3	0–65000	COSP*n*3 := 12
kA PRI INTERRPTD *n*1	0.10–999.00 kA	KASP*n*1 := 1.20[e]
kA PRI INTERRPTD *n*2	0.10–999.00 kA	KASP*n*2 := 8.00
kA PRI INTERRPTD *n*3	0.10–999.00 kA	KASP*n*3 := 20.00[f]
BKR *n* MON CTRL	SELOGIC	BKMON*n* := TRIP*n*

[a] n = 1, 2, 3, or 4 (option n = 3 is only available in the SEL-787-3E, SEL-787-3S, and SEL-787-4X models and option n = 4 is only available in the SEL-787-4X model).
[b] COSPn1 must be set greater than COSPn2.
[c] COSPn2 must be set greater than or equal to COSPn3.
[d] If COSPn2 is set the same as COSPn3, then KASPn2 must be set the same as KASPn3.
[e] KASPn1 must be set less than KASPn2 and KASPn2 must be less than or equal to KASPn3.
[f] KASPn3 must be set at least five times (but no more than 100 times) the KASPn1 setting value.

The following settings are made from the breaker maintenance information in *Table 5.11* and *Figure 5.25*. *Figure 5.26* shows the resultant breaker maintenance curve.

COSP11 = **10000**	KASP11 = **1.20**
COSP12 = **150**	KASP12 = **8.00**
COSP13 = **12**	KASP13 = **20.00**

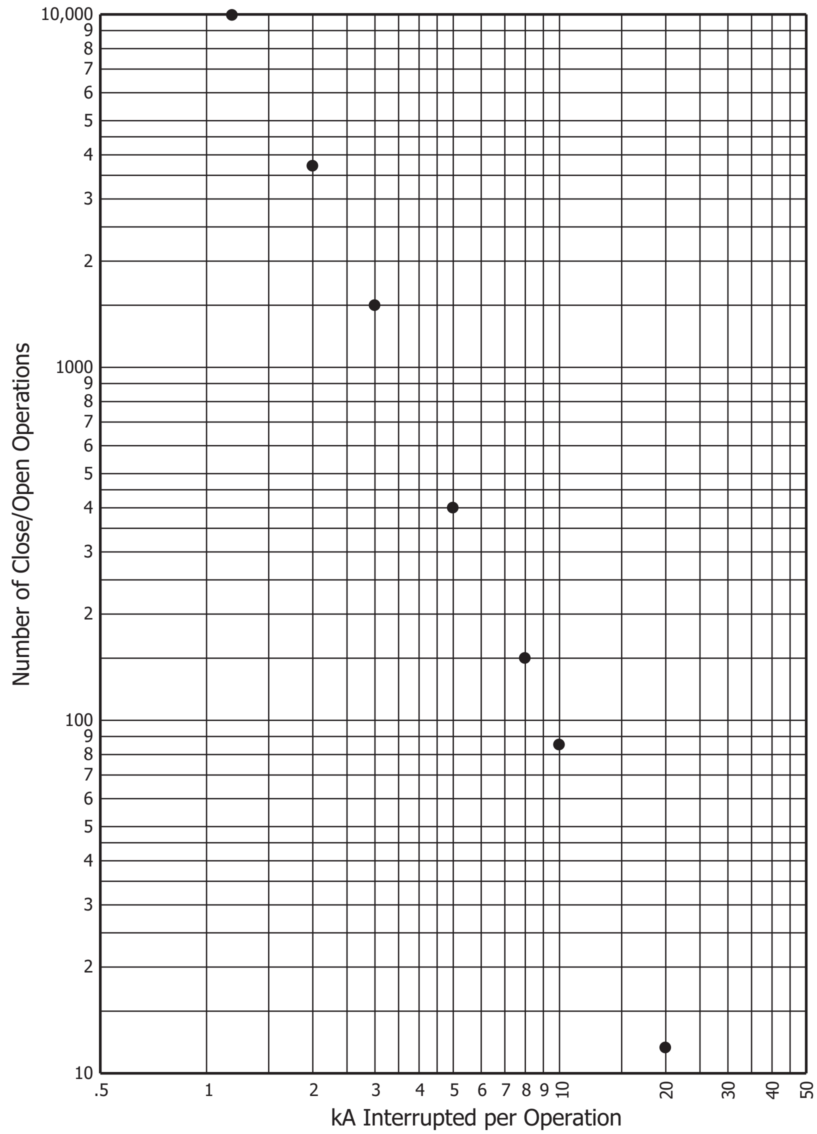


Figure 5.25 Plotted Breaker Maintenance Points for a 25 kV Circuit Breaker

Breaker Maintenance Curve Details

In *Figure 5.26*, note that set points KASP11, COSP11 and KASP13, COSP13 are set with breaker maintenance information from the two extremes in *Table 5.11* and *Figure 5.25*.

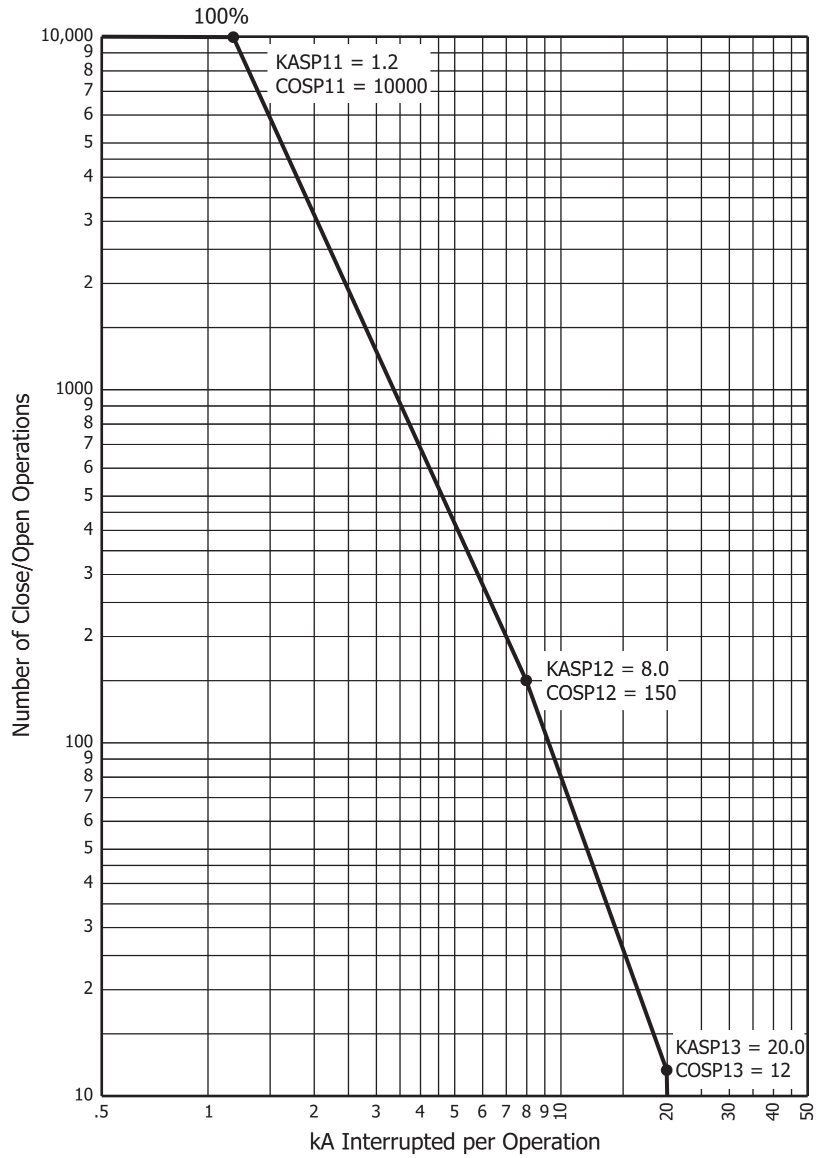


Figure 5.26 SEL-787 Breaker Maintenance Curve for a 25 kV Circuit Breaker

In this example, set point KASP12, COSP12 happens to be from an in-between breaker maintenance point in the breaker maintenance information in *Table 5.11* and *Figure 5.25*, but it does not have to be. Set point KASP12, COSP12 should be set to provide the best "curve-fit" with the plotted breaker maintenance points in *Figure 5.25*.

Each phase (A, B, and C) has its own breaker maintenance curve (like that in *Figure 5.26*), 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).

In *Figure 5.26*, note that the breaker maintenance curve levels off horizontally above set point KASP11, COSP11. This is the close/open operation limit of the circuit breaker (COSP11 = 10000), regardless of interrupted current value.

Also, note that the breaker maintenance curve falls vertically below set point KASP13, COSP13. This is the maximum interrupted current limit of the circuit breaker (KASP13 = 20.0 kA). If the interrupted current is greater than setting KASP13, the interrupted current is accumulated as a current value equal to setting KASP13.

Operation of SELogic Control Equation Breaker Monitor Initiation Setting BKMON

The SELogic control equation breaker monitor initiation setting BKMON1 in *Table 5.12* determines when the breaker monitor reads in current values (Phases A, B, and C) for the breaker maintenance curve (see *Figure 5.26*) and the breaker monitor accumulated currents/trips [see *BRE n Command (Monitor Breaker n Data, where n = 1, 2, 3, or 4) on page 7.35*].

The BKMON1 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. In the factory-default settings, the SELogic control equation breaker monitor initiation setting is set:

BKMON1 = **TRIP1** (TRIP1 is the logic output of *Figure 4.66*)

Refer to *Figure 5.27*. When BKMON1 asserts (Relay Word bit TRIP1 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 5.27*, the breaker monitor actually reads in the current values 1.5 cycles after the assertion of BKMON1. 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, at which it levels off. The 1.5-cycle delay on reading in the current values allows time for the fault current to level off.

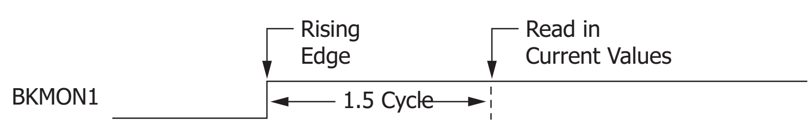


Figure 5.27 Operation of SELogic Control Equation Breaker Monitor Initiation Setting

See *Figure 5.32* and accompanying text for more information on setting BKMON1. The operation of the breaker monitor maintenance curve, when new current values are read in, is explained in the following example.

Breaker 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 5.28–Figure 5.31*. 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 5.28–Figure 5.31*) that the interrupted current in a given figure is the same magnitude for all the interruptions (e.g., in *Figure 5.29*, 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 5.28*. 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.

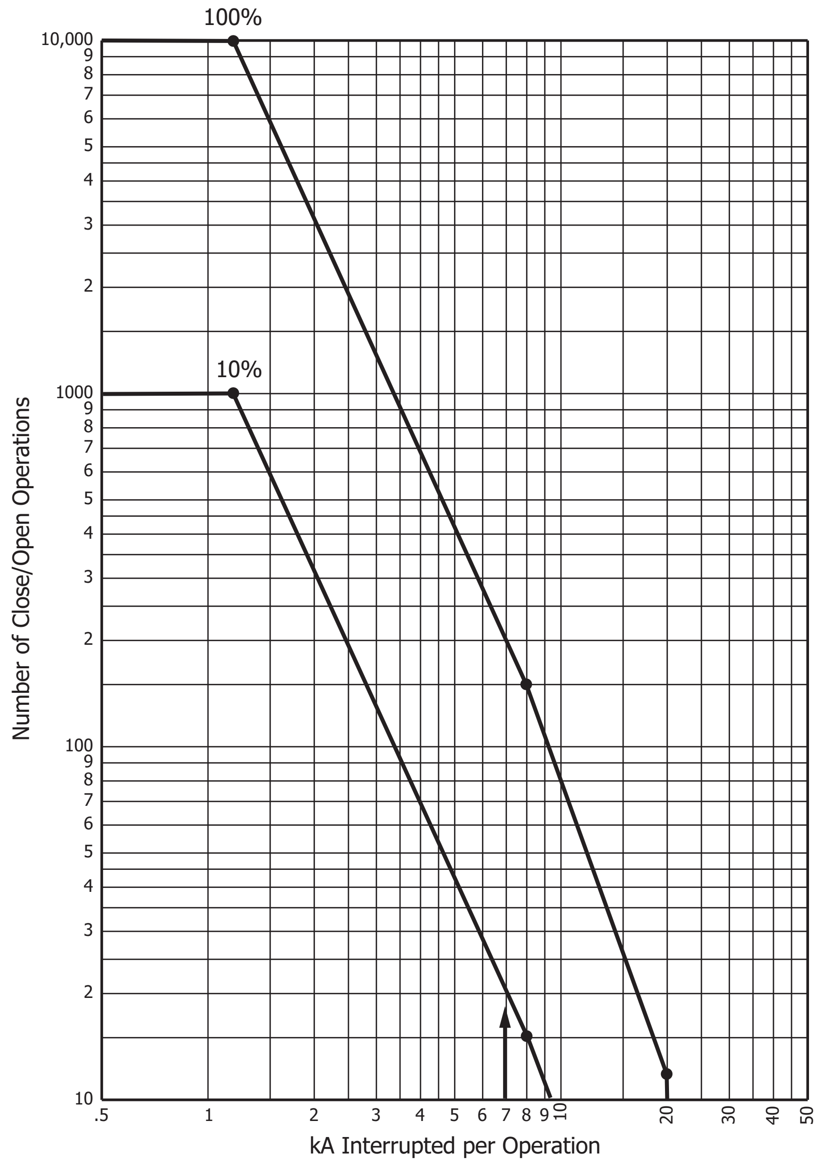


Figure 5.28 Breaker Monitor Accumulates 10 Percent Wear

10 Percent to 25 Percent Breaker Wear

Refer to *Figure 5.29*. 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.

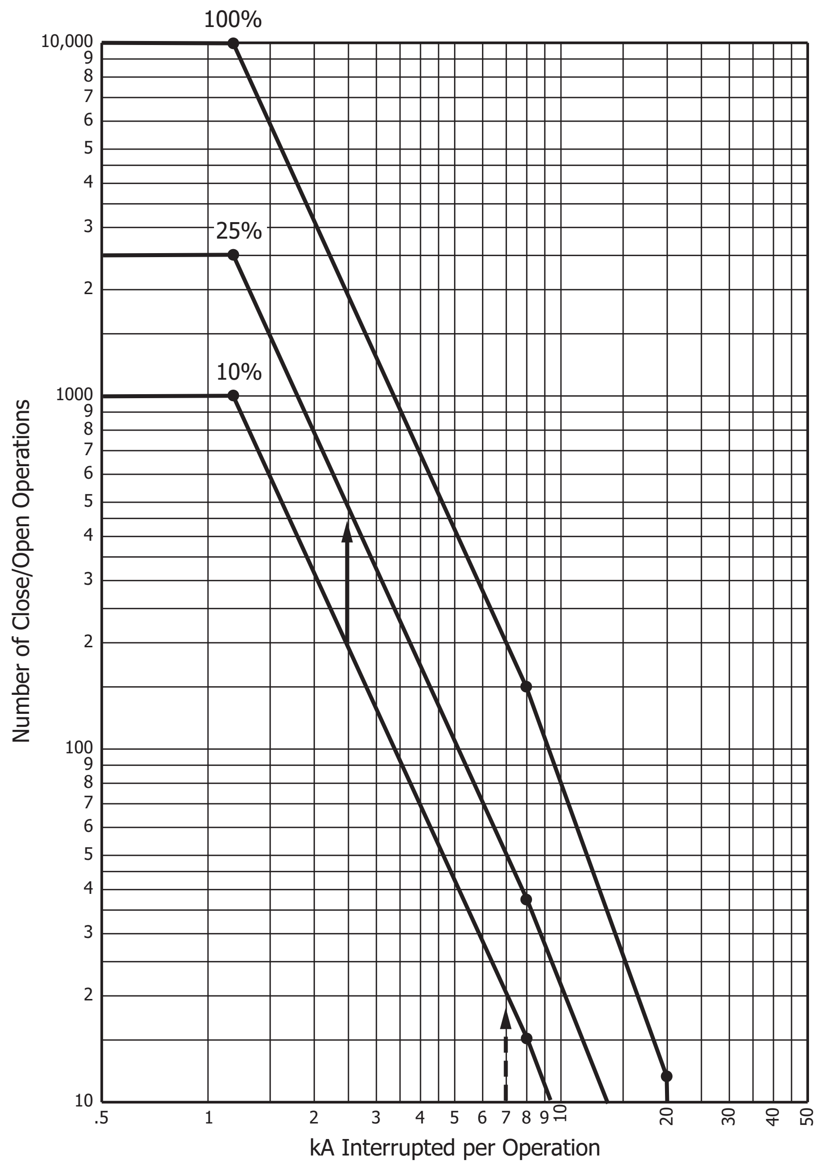


Figure 5.29 Breaker Monitor Accumulates 25 Percent Wear

25 Percent to 50 Percent Breaker Wear

Refer to *Figure 5.30*. 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.

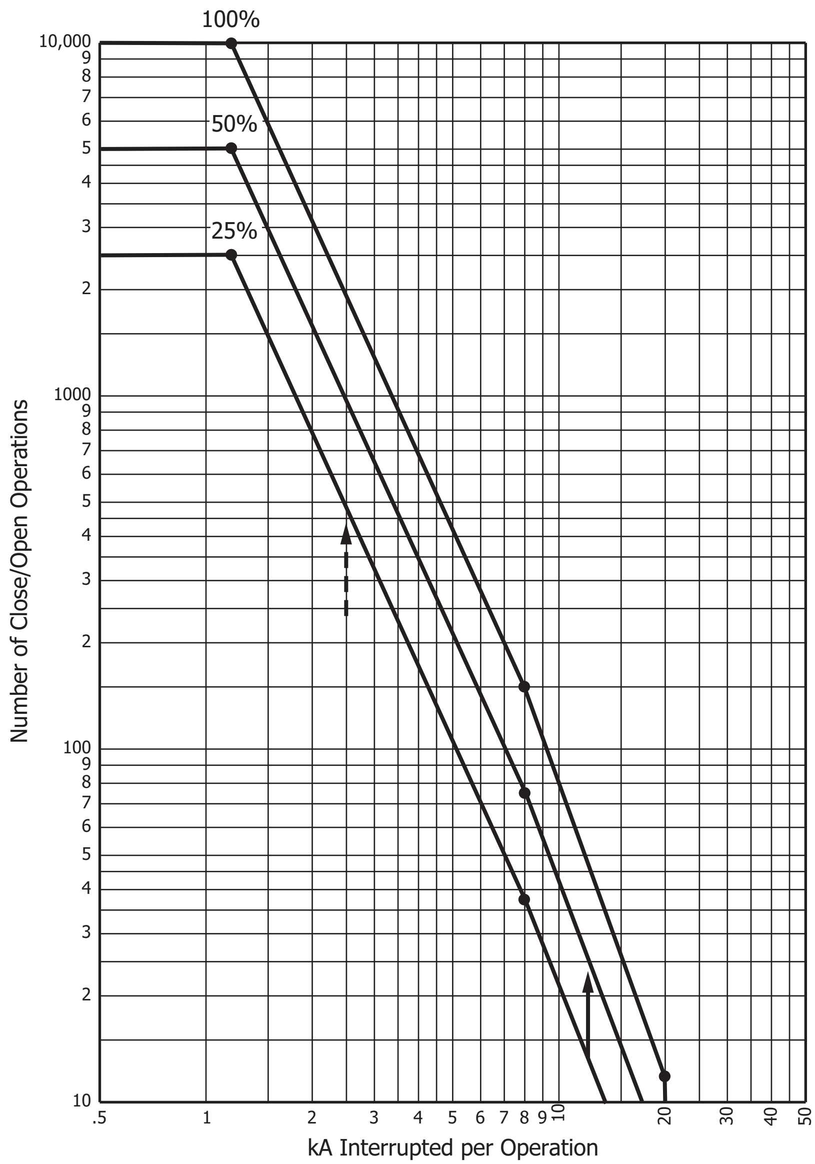


Figure 5.30 Breaker Monitor Accumulates 50 Percent Wear

50 Percent to 100 Percent Breaker Wear

Refer to *Figure 5.31*. The current value changes from 12.0 kA to 1.5 kA. The 1.5 kA current 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 *n* R** command (see *View or Reset Breaker Monitor Information on page 5.34*). But the current and trip counts continue to be accumulated, until reset by the **BRE *n* R** command.

Additionally, logic outputs assert for alarm or other control applications—see *Breaker Monitor Output*.

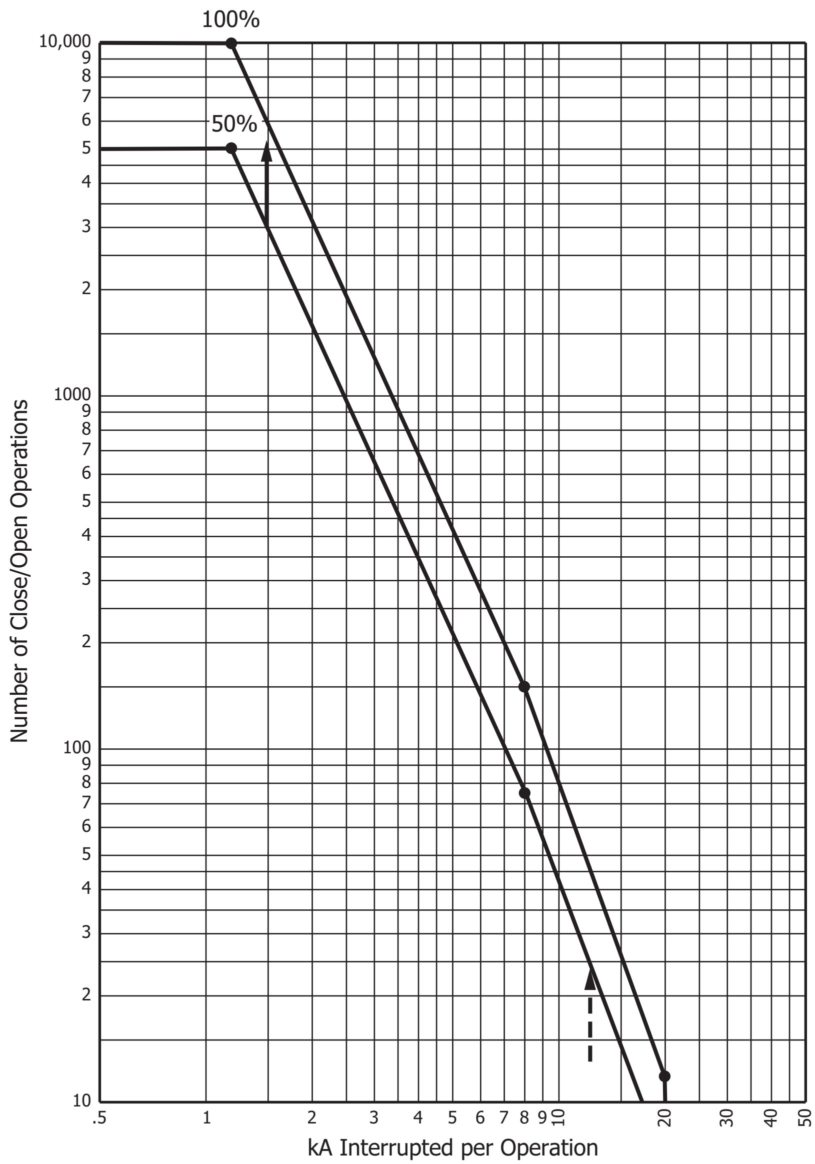


Figure 5.31 Breaker Monitor Accumulates 100 Percent Wear

Breaker Monitor Output

When the breaker maintenance curve for a particular phase (A, B, or C) reaches the 100 percent wear level (see *Figure 5.31*), a corresponding Relay Word bit (BCW1A, BCW1B, or BCW1C) asserts.

Relay Word Bits	Definition
BCW*n*A	Phase A Breaker *n* contact wear has reached the 100 percent wear level
BCW*n*B	Phase B Breaker *n* contact wear has reached the 100 percent wear level
BCW*n*C	Phase C Breaker *n* contact wear has reached the 100 percent wear level
BCW*n*	BCW*n*A or BCW*n*B or BCW*n*C
where *n* = 1, 2, 3, or 4	

EXAMPLE 5.1 Example Applications

These logic outputs can be used to alarm:

OUTxxx = **BCW1 OR BCW2 OR BCW3 OR BCW4**

or drive the relay to lockout the next time the relay trips:

79DTL = **TRIP AND BCW1 OR BCW2 OR BCW3 OR BCW4**

View or Reset Breaker Monitor Information

Accumulated breaker wear/operations data are retained if the relay loses power or the breaker monitor is disabled (setting EBMON*n* := N). The accumulated data can only be reset if the **BRE *n* R** command is executed.

Via Serial Port

See *Section 7: Communications*. The **BRE *n*** (*n* = 1, 2, 3, or 4) 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
- Date when the preceding items were last reset (via the **BRE *n* R** command)

See *Section 7: Communications*. The **BRE *n* W** command allows the trip counters, accumulated values, and percent breaker wear to be preloaded for each individual phase.

The **BRE *n* R** command resets the accumulated values and the percent wear for all three phases on the corresponding breaker. For example, if Breaker 1 contact wear has reached the 100 percent wear level for A-phase, the corresponding Relay Word bit BCW1A asserts (BCW1A = logical 1). Execution of the **BRE 1 R** command resets the wear levels for all three phases back to 0 percent on Breaker 1 and consequently causes Relay Word bit BCW1A to deassert (BCW1A = logical 0).

Via Front Panel

The information and reset functions available via the previously discussed serial port commands **BRE *n*** and **BRE *n* R** are available via the front panel. See *Section 8: Front-Panel Operations* for details.

Breaker wear data are also available as a read-only file that can be retrieved through the use of Ethernet FTP or MMS. MMS is only available in models that support IEC 61850 and only when IEC 61850 and MMS file transfer are enabled (E61850 = Y, EMMSFS := Y). See *File Transfer Protocol (FTP) and MMS File Transfer on page 7.15*, *Virtual File Interface on page 7.73*, and *MMS on page G.5* for additional information.

Determination of Relay-Initiated Trips and Externally Initiated Trips

See *Section 7: Communications*. Note in the **BRE *n*** command response that the accumulated number of trips and accumulated interrupted current are separated into two groups of data: those generated by relay-initiated trips (Rly Trips) and those generated by externally initiated trips (Ext Trips). The categorization of these data is determined by the status of the TRIP*n* Relay Word bit when the SELOGIC control equation breaker monitor initiation setting BKMON*n* operates.

Refer to *Figure 5.27* and accompanying explanation. If BKMON*n* newly asserts (logical 0 to logical 1 transition), the relay reads in the current values (Phases A, B, and C). Now, the relay must determine whether to accumulate this current and trip count information under relay-initiated trips or externally initiated trips.

To make this determination, the relay checks the status of the TRIP*n* Relay Word bit at the instant BKMON*n* newly asserts (TRIP*n* is the logic output of *Figure 4.66 on page 4.102*). If TRIP*n* is asserted (TRIP*n* = logical 1), the current and trip count information is accumulated under relay-initiated trips (Rly Trips). If TRIP*n* is deasserted (TRIP*n* = 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 5.27–Figure 5.31*).

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.

EXAMPLE 5.2 Factory-Default Setting Example

As discussed previously, the SELOGIC control equation breaker monitor initiation factory-default setting is:

BKMON1 = **TRIP1**

Thus, any new assertion of BKMON1 is deemed a relay trip, and the current and trip count information is accumulated under relay initiated trips (Rly Trips).

EXAMPLE 5.3 Additional Example

Refer to Figure 5.32. Output contact **OUT103** is set to provide tripping:

OUT103 = **TRIP1**

Note that optoisolated input **INxxx** monitors the trip bus. If the trip bus is energized by output contact **OUT103**, an external control switch, or some other external trip, then **INxxx** is asserted.

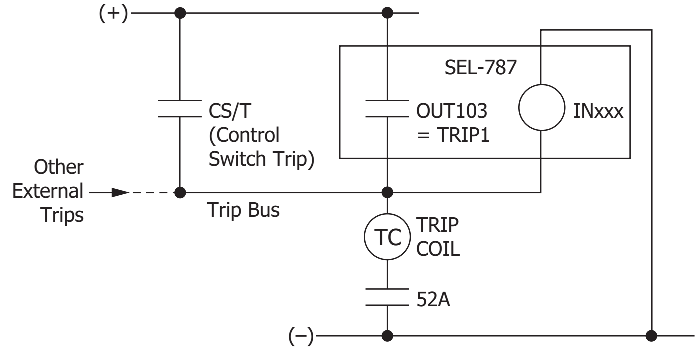


Figure 5.32 Input INxxx Connected to Trip Bus for Breaker Monitor Initiation

If the SELOGIC control equation breaker monitor initiation setting is set:

BKMONn = **INxxx**

then the SEL-787 breaker monitor sees all trips.

If output contact **OUT103** asserts, energizing the trip bus, the breaker monitor deems it a relay initiated trip. This is because when BKMONn is newly asserted (input **INxxx** 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 deems it an externally initiated trip. This is because when BKMONn is newly asserted (input **INxxx** energized), the TRIP Relay Word bit is deasserted. Thus, the current and trip count information is accumulated under externally initiated trips (Ext Trips).

Through-Fault Event Monitoring

Figure 5.33 shows a fault that occurs outside the area of unit protection of the transformer. Such through faults can last for several cycles, subjecting the transformer windings to mechanical stress and the transformer winding insulation to thermal stress. Monitor and document this through-fault activity with the through-fault element in the SEL-787. The through-fault element also calculates the cumulative mechanical stress on the transformer windings.

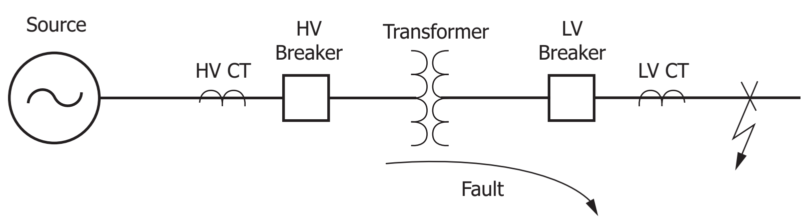


Figure 5.33 Transformer Bank Subjected to Through Fault

Figure 5.34 shows through-fault curves for Category IV transformers as published in IEEE Standard C57.109-1993. These curves apply to transformers that are covered by the IEEE standard or, in general, to transformers that were built beginning in the early 1970s. For transformers built prior to 1970, consult the manufacturer to obtain the transformer short-circuit withstand capabilities.

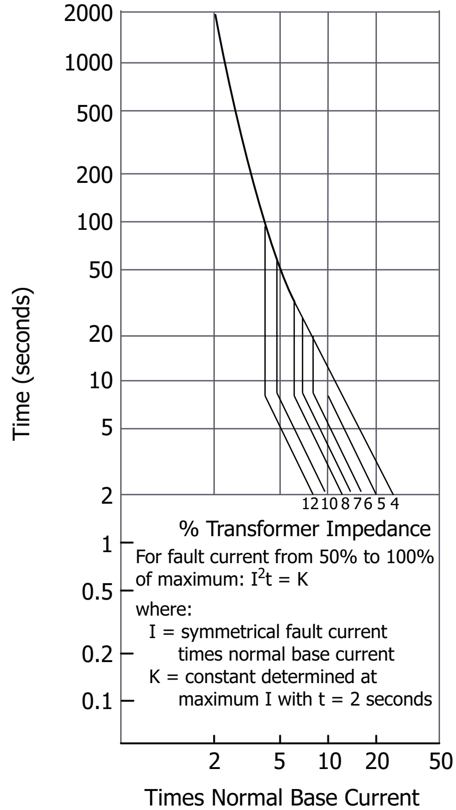


Figure 5.34 Category IV Transformers Through-Fault Protection Curves

The curves in *Figure 5.34* are a function of the transformer short-circuit impedance, and are keyed to the maximum I^2t of the worst-case mechanical duty (maximum fault current for 2 seconds). *Equation 5.1* through *Equation 5.3* show the three equations that the element uses to evaluate the thermal curve each processing interval. Note that the calculated currents are in primary values. To convert the secondary current to primary current, the element multiplies the secondary current by the CT ratio of the particular winding.

$$I_{PU} = \frac{I \bullet \sqrt{3} \bullet kV_{LL}}{1000 \bullet S}$$

Equation 5.1

$$I_{MAX\_PU} = \frac{1}{Z_{PU}}$$

Equation 5.2

$$t(I_{PU}) = \frac{K}{(I_{PU})^2}$$

Equation 5.3

where:

I = Measured current
S = Transformer MVA rating (MVA)
kV_{LL} = Line-to-line voltage (kV)
Z_{PU} = Transformer impedance (per unit)
K = 1250 if $(4.5 \le I_{PU} \le 0.5 \bullet I_{MAX\_PU})$ or $2 \bullet (I_{MAX\_PU})^2$ if $I_{PU} > 0.5 \bullet I_{MAX\_PU}$

To enable through-fault event monitoring, set the MVA setting to something other than OFF. MVA is typically set to the transformer MVA rating. There are only four settings to set the through-fault event monitor, all under the Through Fault category in Global Settings (**SET G** command) (see *Table 5.13*). Enable the through-fault element by setting the SELOGIC control equation ETHRFLT for the conditions that you want the element to run. The default setting for ETHRFLT := NOT TRXFMR disables Through-Fault Monitor for all transformer internal faults (Relay Word Bit TRFXMR := 1). Use Setting THFLTD to select the winding that you want the element to use when calculating the through-fault current. Switch S1, in *Figure 5.35*, selects OFF or one of the windings (1, 2, 3, 4, 12, 23, or 34). Set the through-fault alarm pickup (THFLTPU) to the desired value, and enter the transformer percentage impedance at the XFMRZ setting.

NOTE: When you change the ETHRFLT setting, the relay also clears the data and records, i.e., it has the same effect as the **TFE C** or **TFE R** command.

Table 5.13 Through-Fault Element Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
THR FLT WDG	OFF, 1, 2, 3, 4, 12, 23, 34[a]	THFLTD := OFF
ENABLE THR FLT	SELOGIC	ETHRFLT := NOT TRXFMR
THR FLT ALARM PU	50.0%–900.0%	THFLTPU := 100.0
XFMR IMPEDANCE	2.0%–40.0%	XFMRZ := 10.0

[a] Option n = 3, 12, and 23 are only available in the SEL-787-3E, SEL-787-3S, SEL-787-4X models and option n = 4 and 34 are only available in the SEL-787-4X model.

On the basis that mechanical stress takes effect only at high current values, the through-fault element runs only if the selected phase current is greater than 4.75 times full load current. Allowing a hysteresis of 0.25 of full load, the through-fault element resets when the current falls below 4.5 times the full load current.

Figure 5.35 shows a functional diagram of the through-fault element for the A-phase of Winding 1 (THFLTD := 1), the B-phase and C-phase elements have identical diagrams. When SELOGIC control equation ETHRFLT asserts and the A-phase current exceeds 4.75 times the transformer full-load current, Enable asserts and the 1-minute Timer starts.

When Enable asserts, the following occurs:

- The thermal element advances the A-phase fault counter by 1 count.
- The thermal element advances the total fault counter by 1 count.
- The thermal element records the time when the fault starts (rising edge of Enable).
- The process to determine the maximum through-fault current for the fault duration starts.
- The integration process starts, whereby the element sums the values (*Equation 5.3*) calculated each processing interval (1/4 of a power system cycle).

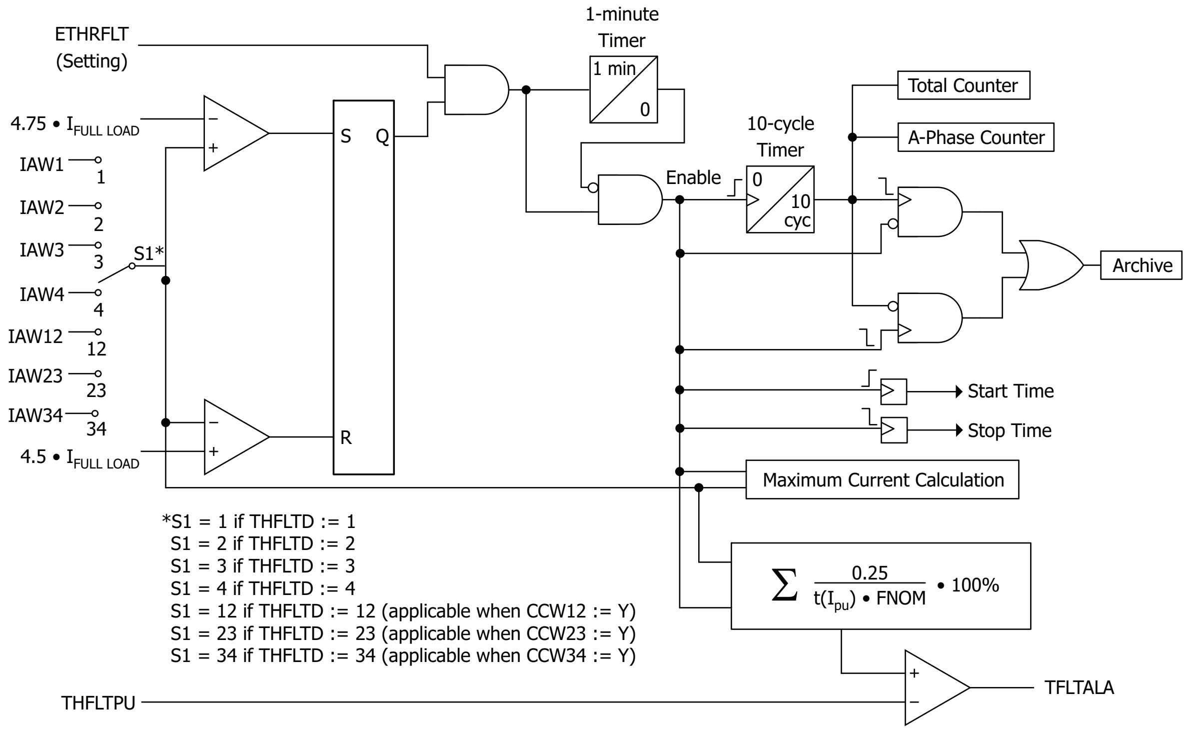


Figure 5.35 Through-Fault Diagram

The 10-cycle timer avoids the inadvertent increment of the counters or archiving of the data if the fault current momentarily drops below the lower threshold level.

Setting threshold THFLTPU would usually be set to alarm for excessive, cumulative transformer bank stress. When the integration exceeds the value as specified by the THFLTPU setting, Relay Word bit TFLTALA asserts. Assign output Relay Word bit TFLTALA to an output for annunciation or control action such as to modify distribution feeder auto-reclosing (e.g., reduce the number of reclosures from 3 to 2).

When the fault current falls below 4.5 times the full load level, the element deasserts, and the following occurs:

- ➤ The thermal element records the stop time; then calculates (and records) the fault duration.
- ➤ The thermal element records the maximum value of the fault current during the fault.
- ➤ The integration process stops.

The relay can store (archive) the data of 500 through faults in a first-in-first-out (FIFO) buffer. The element automatically archives the data when one of the following conditions is true:

- ➤ The 10-cycle Timer deasserts and the enable signal is already de-asserted.
- ➤ The 10-cycle Timer is already de-asserted and the enable signal de-asserts.

Through-Fault Element (TFE) Serial Command

The format of the **TFE** command is as follows:

TFE [*nnn* A|P|C|R]

where:

nnn	Specifies number of through faults to display.
A	The relay displays all the Through Fault Records in the memory.
P	Use to specify pre-loading
C or R	Sets the accumulated values to 0 and deletes the history.

Figure 5.36 displays the relay response to the **TFE** (no other parameters) command. Notice that Winding 1 is the winding whose current inputs the element uses in the calculations (THFLTD = 1). The **TFE** command lists as many as 20 of the most recent through-faults. "Total Number of Transformer Through Faults:" is the sum of the detected through faults of all three phases since the last reset, with a maximum of 65,535 counts. "Number of *n* Phase Through Faults:" (*n* = A, B, C) refers to the through faults detected for that particular phase since the last reset, also with a maximum of 65,535 counts. The "Total Accumulated Percentage of Through Fault Capability" shows the per phase value. The value represents the percent amount of through fault capability used up based on the per unitized capability from the curve of *Figure 5.34*. The through-fault alarm state is either a 1 (indicating an alarm state), or a 0 (indicating a normal state).

```
=>>TFE <Enter>

SEL-787-4X                                  Date: 04/03/2014 Time: 15:24:02
TRNSFRMR RELAY                              Time Source: Internal

Winding 1
Total Number of Transformer Through Faults: 4
Total Number of A Phase Through Faults:     2
Total Number of B Phase Through Faults:     1
Total Number of C Phase Through Faults:     1

Total Accumulated Percentage of Through Fault Capability:
                     A-Phase    B-Phase    C-Phase
                     95.97      60.00      60.00
Through Fault Alarm: 0          0          0

Last Reset: 04/03/2014 15:16:27

#   DATE       TIME         Duration   IA     IB     IC    A     B     C   Alarm
                            (seconds)   (max primary kA)    (Increment %)
1   04/03/2014 15:23:37.102 19.983    1.99   0.00   0.00 35.97  0.00  0.00
2   04/03/2014 15:20:23.256  1.663    0.00   0.00   3.28  0.00  0.00 50.94 ABC
3   04/03/2014 15:20:19.918  1.675    0.00   6.37   0.00  0.00 99.99  0.00 AB
4   04/03/2014 15:20:16.596  1.650    1.99   0.00   0.00  2.97  0.00  0.00 A

=>>
```

Figure 5.36 Result of the TFE Command

Following is a description of each column (#, Date, Time, etc.) of the event report. Through-fault events are numbered (# column) from 1 (the most recent event, at the top) to a maximum of 500 through-fault events.

Under the date and time columns, the event shows the date of occurrence and the start time of each event (the date format depends upon the DATE_F setting).

Although the element processes all values each cycle, event duration (Duration column) is reported in seconds with processing interval resolution. If the event duration is equal to or greater than 60 seconds, the element appends a “+” to the time value of 60 seconds.

IA, IB, and IC show the maximum primary current for each phase, with a maximum of 100,000 A primary.

A, B, and C show the amount (percent increase) of the present fault for each phase. Alarm shows those phase(s) that were in the alarm state at the end of the through-fault event.

Table 5.14 shows events report messages and the reason why these messages may appear in the events report.

Table 5.14 Through-Fault Events Report Messages

Message	Cause
Invalid Data	The accumulated data are corrupt.
Through Fault Event Monitor Disabled	The ETHRFLT setting is NA, or evaluates to logical 0.
Too many events - Data Lost	The memory is full.
Through Fault Event Buffer Empty	There are no event records in the nonvolatile memory.
Memory resources are low; check for activity on other ports	There is insufficient memory to display the event records.

Use the **TFE A** command to list all the stored through-fault events (not only the last 20 events) since the monitor was last reset. To list a particular number of through-fault events, enter the **TFE *n*** command (*n* = 1 to 500).

To clear event accumulated data, and all event records, use either the **TFE C** (clear) or **TFE R** (reset) command. Both commands have the same result, so you can use either of them. Note that when you change the ETHRFLT setting, the relay also clears the data and records, i.e., it has the same effect as the **TFE C** or **TFE R** command.

Use the **TFE P** command to preload or change the values of the through fault event accumulated data, as shown in *Figure 5.37*. Enter these values in percent for each phase, to a maximum value of 100.0 percent.

```
=>>TFE P
Winding 1 Total Accumulated Percentage of Through Fault Capability:
A_Phase = 0.00? 60.20
B_Phase = 0.00? 56.0
C_Phase = 0.00? 52
Are you sure (Y,N)? Y
Command Completed
=>>
```

Figure 5.37 Preload the Values of the Accumulated Data

The TFE report is available as a read-only file that can be retrieved through the use of Ethernet FTP or MMS. MMS is only available in models that support IEC 61850 and only when IEC 61850 and MMS file transfer are enabled (E61850 = Y, EMMSFS := Y). See *File Transfer Protocol (FTP) and MMS File Transfer on page 7.15*, *Virtual File Interface on page 7.73*, and *MMS on page G.5* for additional information.

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Section 6

Settings

Overview

IMPORTANT: Upon relay initial turn on, Port 1 setting changes, or Logic setting changes, you may have to wait as long as two minutes before an additional setting change can occur. Note that the relay is functional with protection enabled as soon as the **ENABLED** LED comes ON (about 5–10 seconds from turn on).

The SEL-787 Transformer Protection Relay stores the settings you enter in nonvolatile memory. Settings are divided into the following eleven setting classes:

1. Group *n* (where *n* = 1, 2, 3, or 4)
2. Logic Group *n* (where *n* = 1, 2, 3, or 4)
3. Global
4. Port *p* (where *p* = F, 1 [Ethernet], 2, 3, or 4)
5. Front Panel
6. Report
7. Modbus
8. EtherNet/IP
9. DNP3
10. IEC 60870-5-103
11. Touchscreen (this setting class is only available for models with the color touchscreen display)

Some setting classes have multiple instances. In the previous list, there are five port setting instances, one for each port. Settings may be viewed or set in several ways, as shown in *Table 6.1*.

Table 6.1 Methods of Accessing Settings[a]

	Web Server[b]	Serial Port Commands[c]	Front-Panel HMI Set/Show Menu[d]	ACSELERATOR QuickSet SEL-5030 (PC Software)[b]
Display Settings	All settings	All settings (**SHO** command)	Global, Group, and Port settings	All settings
Change Settings	Not available	All settings (**SET** command)	Global, Group, and Port settings	All settings

[a] These setting access methods do not apply to the touchscreen settings.
[b] Refer to Section 3: PC Interface for detailed information.
[c] Refer to Section 7: Communications for detailed information on setup and use of the serial communications port.
[d] Refer to Section 8: Front-Panel Operations for detailed information on the front-panel layout, menus and screens, and operator control pushbuttons.

Setting entry error messages, together with corrective actions, are also discussed in this section to assist in correct settings entry.

The *SEL-787-2, -3, -4 Settings Sheets* at the end of this section list all the SEL-787 settings, the setting definitions, and the input ranges. Refer to *Section 4: Protection and Logic Functions* for detailed information on individual elements and settings.

Touchscreen settings are only available through QuickSet for models with the color touchscreen display. These settings are not available via ASCII terminal, unlike the other relay settings. Refer to *Section 9: Bay Control* for detailed information on individual settings.

View/Change Settings

Two-Line Front Panel

You can use the pushbuttons on the front panel to view/change settings. See *Section 8: Front-Panel Operations* for the operating details of the front panel.

Enter the front-panel menu by pressing the **ESC** pushbutton. It displays the following message:

```
MAIN
Meter
```

Scroll down the menu by using the **Down Arrow** pushbutton until the display shows the following message:

```
Control
Set/Show
```

The cursor (underline) should be on the `Set/Show` command. Enter the `Set/Show` command by pushing the **ENT** pushbutton. The display shows the following message:

```
SET/SHOW
Global
```

Enter the underlined relay message with the **ENT** pushbutton, and the relay presents you with the relay settings as listed in the *SEL-787-2, -3, -4 Settings Sheets*. Use the **Up Arrow**, **Down Arrow**, **Left Arrow**, and **Right Arrow** pushbuttons to scroll through the relay settings. View and change the settings according to your needs by selecting and editing them. After viewing or changing the relay settings, press the **ESC** pushbutton until the following message appears:

NOTE: Each SEL-787 is shipped with default factory settings. Calculate the settings for your application to ensure secure and dependable protection. Document the settings on the SEL-787-2, -3, -4 Settings Sheets at the end of this section before entering new settings in the relay.

```
Save Changes?
Yes   No
```

Select and enter the appropriate command by pressing the **ENT** pushbutton. Select `Yes` to save the settings changes and `No` to discard the changes.

Figure 6.1 shows a front-panel menu navigation example for the relay to set the Winding 2 differential enable setting, `WDG2 DIFF ENABLE`, `E87W2`.

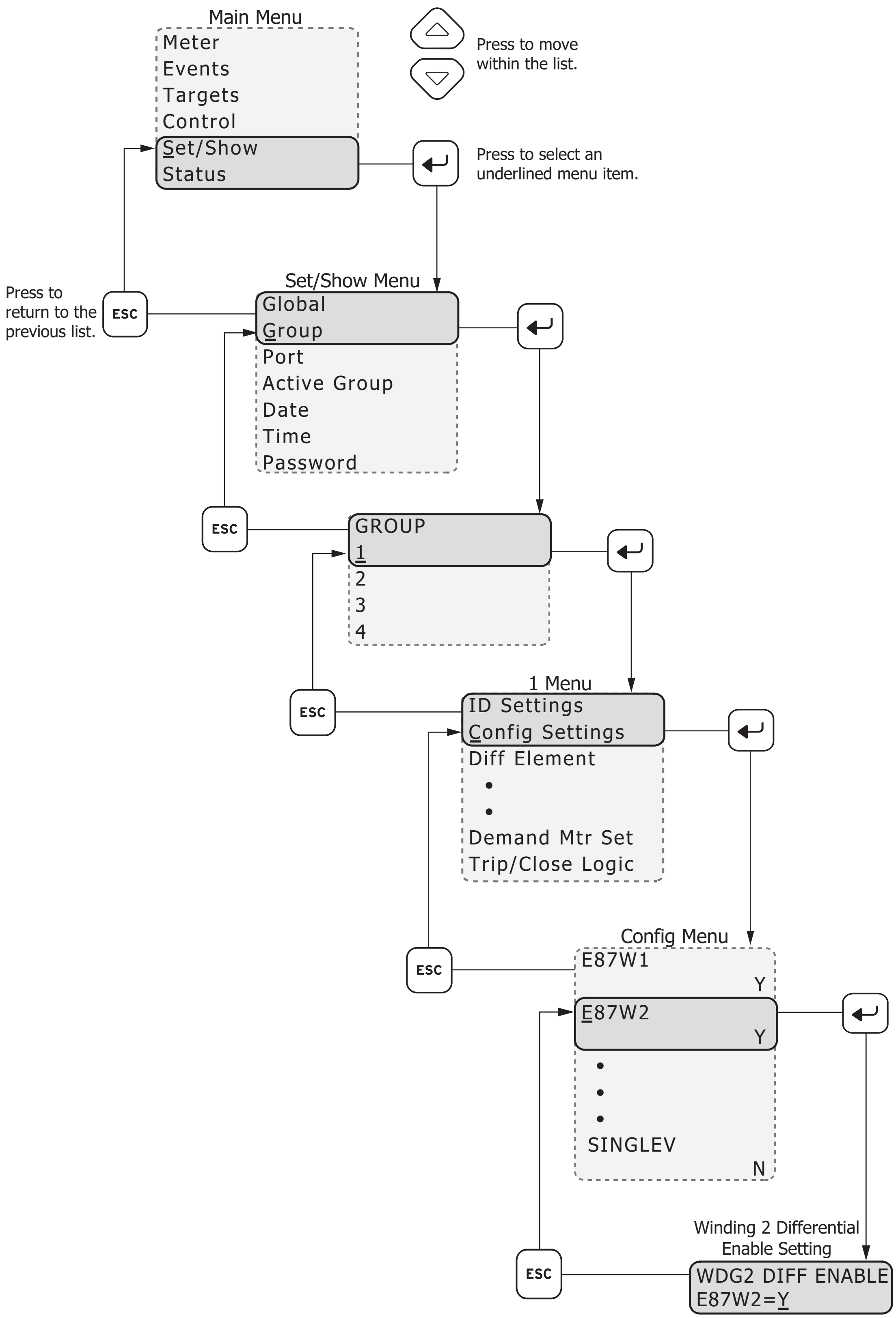

Figure 6.1 Front-Panel Setting Entry Example

Touchscreen Front Panel

You can view or change Port, Global, Group, Date and Time, and Touchscreen settings using the touchscreen display. Tap the **Settings** folder on the **Home** screen to navigate to the **Settings** screen, through which you can view or change settings. Refer to *Touchscreen Display Front Panel on page 8.20* for detailed information on how to view or change settings using the touchscreen display.

Communications Port

Refer to *Section 7: Communications* for information on how to set up and access the relay serial or Ethernet port with a personal computer and how to use ASCII commands to communicate with the relay.

View Settings

Use the **SHOW** command to view the relay settings. The **SHOW** command is available from Access Level 1 and Access Level 2. *Table 6.2* lists the **SHOW** command options.

Table 6.2 SHOW Command Options

Command	Description
SHO *n*	Show relay group settings: *n* specifies the settings group (1, 2, 3, or 4); *n* defaults to the active settings group if not listed.
SHO L *n*	Show logic settings: *n* specifies the settings group (1, 2, 3, or 4); *n* defaults to the active settings group if not listed.
SHO G	Show global configuration settings.
SHO P *n*	Show serial port settings for Port *n* (*n* = F, 1, 2, 3, or 4).
SHO F	Show front-panel display and LED settings.
SHO R	Show Sequential Events Recorder (SER) and event report settings.
SHO M	Show Modbus map settings.
SHO E	Show EtherNet/IP assembly map settings.
SHO D	Show DNP3 map settings.
SHO I	Show IEC 60870-5-103 map settings.

You can append a setting name to each of the commands to specify the first setting to display (e.g., **SHO 50P11P** displays the relay settings starting with setting **50P11P**). The default is the first setting. The **SHOW** command displays only the enabled settings.

Enter Settings

The **SET** command (available from Access Level 2) allows you to view or change settings. *Table 6.3* lists the **SET** command options.

Table 6.3 SET Command Options (Sheet 1 of 2)

Command	Settings Type	Description
SET *n*	Group	Protection elements, timers, etc. for settings Group *n* (1, 2, 3, or 4)
SET L *n*	Logic	SELOGIC control equations for settings group *n* (1, 2, 3, or 4)
SET G	Global	Global configuration settings including Event Messenger, optoisolated input debounce timers, etc.

Table 6.3 SET Command Options (Sheet 2 of 2)

Command	Settings Type	Description
SET P *n*	Port	Serial port settings for serial Port *n* (1, 2, 3, 4, or F)
SET F	Front Panel	Front-panel display and LED settings
SET R	Reports	SER and Event Report settings
SET M	Modbus	Modbus user map settings
SET E	EtherNet/IP	EtherNet/IP assembly map settings
SET D	DNP3	DNP3 map settings
SET I	IEC 60870-5-103	IEC 60870-5-103 user map

NOTE: The **SET** command is unavailable for as long as 90 seconds after the relay is turned on and for as long as 40 seconds after a setting change. If you issue a **SET** command during this period, the relay responds with the following message:

```
Command Unavailable;
Relay Configuration in
Progress, Try Again.
```

You may append a setting name to each of the commands to specify the first setting to set (e.g., **SET 50P11P** presents the relay setting starting with 50P11P). The default is the first setting.

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 listed in *Table 6.4*.

Table 6.4 SET Command Editing Keystrokes

Press Key(s)	Results
<Enter>	Retains the setting and moves to the next setting.
^ <Enter>	Returns to the previous setting.
< <Enter>	Returns to the previous setting category.
> <Enter>	Moves to the next setting category.
END <Enter>	Exits the editing session, then prompts you to save the settings.
<Ctrl+X>	Aborts the editing session without saving changes.

The relay checks each entry to ensure that the entry is within the setting range. If it is not in range, an `Out of Range` message is generated, and the relay prompts you for the setting again.

When all the settings are entered, the relay displays the new settings and prompts you for approval to enable them. Press **Y <Enter>** to enable the new settings. The relay is disabled for as long as five seconds while it saves the new settings. The SALARM Relay Word bit is set momentarily, and the **ENABLED** LED extinguishes while the relay is disabled. In the touchscreen display model, the **ENABLED** LED stays illuminated while the relay saves the setting.

To change a specific setting, enter the command shown in *Table 6.5*.

Table 6.5 SET Command Format

SET n m s TERSE	
where:	
n	is left blank or is D, G, L, F, R, M, or P to identify the class of settings.
m	is left blank or is F, 1, 2, 3, or 4 when *n* = P.
s	is the name of the specific setting you wish to jump to and begin setting. If *s* is not entered, the relay starts at the first setting (e.g., enter **50P11P** to start at Phase Overcurrent Trip level setting).
TERSE	instructs the relay to skip the settings display after the last setting. Use this parameter to speed up the **SET** command. If you wish to review the settings before saving, do not use the TERSE option.

Web Server

Refer to *Section 3: PC Interface* for information on how to set up communication and how to access the relay on an Ethernet port with a personal computer.

View Settings

Once communication with the relay is established through the web server, the home page screen appears in your browser window. Click **Settings** on the navigation pane to view all the available settings classes, as shown in *Figure 6.2*. You can only view SEL-787 relay settings through the web server, even at Access Level 2. Click on a settings class to view its settings.

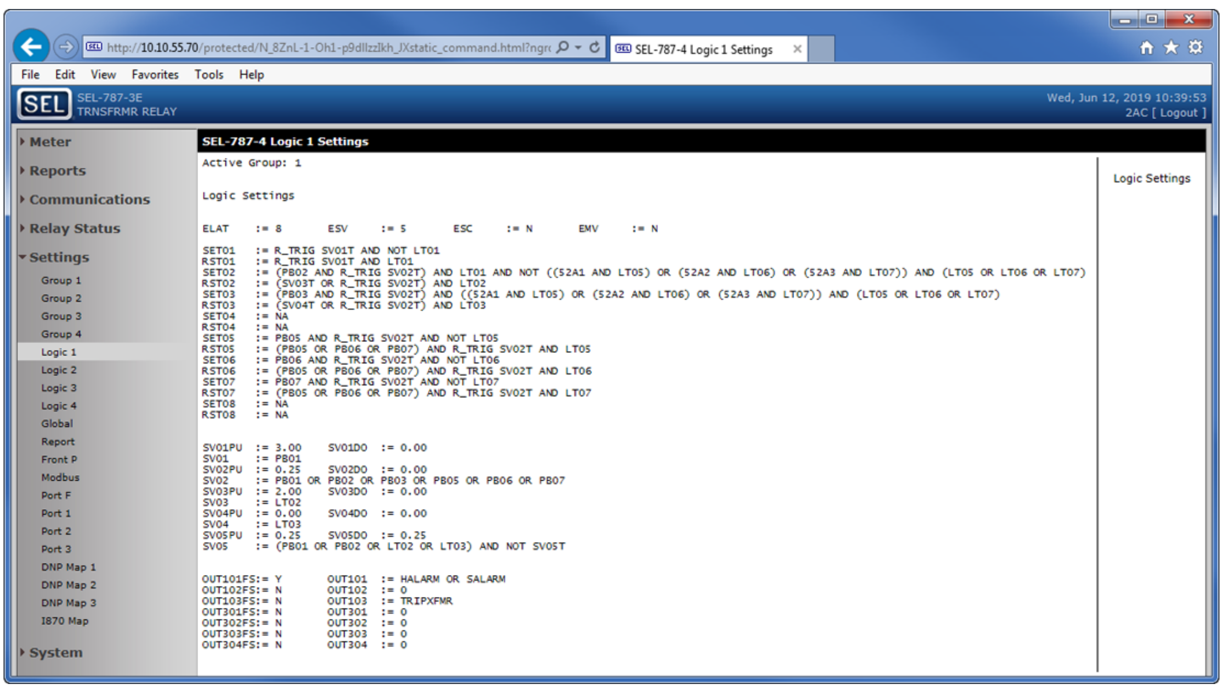

Figure 6.2 Web Server Settings Screen

Setting Entry Error Messages

As you enter relay settings, the relay checks the setting entered against the range for the setting as published on the relay setting sheet. If any setting entered falls outside the corresponding range for that setting, the relay immediately responds `Out of Range` and prompts you to reenter the setting.

In addition to the immediate range check, several of the settings have interdependency checks with other settings. The relay checks setting interdependencies after you answer `Y` to the `Saves Settings?` prompt, but before the settings are stored. If any of these checks fail, the relay issues a self-explanatory error message, and returns you to the settings list for a correction. *Table 6.6* shows the settings interdependency error messages that require some additional explanation and guidance.

Table 6.6 Setting Interdependency Error Messages

Error Message	Setting/Function	Correct the Condition
`Tap(s) out of range, enter values manually`[a]	Group settings, differential element autocalculation of TAP1, TAP2, TAP3, and TAP4	Check: $0.10 \cdot I_{NOMn} < TAPn < 31.00 \cdot I_{NOMn}$ (I_{NOMn} = 5 or 1 for 5 A and 1 A winding CT based on PARTNO). Should either TAP*n* value violate this requirement, adjust the affected TAP*n* to satisfy the check (*n* = 1, 2, 3, or 4).
`Maximum-to-minimum TAP ratio must be ≤ 32.00`[a]	Group settings, differential element autocalculation of TAP1 and TAP2	Check: $[MAX(TAP1/I_{NOM1}, TAP2/I_{NOM2}, TAP3/I_{NOM3}, TAP4/I_{NOM4})/MIN(TAP1/I_{NOM1}, TAP2/I_{NOM2}, TAP3/I_{NOM3}, TAP4/I_{NOM4})] \leq 32.00$. Adjust TAP1, TAP2, TAP3, or TAP4 setting until the check is satisfied.
`W1CT, REF1POL Setting Combination Invalid`	Group settings, REF element	REF element is only available when setting W*n*CT := WYE (*n* = 1, 2, 3, or 4).

[a] Relay forces MVA := OFF prior to this message.

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SEL-787-2, -3, -4 Settings Sheets

These settings sheets include the definition and input range for each setting in the relay. You can access the settings from the relay front panel and the serial ports.

- Some settings require an optional module (see *Section 4: Protection and Logic Functions* for details).
- Some of the settings ranges may be more restrictive than shown because of settings interdependency checks performed when new settings are saved (see *Web Server on page 6.6*).
- The settings are not case sensitive.
- NOM in the setting range implies nominal rating of the corresponding CT input.

Group Settings (SET Command)

Identifier

UNIT ID LINE 1 (16 Characters) **RID** := ____________

UNIT ID LINE 2 (16 Characters) **TID** := ____________

Configuration

WDG1 DIFF ENABLE (Y, N) **E87W1** := ____________

WDG2 DIFF ENABLE (Y, N) **E87W2** := ____________

WDG3 DIFF ENABLE (Y, N, REF) **E87W3** := ____________
(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI)

WDG4 DIFF ENABLE (Y, N) **E87W4** := ____________
(Shown if Slot E card is 6 ACI)

WDG1 CT CONN (DELTA, WYE) **W1CT** := ____________

WDG2 CT CONN (DELTA, WYE) **W2CT** := ____________

WDG3 CT CONN (DELTA, WYE) **W3CT** := ____________
(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI; hidden and forced to WYE if E87W3 := REF)

WDG4 CT CONN (DELTA, WYE) **W4CT** := ____________
(Shown if Slot E card is 6 ACI)

WDG1 PHASE CTR **CTR1** := ____________
(1–10000 {5 A NOM}; 1–50000 {1 A NOM})
(Shown if Slot Z ≠ L0)

CURR SENSOR TYPE (RCOIL, LPCT) **CS_TYP1** := ____________
(Shown if Slot Z = L0)

RATED PRI CURR (1–6000 A pri) **IPR1** := ____________
(Shown if Slot Z = L0)

RATED SENS VOLT (10.0–1000.0 mV at FNOM) **USR1** := ____________
(Shown if Slot Z = L0)

NOMINAL CURRENT (1 A) **INOM1** := ____________
(Shown if Slot Z = L0)

RATED FEEDER CUR (1–10000 A pri) **FDR_CR1** := ____________
(Shown if Slot Z = L0)

PHASE ILEA SCALE (1.00–10000.00 [autocalculated]) *(Shown if Slot Z = L0)*	**ILEA_S1** := ____________
WDG2 PHASE CTR (1–10000 {5 A NOM}; 1–50000 {1 A NOM}) *(Shown if Slot Z ≠ L0)*	**CTR2** := ____________
CURR SENSOR TYPE (RCOIL, LPCT) *(Shown if Slot Z = L0)*	**CS_TYP2** := ____________
RATED PRI CURR (1–6000 A pri) *(Shown if Slot Z = L0)*	**IPR2** := ____________
RATED SENS VOLT (10.0–1000.0 mV at FNOM) *(Shown if Slot Z = L0)*	**USR2** := ____________
NOMINAL CURRENT (1 A) *(Shown if Slot Z = L0)*	**INOM2** := ____________
RATED FEEDER CUR (1–10000 A pri) *(Shown if Slot Z = L0)*	**FDR_CR2** := ____________
PHASE ILEA SCALE (1.00–10000.00 [autocalculated]) *(Shown if Slot Z = L0)*	**ILEA_S2** := ____________
WDG3 PHASE CTR (1–10000 {5 A NOM}; 1–50000 {1 A NOM}) *(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI (Slot E ≠ (L0 or L1 or L2); hidden if E87W3 := REF))*	**CTR3** := ____________
CURR SENSOR TYPE (RCOIL, LPCT) *(Shown if Slot E card (L0 or L1 or L2); hidden if E87W3 := REF)*	**CS_TYP3** := ____________
RATED PRI CURR (1–6000 A pri) *(Shown if Slot E card (L0 or L1 or L2); hidden if E87W3 := REF)*	**IPR3** := ____________
RATED SENS VOLT (10.0–1000.0 mV at FNOM) *(Shown if Slot E card (L0 or L1 or L2); hidden if E87W3 := REF)*	**USR3** := ____________
NOMINAL CURRENT (1 A) *(Shown if Slot E card (L0 or L1 or L2); hidden if E87W3 := REF)*	**INOM3** := ____________
RATED FEEDER CUR (1–10000 A pri) *(Shown if Slot E card (L0 or L1 or L2); hidden if E87W3 := REF)*	**FDR_CR3** := ____________
PHASE ILEA SCALE (1.00–10000.00 [autocalculated]) *(Shown if Slot E card (L0 or L1 or L2); hidden if E87W3 := REF)*	**ILEA_S3** := ____________
WDG3 A PHASE CTR (1–10000 {5 A NOM}; 1–50000 {1 A NOM}) *(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI (Slot E ≠ (L0 or L1 or L2); shown if E87W3 := REF, else forced to CTR3 and hidden))*	**CTR3A** := ____________
CURR SENSOR TYPE (RCOIL, LPCT) *(Shown if Slot E card = (L0 or L1 or L2); shown if E87W3 := REF, else forced to CTR3 and hidden))*	**CS_TYP3A** := ____________
RATED PRI CURR (1–6000 A pri) *(Shown if Slot E card = (L0 or L1 or L2); shown if E87W3 := REF, else forced to CTR3 and hidden)*	**IPR3A** := ____________
RATED SENS VOLT (10.0–1000.0 mV at FNOM) *(Shown if Slot E card = (L0 or L1 or L2); shown if E87W3 := REF, else forced to CTR3 and hidden))*	**USR3A** := ____________
RATED FEEDER CUR (1–10000 A pri) *(Shown if Slot E card = (L0 or L1 or L2); shown if E87W3 := REF, else forced to CTR3 and hidden))*	**FDR_CR3A** := ____________
PHASE ILEA SCALE (1.00–10000.00 [autocalculated]) *(Shown if Slot E card = (L0 or L1 or L2); shown if E87W3 := REF, else forced to CTR3 and hidden))*	**ILEA_S3A** := ____________

WDG3 B PHASE CTR (1–10000 {5 A NOM}; 1–50000 {1 A NOM}) *(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI (Slot E ≠ (L0 or L1 or L2); shown if E87W3 := REF, else forced to CTR3 and hidden))*	**CTR3B** := ______________
CURR SENSOR TYPE (RCOIL, LPCT) *(Shown if Slot E card = (L0 or L1 or L2); shown if E87W3 := REF, else forced to CTR3 and hidden))*	**CS_TYP3B** := ______________
RATED PRI CURR (1–6000 A pri) *(Shown if Slot E card = (L0 or L1 or L2); shown if E87W3 := REF, else forced to CTR3 and hidden))*	**IPR3B** := ______________
RATED SENS VOLT (10.0–1000.0 mV at FNOM) *(Shown if Slot E card = (L0 or L1 or L2); shown if E87W3 := REF, else forced to CTR3 and hidden))*	**USR3B** := ______________
RATED FEEDER CUR (1–10000 A pri) *(Shown if Slot E card = (L0 or L1 or L2); shown if E87W3 := REF, else forced to CTR3 and hidden))*	**FDR_CR3B** := ______________
PHASE ILEA SCALE (1.00–10000.00 [autocalculated]) *(Shown if Slot E card = (L0 or L1 or L2); shown if E87W3 := REF, else forced to CTR3 and hidden))*	**ILEA_S3B** := ______________
WDG3 C PHASE CTR (1–10000 {5 A NOM}; 1–50000 {1 A NOM}) *(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI (Slot E ≠ (L0 or L1 or L2); shown if E87W3 := REF, else forced to CTR3 and hidden))*	**CTR3C** := ______________
CURR SENSOR TYPE (RCOIL, LPCT) *(Shown if Slot E card = (L0 or L1 or L2); shown if E87W3 := REF, else forced to CTR3 and hidden))*	**CS_TYP3C** := ______________
RATED PRI CURR (1–6000 A pri) *(Shown if Slot E card = (L0 or L1 or L2); shown if E87W3 := REF, else forced to CTR3 and hidden))*	**IPR3C** := ______________
RATED SENS VOLT (10.0–1000.0 mV at FNOM) *(Shown if Slot E card = (L0 or L1 or L2); shown if E87W3 := REF, else forced to CTR3 and hidden))*	**USR3C** := ______________
RATED FEEDER CUR (1–10000 A pri) *(Shown if Slot E card = (L0 or L1 or L2); shown if E87W3 := REF, else forced to CTR3 and hidden))*	**FDR_CR3C** := ______________
PHASE ILEA SCALE (1.00–10000.00 [autocalculated]) *(Shown if Slot E card = (L0 or L1 or L2); shown if E87W3 := REF, else forced to CTR3 and hidden))*	**ILEA_S3C** := ______________
WDG4 PHASE CTR (1–10000 {5 A NOM}; 1–50000 {1 A NOM}) *(Shown if Slot E card is 6 ACI (Slot E ≠ L0))*	**CTR4** := ______________
CURR SENSOR TYPE (RCOIL, LPCT) *(Shown if Slot E card = L0)*	**CS_TYP4** := ______________
RATED PRI CURR (1–6000 A pri) *(Shown if Slot E card = L0)*	**IPR4** := ______________
RATED SENS VOLT (10.0–1000.0 mV at FNOM) *(Shown if Slot E card = L0)*	**USR4** := ______________
NOMINAL CURRENT (1 A) *(Shown if Slot E card = L0)*	**INOM4** := ______________
RATED FEEDER CUR (1–10000 A pri) *(Shown if Slot E card = L0)*	**FDR_CR4** := ______________

PHASE ILEA SCALE (1.00–10000.00 [autocalculated]) *(Shown if Slot E card = L0)*	**ILEA_S4** := ____________
MAX XMFR CAP (OFF, 0.2–5000.0 MVA)	**MVA** := ____________
DEFINE CT COMP (Y, N)	**ICOM** := ____________
WDG1 CT COMP (0–12) *(Hidden and forced to 0 if ICOM := N or E87W1 := N)*	**W1CTC** := ____________
WDG2 CT COMP (0–12) *(Hidden and forced to 0 if ICOM := N or E87W2 := N)*	**W2CTC** := ____________
WDG3 CT COMP (0–12) *(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI; hidden and forced to 0 if ICOM := N or E87W3 := N or REF)*	**W3CTC** := ____________
WDG4 CT COMP (0–12) *(Shown if Slot E is 6 ACI; hidden and forced to 0 if ICOM := N or E87W4 := N)*	**W4CTC** := ____________
COMB CURR W1 W2 (Y, N) *(Hidden and forced to N if $I_{NOM1} \neq I_{NOM2}$; hidden and forced to N if Slot E card is not equal to 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI)*	**CCW12** := ____________
COMB CURR W2 W3 (Y, N) *(Hidden and forced to N if $I_{NOM2} \neq I_{NOM3}$; hidden and forced to N if Slot E card is not equal to (6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI))*	**CCW23** := ____________
COMB CURR W3 W4 (Y, N) *(Hidden and forced to N if $I_{NOM3} \neq I_{NOM4}$; hidden and forced to N if Slot E card is not equal to 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI)*	**CCW34** := ____________
WDG1 L-L VOLTS (0.20–1000.00 kV) *(Hidden if MVA := OFF)*	**VWDG1** := ____________
WDG2 L-L VOLTS (0.20–1000.00 kV) *(Hidden if MVA := OFF)*	**VWDG2** := ____________
WDG3 L-L VOLTS (0.20–1000.00 kV) *(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI; hidden if MVA := OFF or E87W3 := REF)*	**VWDG3** := ____________
WDG4 L-L VOLTS (0.20–1000.00 kV) *(Shown if Slot E card is 6 ACI; hidden if MVA := OFF)*	**VWDG4** := ____________
NEUT 1 CT RATIO (1–10000 {5 A NOM}, 1–50000 {1 A NOM}) *(Shown if Slot E is 4 ACI/3 AVI, 1 ACI, or 1 ACI/3 AVI card and Slot E ≠ (L2 or L6 or L8))*	**CTRN1** := ____________
CURR SENSOR TYPE (RCOIL, LPCT) *(Shown if Slot E = L2 or L6 or L8)*	**CS_TYPN1** := ____________
RATED PRI CURRENT (1–6000 A pri) *(Shown if Slot E = L2 or L6 or L8)*	**IPRN1** := ____________
RATED SENS VOLT (10.0–1000.0 mV at FNOM) *(Shown if Slot E = L2 or L6 or L8)*	**USRN1** := ____________
NOMINAL CURRENT (1 A) *(Shown if Slot E = L2 or L6 or L8)*	**INOMN1** := ____________
RATED FEEDER CUR (1–10000 A pri) *(Shown if Slot E = L2 or L6 or L8)*	**FDR_CRN1** := ____________
NEUT ILEA SCALE (1–10000.00 [autocalculated]) *(Shown if Slot E = L2 or L6 or L8)*	**ILEA_SN1** := ____________
PHASE PT RATIO (1.00–10000.00) *(Shown if Slot E is 4 ACI/3 AVI, 3 ACI/4 AVI, or 1 ACI/3 AVI card and Slot E ≠ (L1 OR L2 OR L8))*	**PTR** := ____________

PHASE LPVT RATIO (37.50–500000.00 **LEA_R** := ____________________
(Shown if Slot E = L1 OR L2 OR L8)

PHASE LPVT SCALE (1.00–13333.33 [autocalculated]) **LEA_SC** := ____________________
(Shown if Slot E = L1 OR L2 OR L8)

SYNCV PT RATIO (1.00–10000.00) **PTRS** := ____________________
(Shown if Slot E is 3 ACI/4 AVI card and Slot E ≠ L1; hidden if the Global setting VS_BAT is set to VBAT)

SYNCV LPVT RATIO (37.50–500000.00) **LEA_S_R** := ____________________
(Shown if Slot E = L1; hidden if the Global setting VS_BAT is set to VBAT)

SYNCV LPVT SCALE (1.00–13333.33 [autocalculated]) **LEA_SC** := ____________________
(Shown if Slot E = L1; hidden if the Global setting VS_BAT is set to VBAT)

NOMINAL VOLTAGE (0.20–1000.00 kV) **VNOM** := ____________________
(Shown if Slot E is 4 ACI/3 AVI, 3 ACI/4 AVI, or 1 ACI/3 AVI card)

PT CONNECTION (DELTA, WYE) **DELTA_Y** := ____________________
(Shown if Slot E is 4 ACI/3 AVI, 3 ACI/4 AVI, or 1 ACI/3 AVI card)

VOLT-CURR WDG (1, 2, 3 OR 1, 2, 3, 12 OR 1, 2, 3, 23) **VIWDG** := ____________________
(Shown if Slot E is 4 ACI/3 AVI, 3 ACI/4 AVI, or 1 ACI/3 AVI card; 3 is hidden in the range if E87W3 := REF or if Slot E is 1 ACI/3 AVI card; range 1, 2, 3, are applicable when CCW12 := N or CCW23 := N; range 1, 2, 3, 12 are applicable when CCW12 := Y; range 1, 2, 3, 23 are applicable when CCW := Y)

COMP ANGLE (0–360 DEG) **COMPANG** := ____________________
(Shown if Slot E is 4 ACI/3 AVI, 3 ACI/4 AVI, or 1 ACI/3 AVI card)

SINGLE V INPUT (Y, N) **SINGLEV** := ____________________
(Shown if Slot E is 4 ACI/3 AVI, 3 ACI/4 AVI, or 1 ACI/3 AVI card)

Transformer Differential

(All subsequent settings in this category are shown if E87Wn := Y (n = 1, 2, 3, or 4) for at least two windings)

WDG1 CURR TAP (0.50–155.00 A {5 A NOM}; 0.10–31.00 A {1 A NOM}) **TAP1** := ____________________
(Shown if E87W1 := Y; can only be set if MVA := OFF, else the relay calculates the setting automatically)

WDG2 CURR TAP (0.50–155.00 A {5 A NOM}; 0.10–31.00 A {1 A NOM}) **TAP2** := ____________________
(Shown if E87W2 := Y; can only be set if MVA := OFF, else the relay calculates the setting automatically)

WDG3 CURR TAP (0.50–155.00 A {5 A NOM}; 0.10–31.00 A {1 A NOM}) **TAP3** := ____________________
(Shown if E87W1 := Y, shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI; can only be set if MVA := OFF, else the relay calculates the setting automatically)

WDG4 CURR TAP (0.50–155.00 A {5 A NOM}; 0.10–31.00 A {1 A NOM}) **TAP4** := ____________________
(Shown if Slot E is 6 ACI; shown if E87W4 := Y, can only be set if MVA := OFF, else the relay calculates the setting automatically)

OPERATE CURR LVL (0.10–1.00 TAP) **O87P** := ____________________

DIFF CURR AL LVL (OFF, 0.05–1.00 TAP) **87AP** := ____________________

DIFF CURR AL DLY (1.00–120.00 sec) **87AD** := ____________________
(Hidden if 87AP := OFF)

RESTRAINT SLOPE1 (5%–90%) **SLP1** := ____________________

RESTRAINT SLOPE2 (5%–90%) **SLP2** := ____________

RES SLOPE1 LIMIT (1.00–20.00 TAP) **IRS1** := ____________

UNRES CURR LVL (1.00–20.00 TAP) **U87P** := ____________

2ND HARM BLOCK (OFF, 5%–100%) **PCT2** := ____________

4TH HARM BLOCK (OFF, 5%–100%) **PCT4** := ____________

5TH HARM BLOCK (OFF, 5%–100%) **PCT5** := ____________

5TH HARM AL LVL (OFF, 0.02–3.20 TAP) **TH5P** := ____________

5TH HARM AL DLY (0.00–120.00 sec) **TH5D** := ____________
(Hidden if TH5P := OFF)

HARMONIC RESTRNT (Y, N) **HRSTR** := ____________

HARMONIC BLOCK (Y, N) **HBLK** := ____________

Restricted Earth Fault

POL QTY FROM WDG (OFF, 1, 2, 3, 12, 23, 123) **REF1POL** := ____________
(Shown if Slot E is 4 ACI/3 AVI, 1 ACI, or 1 ACI/3 AVI; all subsequent settings are hidden if REF1POL := OFF; 3, 23, and 123 are hidden from the range if Slot E is 1 ACI or 1 ACI/3 AVI; 3, 23, and 123 are hidden from the range if E87W3 := REF)

REF1 TRQ CTRL (SELOGIC) **REF1TC** := ____________

REF1 CURR LEVEL (0.05–3.00 pu) **50REF1P** := ____________

REF1 BYP TQCTRL (SELOGIC) **REF1BYP** := ____________

POL QTY FROM WDG (OFF, 1, 2, 4, 12, 14, 24, 124) **REF3APOL** := ____________
(All subsequent settings are hidden if REF3APOL := OFF; all subsequent settings are hidden if Slot E = 1 ACI, 1 ACI/3 AVI, is empty, or the optional I/O; range OFF, 1, 2, 12 is applicable if Slot E has 3 ACI/4 AVI or 4 ACI/3 AVI card; range OFF, 1, 2, 4, 12, 14, 24, 124 is applicable if Slot E has a 6 ACI card)

REF3A TRQ CTRL (SELOGIC) **REF3ATC** := ____________

REF3A CURR LEVEL (0.05–3.00 pu) **50REF3AP** := ____________

REF3A BYP TQCTRL (SELOGIC) **REF3ABYP** := ____________

POL QTY FROM WDG **REF3BPOL** := ____________
(OFF, 1, 2, 4, 12, 14, 24, 124)
(All subsequent settings are hidden if REF3BPOL := OFF; all subsequent settings are hidden if Slot E = 1 ACI, 1 ACI/3 AVI, is empty, or optional I/O; range OFF, 1, 2, 12 applicable if Slot E has 3 ACI/4 AVI or 4 ACI/3 AVI card; range OFF, 1, 2, 4, 12, 14, 24, 124 is applicable if Slot E has 6 ACI card)

REF3B TRQ CTRL (SELOGIC) **REF3BTC** := ____________

REF3B CURR LEVEL (0.05–3.00 pu) **50REF3BP** := ____________

REF3B BYP TQCTRL (SELOGIC) **REF3BBYP** := ____________

Winding 1 Maximum Phase Overcurrent

PHASE IOC LEVEL **50P11P** := ____________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50P11P := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P11D** := ____________

PH IOC TRQCTRL (SELOGIC) **50P11TC** := ____________________

PHASE IOC LEVEL **50P12P** := ____________________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50P12P := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P12D** := ____________________

PH IOC TRQCTRL (SELOGIC) **50P12TC** := ____________________

PHASE IOC LEVEL **50P13P** := ____________________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50P13P := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P13D** := ____________________

PH IOC TRQCTRL (SELOGIC) **50P13TC** := ____________________

PHASE IOC LEVEL **50P14P** := ____________________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50P14P := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P14D** := ____________________

PH IOC TRQCTRL (SELOGIC) **50P14TC** := ____________________

Winding 1 Residual Overcurrent

RES IOC LEVEL **50G11P** := ____________________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50G11P := OFF)

RES IOC DELAY (OFF, 0.00–5.00 sec) **50G11D** := ____________________

RES IOC TRQCTRL (SELOGIC) **50G11TC** := ____________________

RES IOC LEVEL **50G12P** := ____________________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50G12P := OFF)

RES IOC DELAY (OFF, 0.00–5.00 sec) **50G12D** := ____________________

RES IOC TRQCTRL (SELOGIC) **50G12TC** := ____________________

Winding 1 Negative-Sequence Overcurrent

NSEQ IOC LEVEL **50Q11P** := ____________________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50Q11P := OFF)

NSEQ IOC DELAY (OFF, 0.10–120.00 sec) **50Q11D** := ____________________

NSEQ IOC TRQCTRL (SELOGIC) **50Q11TC** := ____________________

NSEQ IOC LEVEL **50Q12P** := ____________________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50Q12P := OFF)

NSEQ IOC DELAY (OFF, 0.10–120.00 sec) **50Q12D** := ____________________

NSEQ IOC TRQCTRL (SELOGIC) **50Q12TC** := ____________________

Winding 1 Maximum Phase Time-Overcurrent

PHASE TOC LEVEL **51P1P** := ____________________
(OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM})
(All subsequent settings are hidden if 51P1P := OFF)

PHASE TOC CURVE (U1–U5, C1–C5) **51P1C** := ____________________

PHASE TOC TDIAL (0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5) **51P1TD** := ____________

EM RESET DELAY (Y, N) **51P1RS** := ____________

CONST TIME ADDER (0.00–1.00 sec) **51P1CT** := ____________

MIN RESPONSE TIM (0.00–1.00 sec) **51P1MR** := ____________

PH TOC TRQCTRL (SELOGIC) **51P1TC** := ____________

Winding 1 Residual Time-Overcurrent

RES TOC LEVEL (OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM}) **51G1P** := ____________
(All subsequent settings are hidden if 51G1P := OFF)

RES TOC CURVE (U1–U5, C1–C5) **51G1C** := ____________

RES TOC TDIAL (0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5) **51G1TD** := ____________

EM RESET DELAY (Y, N) **51G1RS** := ____________

CONST TIME ADDER (0.00–1.00 sec) **51G1CT** := ____________

MIN RESPONSE TIM (0.00–1.00 sec) **51G1MR** := ____________

RES TOC TRQCTRL (SELOGIC) **51G1TC** := ____________

Winding 1 Negative-Sequence Time-Overcurrent

NSEQ TOC LEVEL (OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM}) **51Q1P** := ____________
(All subsequent settings are hidden if 51Q1P := OFF)

NSEQ TOC CURVE (U1–U5, C1–C5) **51Q1C** := ____________

NSEQ TOC TDIAL (0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5) **51Q1TD** := ____________

EM RESET DELAY (Y, N) **51Q1RS** := ____________

CONST TIME ADDER (0.00–1.00 sec) **51Q1CT** := ____________

MIN RESPONSE TIM (0.00–1.00 sec) **51Q1MR** := ____________

NSEQ TOC TRQCTRL (SELOGIC) **51Q1TC** := ____________

Winding 2 Maximum Phase Overcurrent

PHASE IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) **50P21P** := ____________
(All subsequent settings are hidden if 50P21P := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P21D** := ____________

PH IOC TRQCTRL (SELOGIC) **50P21TC** := ____________

PHASE IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) **50P22P** := ____________
(All subsequent settings are hidden if 50P22P := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P22D** := ____________

PH IOC TRQCTRL (SELOGIC) **50P22TC** := ____________

PHASE IOC LEVEL **50P23P** := ____________________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50P23P := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P23D** := ____________________

PH IOC TRQCTRL (SELOGIC) **50P23TC** := ____________________

PHASE IOC LEVEL **50P24P** := ____________________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50P24P := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P24D** := ____________________

PH IOC TRQCTRL (SELOGIC) **50P24TC** := ____________________

Winding 2 Residual Overcurrent

RES IOC LEVEL **50G21P** := ____________________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50G21P := OFF)

RES IOC DELAY (OFF, 0.00–5.00 sec) **50G21D** := ____________________

RES IOC TRQCTRL (SELOGIC) **50G21TC** := ____________________

RES IOC LEVEL **50G22P** := ____________________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50G22P := OFF)

RES IOC DELAY (OFF, 0.00–5.00 sec) **50G22D** := ____________________

RES IOC TRQCTRL (SELOGIC) **50G22TC** := ____________________

Winding 2 Negative-Sequence Overcurrent

NSEQ IOC LEVEL **50Q21P** := ____________________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent setting are hidden if 50Q21P := OFF)

NSEQ IOC DELAY (OFF, 0.10–120.00 sec) **50Q21D** := ____________________

NSEQ IOC TRQCTRL (SELOGIC) **50Q21TC** := ____________________

NSEQ IOC LEVEL **50Q22P** := ____________________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent setting are hidden if 50Q22P := OFF)

NSEQ IOC DELAY (OFF, 0.10–120.00 sec) **50Q22D** := ____________________

NSEQ IOC TRQCTRL (SELOGIC) **50Q22TC** := ____________________

Winding 2 Maximum Phase Time-Overcurrent

PHASE TOC LEVEL **51P2P** := ____________________
(OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM})
(All subsequent settings are hidden if 51P2P := OFF)

PHASE TOC CURVE (U1–U5, C1–C5) **51P2C** := ____________________

PHASE TOC TDIAL **51P2TD** := ____________________
(0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5)

EM RESET DELAY (Y, N) **51P2RS** := ____________________

CONST TIME ADDER (0.00–1.00 sec) **51P2CT** := ____________________

MIN RESPONSE TIM (0.00–1.00 sec) **51P2MR** := ____________________

PH TOC TRQCTRL (SELOGIC) **51P2TC** := ______________

Winding 2 Residual Time-Overcurrent

RES TOC LEVEL **51G2P** := ______________
(OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM})
(All subsequent settings are hidden if 51G2P := OFF)

RES TOC CURVE (U1–U5, C1–C5) **51G2C** := ______________

RES TOC TDIAL **51G2TD** := ______________
(0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5)

EM RESET DELAY (Y, N) **51G2RS** := ______________

CONST TIME ADDER (0.00–1.00 sec) **51G2CT** := ______________

MIN RESPONSE TIM (0.00–1.00 sec) **51G2MR** := ______________

RES TOC TRQCTRL (SELOGIC) **51G2TC** := ______________

Winding 2 Negative-Sequence Time-Overcurrent

NSEQ TOC LEVEL **51Q2P** := ______________
(OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM})
(All subsequent settings are hidden if 51Q2P := OFF)

NSEQ TOC CURVE (U1–U5, C1–C5) **51Q2C** := ______________

NSEQ TOC TDIAL **51Q2TD** := ______________
(0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5)

EM RESET DELAY (Y, N) **51Q2RS** := ______________

CONST TIME ADDER (0.00–1.00 sec) **51Q2CT** := ______________

MIN RESPONSE TIM (0.00–1.00 sec) **51Q2MR** := ______________

NSEQ TOC TRQCTRL (SELOGIC) **51Q2TC** := ______________

Winding 3 Per-Phase Overcurrent

(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI)

Level 1 Phase A

PHASE IOC LEVEL **50P31AP** := ______________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50P31AP := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P31AD** := ______________

PH IOC TRQCTRL (SELOGIC) **50P31ATC** := ______________

Level 1 Phase B

PHASE IOC LEVEL **50P31BP** := ______________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50P31BP := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P31BD** := ______________

PH IOC TRQCTRL (SELOGIC) **50P31BTC** := ______________

Level 1 Phase C

PHASE IOC LEVEL **50P31CP** := ______________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50P31CP := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P31CD** := ____________

PH IOC TRQCTRL (SELOGIC) **50P31CTC** := ____________

Level 2 Phase A

PHASE IOC LEVEL **50P32AP** := ____________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50P32AP := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P32AD** := ____________

PH IOC TRQCTRL (SELOGIC) **50P32ATC** := ____________

Level 2 Phase B

PHASE IOC LEVEL **50P32BP** := ____________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50P32BP := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P32BD** := ____________

PH IOC TRQCTRL (SELOGIC) **50P32BTC** := ____________

Level 2 Phase C

PHASE IOC LEVEL **50P32CP** := ____________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50P32CP := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P32CD** := ____________

PH IOC TRQCTRL (SELOGIC) **50P32CTC** := ____________

Winding 3 Per-Phase Time-Overcurrent

(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI)

Phase A

PHASE TOC LEVEL **51P3AP** := ____________
(OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM})
(All subsequent settings are hidden if 51P3AP := OFF)

PHASE TOC CURVE (U1–U5, C1–C5) **51P3AC** := ____________

PHASE TOC TDIAL **51P3ATD** := ____________
(0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5)

EM RESET DELAY (Y, N) **51P3ARS** := ____________

CONST TIME ADDER (0.00–1.00 sec) **51P3ACT** := ____________

MIN RESPONSE TIM (0.00–1.00 sec) **51P3AMR** := ____________

PH TOC TRQCTRL (SELOGIC) **51P3ATC** := ____________

Phase B

PHASE TOC LEVEL **51P3BP** := ____________
(OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM})
(All subsequent settings are hidden if 51P3BP := OFF)

PHASE TOC CURVE (U1–U5, C1–C5) **51P3BC** := ____________

PHASE TOC TDIAL **51P3BTD** := ____________
(0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5)

EM RESET DELAY (Y, N) **51P3BRS** := ____________

CONST TIME ADDER (0.00–1.00 sec) **51P3BCT** := ____________

MIN RESPONSE TIM (0.00–1.00 sec) **51P3BMR** := ____________

PH TOC TRQCTRL (SELOGIC) **51P3BTC** := ____________

Phase C

PHASE TOC LEVEL **51P3CP** := ____________
(OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM})
(All subsequent settings are hidden if 51P3CP := OFF)

PHASE TOC CURVE (U1–U5, C1–C5) **51P3CC** := ____________

PHASE TOC TDIAL **51P3CTD** := ____________
(0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5)

EM RESET DELAY (Y, N) **51P3CRS** := ____________

CONST TIME ADDER (0.00–1.00 sec) **51P3CCT** := ____________

MIN RESPONSE TIM (0.00–1.00 sec) **51P3CMR** := ____________

PH TOC TRQCTRL (SELOGIC) **51P3CTC** := ____________

Winding 3 Maximum Phase Overcurrent

(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI; 50P3nP [n = 1, 2, 3, or 4] is hidden and forced to OFF if E87W3 := REF)

PHASE IOC LEVEL **50P31P** := ____________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50P31P := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P31D** := ____________

PH IOC TRQCTRL (SELOGIC) **50P31TC** := ____________

PHASE IOC LEVEL **50P32P** := ____________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50P32P := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P32D** := ____________

PH IOC TRQCTRL (SELOGIC) **50P32TC** := ____________

PHASE IOC LEVEL **50P33P** := ____________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50P33P := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P33D** := ____________

PH IOC TRQCTRL (SELOGIC) **50P33TC** := ____________

PHASE IOC LEVEL **50P34P** := ____________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50P34P := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P34D** := ____________

PH IOC TRQCTRL (SELOGIC) **50P34TC** := ____________

Winding 3 Residual Overcurrent

(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI; 50G3nP [n = 1 or 2] is hidden and forced to OFF if E87W3 := REF)

RES IOC LEVEL **50G31P** := ____________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50G31P := OFF)

RES IOC DELAY (OFF, 0.00–5.00 sec) **50G31D** := ____________

RES IOC TRQCTRL (SELOGIC) **50G31TC** := ____________________

RES IOC LEVEL **50G32P** := ____________________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 50G32P := OFF)

RES IOC DELAY (OFF, 0.00–5.00 sec) **50G32D** := ____________________

RES IOC TRQCTRL (SELOGIC) **50G32TC** := ____________________

Winding 3 Negative-Sequence Overcurrent

(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI; 50Q3nP [n = 1 or 2] is hidden and forced to OFF if E87W3 := REF)

NSEQ IOC LEVEL **50Q31P** := ____________________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(Subsequent settings are hidden if 50Q31P := OFF)

NSEQ IOC DELAY (OFF, 0.00–5.00 sec) **50Q31D** := ____________________

NSEQ IOC TRQCTRL (SELOGIC) **50Q31TC** := ____________________

NSEQ IOC LEVEL **50Q32P** := ____________________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(Subsequent settings are hidden if 50Q32P := OFF)

NSEQ IOC DELAY (OFF, 0.00–5.00 sec) **50Q32D** := ____________________

NSEQ IOC TRQCTRL (SELOGIC) **50Q32TC** := ____________________

Winding 3 Maximum Phase Time-Overcurrent

(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI; 51P3P is hidden and forced to OFF if E87W3 := REF)

PHASE TOC LEVEL **51P3P** := ____________________
(0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM})
(All subsequent settings are hidden if 51P3P := OFF

PHASE TOC CURVE (U1–U5, C1–C5) **51P3C** := ____________________

PHASE TOC TDIAL **51P3TD** := ____________________
(0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5)

EM RESET DELAY (Y, N) **51P3RS** := ____________________

CONST TIME ADDER (0.00–1.00 sec) **51P3CT** := ____________________

MIN RESPONSE TIM (0.00–1.00 sec) **51P3MR** := ____________________

PH TOC TRQCTRL (SELOGIC) **51P3TC** := ____________________

Winding 3 Residual Time-Overcurrent

(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI; 51G3P is hidden and forced to OFF if E87W3 := REF)

RES TOC LEVEL **51G3P** := ____________________
(OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM})
(All subsequent settings are hidden if 51G3P := OFF)

RES TOC CURVE (U1–U5, C1–C5) **51G3C** := ____________________

RES TOC TDIAL **51G3TD** := ____________________
(0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5)

EM RESET DELAY (Y, N) **51G3RS** := ____________________

CONST TIME ADDER (0.00–1.00 sec) **51G3CT** := ____________________

MIN RESPONSE TIM (0.00–1.00 sec) **51G3MR** := ____________________

RES TOC TRQCTRL (SELOGIC) **51G3TC** := ____________________

Winding 3 Negative-Sequence Time-Overcurrent

(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI, 51Q3P is hidden and forced to OFF if E87W3 := REF)

NSEQ TOC LEVEL (OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM}) *(All subsequent settings are hidden if 51Q3P := OFF)*	**51Q3P** := ____________
NSEQ TOC CURVE (U1–U2, C1–C5)	**51Q3C** := ____________
NSEQ TOC TDIAL (0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5)	**51Q3TD** := ____________
EM RESET DELAY (Y, N)	**51Q3RS** := ____________
CONST TIME ADDER (0.00–1.00 sec)	**51Q3CT** := ____________
MIN RESPONSE TIM (0.00–1.00 sec)	**51Q3MR** := ____________
NSEQ TOC TRQCTRL (SELOGIC)	**51Q3TC** := ____________

Winding 4 Maximum Phase Overcurrent

(Shown if Slot E card is 6 ACI)

PHASE IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) *(All subsequent settings are hidden if 50P41P := OFF)*	**50P41P** := ____________
PHASE IOC DELAY (OFF, 0.00–5.00 sec)	**50P41D** := ____________
PH IOC TRQCTRL (SELOGIC)	**50P41TC** := ____________
PHASE IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) *(All subsequent settings are hidden if 50P42P := OFF)*	**50P42P** := ____________
PHASE IOC DELAY (OFF, 0.00–5.00 sec)	**50P42D** := ____________
PH IOC TRQCTRL (SELOGIC)	**50P42TC** := ____________
PHASE IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) *(All subsequent settings are hidden if 50P43P := OFF)*	**50P43P** := ____________
PHASE IOC DELAY (OFF, 0.00–5.00 sec)	**50P43D** := ____________
PH IOC TRQCTRL (SELOGIC)	**50P43TC** := ____________
PHASE IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) *(All subsequent settings are hidden if 50P44P := OFF)*	**50P44P** := ____________
PHASE IOC DELAY (OFF, 0.00–5.00 sec)	**50P44D** := ____________
PH IOC TRQCTRL (SELOGIC)	**50P44TC** := ____________

Winding 4 Residual Overcurrent

(Shown if Slot E card is 6 ACI)

RES IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) *(All subsequent settings are hidden if 50G41P := OFF)*	**50G41P** := ____________
RES IOC DELAY (OFF, 0.00–5.00 sec)	**50G41D** := ____________
RES IOC TRQCTRL (SELOGIC)	**50G41TC** := ____________
RES IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) *(All subsequent settings are hidden if 50G42P := OFF)*	**50G42P** := ____________

RES IOC DELAY (OFF, 0.00–5.00 sec) **50G42D** := ______________

RES IOC TRQCTRL (SELOGIC) **50G42TC** := ______________

Winding 4 Negative-Sequence Overcurrent

(Shown if Slot E card is 6 ACI)

NSEQ IOC LEVEL **50Q41P** := ______________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(Subsequent settings are hidden if 50Q41P := OFF)

NSEQ IOC DELAY (OFF, 0.00–5.00 sec) **50Q41D** := ______________

NSEQ IOC TRQCTRL (SELOGIC) **50Q41TC** := ______________

NSEQ IOC LEVEL **50Q42P** := ______________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(Subsequent settings are hidden if 50Q42P := OFF)

NSEQ IOC DELAY (OFF, 0.00–5.00 sec) **50Q42D** := ______________

NSEQ IOC TRQCTRL (SELOGIC) **50Q42TC** := ______________

Winding 4 Maximum Phase Time-Overcurrent

(Shown if Slot E card is 6 ACI)

PHASE TOC LEVEL **51P4P** := ______________
(OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM})
(All subsequent settings are hidden if 51P4P := OFF)

PHASE TOC CURVE (U1–U5, C1–C5) **51P4C** := ______________

PHASE TOC TDIAL **51P4TD** := ______________
(0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5)

EM RESET DELAY (Y, N) **51P4RS** := ______________

CONST TIME ADDER (0.00–1.00 sec) **51P4CT** := ______________

MIN RESPONSE TIM (0.00–1.00 sec) **51P4MR** := ______________

PH TOC TRQCTRL (SELOGIC) **51P4TC** := ______________

Winding 4 Residual Time-Overcurrent

(Shown if Slot E card is 6 ACI)

RES TOC LEVEL **51G4P** := ______________
(OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM})
(All subsequent settings are hidden if 51G4P := OFF)

RES TOC CURVE (U1–U5, C1–C5) **51G4C** := ______________

RES TOC TDIAL **51G4TD** := ______________
(0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5)

EM RESET DELAY (Y, N) **51G4RS** := ______________

CONST TIME ADDER (0.00–1.00 sec) **51G4CT** := ______________

MIN RESPONSE TIM (0.00–1.00 sec) **51G4MR** := ______________

RES TOC TRQCTRL (SELOGIC) **51G4TC** := ______________

Winding 4 Negative-Sequence Time-Overcurrent

(Shown if Slot E card is 6 ACI)

NSEQ TOC LEVEL **51Q4P** := ______________
(OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM})
(All subsequent settings are hidden if 51Q4P := OFF)

NSEQ TOC CURVE (U1–U5, C1–C5)	**51Q4C** := ____________
NSEQ TOC TDIAL (0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5)	**51Q4TD** := ____________
EM RESET DELAY (Y, N)	**51Q4RS** := ____________
CONST TIME ADDER (0.00–1.00 sec)	**51Q4CT** := ____________
MIN RESPONSE TIM (0.00–1.00 sec)	**51Q4MR** := ____________
NSEQ TOC TRQCTRL (SELOGIC)	**51Q4TC** := ____________

Winding 12 Maximum Phase Overcurrent

(50P121P and 50P122P is hidden and forced to OFF if CCW12 := N)

PHASE IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) *(All subsequent settings are hidden if 50P121P := OFF)*	**50P121P** := ____________
PHASE IOC DELAY (OFF, 0.00–5.00 sec)	**50P121D** := ____________
PH IOC TRQCTRL (SELOGIC)	**50P121TC** := ____________
PHASE IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) *(All subsequent settings are hidden if 50P122P := OFF)*	**50P122P** := ____________
PHASE IOC DELAY (OFF, 0.00–5.00 sec)	**50P122D** := ____________
PH IOC TRQCTRL (SELOGIC)	**50P122TC** := ____________

Winding 12 Residual Overcurrent

(50G121P and 50G122P is hidden and forced to OFF if CCW12 := N)

RES IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) *(All subsequent settings are hidden if 50G121P := OFF)*	**50G121P** := ____________
RES IOC DELAY (OFF, 0.00–5.00 sec)	**50G121D** := ____________
RES IOC TRQCTRL (SELOGIC)	**50G121TC** := ____________
RES IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) *(All subsequent settings are hidden if 50G122P := OFF)*	**50G122P** := ____________
RES IOC DELAY (OFF, 0.00–5.00 sec)	**50G122D** := ____________
RES IOC TRQCTRL (SELOGIC)	**50G122TC** := ____________

Winding 12 Maximum Phase Time-Overcurrent

(51PC12P is hidden and forced to OFF if CCW12 := N)

PHASE TOC LEVEL (OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM}) *(All subsequent settings are hidden if 51PC12P := OFF)*	**51PC12P** := ____________
PHASE TOC CURVE (U1–U5, C1–C5)	**51PC12C** := ____________
PHASE TOC TDIAL (0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5)	**51PC12TD** := ____________
EM RESET DELAY (Y, N)	**51PC12RS** := ____________
CONST TIME ADDER (0.00–1.00 sec)	**51PC12CT** := ____________
MIN RESPONSE TIM (0.00–1.00 sec)	**51PC12MR** := ____________
PH TOC TRQCTRL (SELOGIC)	**51PC12TC** := ____________

Winding 12 Residual Time-Overcurrent

(51GC12P is hidden and forced to OFF if CCW12 := N)

RES TOC LEVEL **51GC12P** := ____________
(OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM})
(All subsequent settings are hidden if 51GC12P := OFF)

RES TOC CURVE (U1–U5, C1–C5) **51GC12C** := ____________

RES TOC TDIAL **51GC12TD** := ____________
(0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5)

EM RESET DELAY (Y, N) **51GC12RS** := ____________

CONST TIME ADDER (0.00–1.00 sec) **51GC12CT** := ____________

MIN RESPONSE TIM (0.00–1.00 sec) **51GC12MR** := ____________

RES TOC TRQCTRL (SELOGIC) **51GC12TC** := ____________

Winding 23 Maximum Phase Overcurrent

(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI; 50P231P and 50P232P is hidden and forced to OFF if CCW23 := N)

PHASE IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) **50P231P** := ____________
(All subsequent settings are hidden if 50P231P := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P231D** := ____________

PH IOC TRQCTRL (SELOGIC) **50P231TC** := ____________

PHASE IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) **50P232P** := ____________
(All subsequent settings are hidden if 50P232P := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P122D** := ____________

PH IOC TRQCTRL (SELOGIC) **50P122TC** := ____________

Winding 23 Residual Overcurrent

(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI; 50G231P and 50G232P is hidden and forced to OFF if CCW23 := N)

RES IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) **50G231P** := ____________
(All subsequent settings are hidden if 50G231P := OFF)

RES IOC DELAY (OFF, 0.00–5.00 sec) **50G231D** := ____________

RES IOC TRQCTRL (SELOGIC) **50G231TC** := ____________

RES IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) **50G232P** := ____________
(All subsequent settings are hidden if 50G232P := OFF)

RES IOC DELAY (OFF, 0.00–5.00 sec) **50G232D** := ____________

RES IOC TRQCTRL (SELOGIC) **50G232TC** := ____________

Winding 23 Maximum Phase Time-Overcurrent

(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI; 51PC23P is hidden and forced to OFF if CCW23 := N)

PHASE TOC LEVEL (OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM}) **51PC23P** := ____________
(All subsequent settings are hidden if 51PC23P := OFF)

PHASE TOC CURVE (U1–U5, C1–C5) **51PC23C** := ____________

PHASE TOC TDIAL (0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5) **51PC23TD** := ____________

EM RESET DELAY (Y, N) **51PC23RS** := ____________

CONST TIME ADDER (0.00–1.00 sec) **51PC23CT** := ____________

MIN RESPONSE TIM (0.00–1.00 sec) **51PC23MR** := ____________

RES TOC TRQCTRL (SELOGIC) **51PC23TC** := ____________

Winding 23 Residual Time-Overcurrent

(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI; 51GC23P is hidden and forced to OFF if CCW23 := N)

RES TOC LEVEL (OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM}) **51GC23P** := ____________

(All subsequent settings are hidden if 51GC23P := OFF)

RES TOC CURVE (U1–U5, C1–C5) **51GC23C** := ____________

RES TOC TDIAL (0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5) **51GC23TD** := ____________

EM RESET DELAY (Y, N) **51GC23RS** := ____________

CONST TIME ADDER (0.00–1.00 sec) **51GC23CT** := ____________

MIN RESPONSE TIM (0.00–1.00 sec) **51GC23MR** := ____________

RES TOC TRQCTRL (SELOGIC) **51GC23TC** := ____________

Winding 34 Maximum Phase Overcurrent

(Shown if Slot E card is 6 ACI; 50P341P and 50P342P is hidden and forced to OFF if CCW34 := N)

PHASE IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) **50P341P** := ____________

(All subsequent settings are hidden if 50P341P := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P341D** := ____________

PH IOC TRQCTRL (SELOGIC) **50P341TC** := ____________

PHASE IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) **50P342P** := ____________

(All subsequent settings are hidden if 50P342P := OFF)

PHASE IOC DELAY (OFF, 0.00–5.00 sec) **50P342D** := ____________

PH IOC TRQCTRL (SELOGIC) **50P342TC** := ____________

Winding 34 Residual Overcurrent

(Shown if Slot E card is 6 ACI; 50G341P and 50G342P is hidden and forced to OFF if CCW34 := N)

RES IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) **50G341P** := ____________

(All subsequent settings are hidden if 50G341P := OFF)

RES IOC DELAY (OFF, 0.00–5.00 sec) **50G341D** := ____________

RES IOC TRQCTRL (SELOGIC) **50G341TC** := ____________

RES IOC LEVEL (OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM}) **50G342P** := ____________

(All subsequent settings are hidden if 50G342P := OFF)

RES IOC DELAY (OFF, 0.00–5.00 sec) **50G342D** := ____________

RES IOC TRQCTRL (SELOGIC) **50G342TC** := ____________

Winding 34 Maximum Phase Time-Overcurrent

(Shown if Slot E card is 6 ACI; 51PC34P is hidden and forced to OFF if CCW34 := N)

PHASE TOC LEVEL **51PC34P** := ____________________
(OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM})
(All subsequent settings are hidden if 51PC34P := OFF)

PHASE TOC CURVE (U1–U5, C1–C5) **51PC34C** := ____________________

PHASE TOC TDIAL **51PC34TD** := ____________________
(0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5)

EM RESET DELAY (Y, N) **51PC34RS** := ____________________

CONST TIME ADDER (0.00–1.00 sec) **51PC34CT** := ____________________

MIN RESPONSE TIM (0.00–1.00 sec) **51PC34MR** := ____________________

PH TOC TRQCTRL (SELOGIC) **51PC34TC** := ____________________

Winding 34 Residual Time-Overcurrent

(Shown if Slot E card is 6 ACI; 51GC34P is hidden and forced to OFF if CCW34 := N)

RES TOC LEVEL **51GC34P** := ____________________
(OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM})
(All subsequent settings are hidden if 51GC34P := OFF)

RES TOC CURVE (U1–U5, C1–C5) **51GC34C** := ____________________

RES TOC TDIAL **51GC34TD** := ____________________
(0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5)

EM RESET DELAY (Y, N) **51GC34RS** := ____________________

CONST TIME ADDER (0.00–1.00 sec) **51GC34CT** := ____________________

MIN RESPONSE TIM (0.00–1.00 sec) **51GC34MR** := ____________________

RES TOC TRQCTRL (SELOGIC) **51GC34TC** := ____________________

Neutral Overcurrent

(Shown if Slot E card is 4 ACI/3 AVI, 1 ACI, or 1 ACI/3 AVI card)

NEUT IOC LEVEL **50N11P** := ____________________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 51N11P := OFF)

NEUT IOC DELAY (OFF, 0.00–5.00 sec) **50N11D** := ____________________

NEUT IOC TRQCTRL (SELOGIC) **50N11TC** := ____________________

NEUT IOC LEVEL **50N12P** := ____________________
(OFF, 0.25–96.00 A {5 A NOM}; 0.05–19.20 A {1 A NOM})
(All subsequent settings are hidden if 51N12P := OFF)

NEUT IOC DELAY (OFF, 0.00–5.00 sec) **50N12D** := ____________________

NEUT IOC TRQCTRL (SELOGIC) **50N12TC** := ____________________

Neutral Time-Overcurrent

(Shown if Slot E card is 4 ACI/3 AVI, 1 ACI, or 1 ACI/3 AVI card)

NEUT TOC LEVEL **51N1P** := ____________________
(OFF, 0.25–16.00 A {5 A NOM}; 0.05–3.20 A {1 A NOM})
(All subsequent settings are hidden if 51N1P := OFF)

NEUT TOC CURVE (U1–U5, C1–C5) **51N1C** := ____________________

NEUT TOC TDIAL (0.50–15.00 for U1–U5; 0.05–1.00 for C1–C5) **51N1TD** := ____________

EM RESET DELAY (Y, N) **51N1RS** := ____________

CONST TIME ADDER (0.00–1.00 sec) **51N1CT** := ____________

MIN RESPONSE TIM (0.00–1.00 sec) **51N1MR** := ____________

NEUT TOC TRQCTRL (SELOGIC) **51N1TC** := ____________

RTD

RTD ENABLE (INT, EXT, NONE) **E49RTD** := ____________
(All subsequent RTD settings are hidden if E49RTD := NONE; INT hidden if the internal RTD card is not detected; only one RTDnLOC (n = 1–12) is allowed to be configured for AMB)

RTD1 LOCATION (OFF, AMB, OTH) **RTD1LOC** := ____________
(All subsequent RTD1 settings are hidden if RTD1LOC := OFF)

RTD1 IDENTIFIER (10 Characters) **RTD1NAM** := ____________
(Shown only if RTD1LOC equals OTH)

RTD1 TYPE (PT100, NI100, NI120, CU10) **RTD1TY** := ____________

RTD1 TRIP LEVEL (OFF, 1–250°C) **TRTMP1** := ____________

RTD1 WARN LEVEL (OFF, 1–250°) **ALTMP1** := ____________

RTD2 LOCATION (OFF, AMB, OTH) **RTD2LOC** := ____________
(All subsequent RTD2 settings are hidden if RTD2LOC := OFF)

RTD2 IDENTIFIER (10 Characters) **RTD2NAM** := ____________
(Shown only if RTD2LOC equals OTH)

RTD2 TYPE (PT100, NI100, NI120, CU10) **RTD2TY** := ____________

RTD2 TRIP LEVEL (OFF, 1–250°C) **TRTMP2** := ____________

RTD2 WARN LEVEL (OFF, 1–250°C) **ALTMP2** := ____________

RTD3 LOCATION (OFF, AMB, OTH) **RTD3LOC** := ____________
(All subsequent RTD3 settings are hidden if RTD3LOC := OFF)

RTD3 IDENTIFIER (10 Characters) **RTD3NAM** := ____________
(Shown only if RTD3LOC equals OTH)

RTD3 TYPE (PT100, NI100, NI120, CU10) **RTD3TY** := ____________

RTD3 TRIP LEVEL (OFF, 1–250°C) **TRTMP3** := ____________

RTD3 WARN LEVEL (OFF, 1–250°C) **ALTMP3** := ____________

RTD4 LOCATION (OFF, AMB, OTH) **RTD4LOC** := ____________
(All subsequent RTD4 settings are hidden if RTD4LOC := OFF)

RTD4 IDENTIFIER (10 Characters) **RTD4NAM** := ____________
(Shown only if RTD4LOC equals OTH)

RTD4 TYPE (PT100, NI100, NI120, CU10) **RTD4TY** := ____________

RTD4 TRIP LEVEL (OFF, 1–250°C) **TRTMP4** := ____________

RTD4 WARN LEVEL (OFF, 1–250°C) **ALTMP4** := ____________

RTD5 LOCATION (OFF, AMB, OTH) **RTD5LOC** := ____________
(All subsequent RTD5 settings are hidden if RTD5LOC := OFF)

RTD5 IDENTIFIER (10 Characters) **RTD5NAM** := ____________
(Shown only if RTD5LOC equals OTH)

RTD5 TYPE (PT100, NI100, NI120, CU10) **RTD5TY** := ____________

RTD5 TRIP LEVEL (OFF, 1–250°C) **TRTMP5** := ____________

RTD5 WARN LEVEL (OFF, 1–250°C) **ALTMP5** := ____________

RTD6 LOCATION (OFF, AMB, OTH) **RTD6LOC** := ____________
(All subsequent RTD6 settings are hidden if RTD6LOC := OFF)

RTD6 IDENTIFIER (10 Characters) **RTD6NAM** := ____________
(Shown only if RTD6LOC equals OTH)

RTD6 TYPE (PT100, NI100, NI120, CU10) **RTD6TY** := ____________

RTD6 TRIP LEVEL (OFF, 1–250°C) **TRTMP6** := ____________

RTD6 WARN LEVEL (OFF, 1–250°C) **ALTMP6** := ____________

RTD7 LOCATION (OFF, AMB, OTH) **RTD7LOC** := ____________
(All subsequent RTD7 settings are hidden if RTD7LOC := OFF)

RTD7 IDENTIFIER (10 Characters) **RTD7NAM** := ____________
(Shown only if RTD7LOC equals OTH)

RTD7 TYPE (PT100, NI100, NI120, CU10) **RTD7TY** := ____________

RTD7 TRIP LEVEL (OFF, 1–250°C) **TRTMP7** := ____________

RTD7 WARN LEVEL (OFF, 1–250°C) **ALTMP7** := ____________

RTD8 LOCATION (OFF, AMB, OTH) **RTD8LOC** := ____________
(All subsequent RTD8 settings are hidden if RTD8LOC := OFF)

RTD8 IDENTIFIER (10 Characters) **RTD8NAM** := ____________
(Shown only if RTD8LOC equals OTH)

RTD8 TYPE (PT100, NI100, NI120, CU10) **RTD8TY** := ____________

RTD8 TRIP LEVEL (OFF, 1–250°C) **TRTMP8** := ____________

RTD8 WARN LEVEL (OFF, 1–250°C) **ALTMP8** := ____________

RTD9 LOCATION (OFF, AMB, OTH) **RTD9LOC** := ____________
(All subsequent RTD9 settings are hidden if RTD9LOC := OFF)

RTD9 IDENTIFIER (10 Characters) **RTD9NAM** := ____________
(Shown only if RTD9LOC equals OTH)

RTD9 TYPE (PT100, NI100, NI120, CU10) **RTD9TY** := ____________

RTD9 TRIP LEVEL (OFF, 1–250°C) **TRTMP9** := ____________

RTD9 WARN LEVEL (OFF, 1–250°C) **ALTMP9** := ____________

RTD10 LOCATION (OFF, AMB, OTH) **RTD10LOC** := ____________
(All subsequent RTD10 settings are hidden if RTD10LOC := OFF)

RTD10 IDENTIFIER (10 Characters) **RTD10NAM** := ____________
(Shown only if RTD10LOC equals OTH)

Date ___________
Group___________

RTD10 TYPE (PT100, NI100, NI120, CU10) **RTD10TY** := ____________

RTD10 TRIP LEVEL (OFF, 1–250°C) **TRTMP10** := ____________

RTD10 WARN LEVEL (OFF, 1–250°C) **ALTMP10** := ____________

RTD11 LOCATION (OFF, AMB, OTH) **RTD11LOC** := ____________
(RTD11LOC is hidden and forced to OFF if E49RTD equals INT; all subsequent RTD11 settings are hidden if RTD11LOC := OFF)

RTD11 IDENTIFIER (10 Characters) **RTD11NAM** := ____________
(Shown only if RTD11LOC equals OTH)

RTD11 TYPE (PT100, NI100, NI120, CU10) **RTD11TY** := ____________

RTD11 TRIP LEVEL (OFF, 1–250°C) **TRTMP11** := ____________

RTD11 WARN LEVEL (OFF, 1–250°C) **ALTMP11** := ____________

RTD12 LOCATION (OFF, AMB, OTH) **RTD12LOC** := ____________
(RTD12LOC is hidden and forced to OFF if E49RTD equals INT; all subsequent RTD12 settings are hidden if RTD12LOC := OFF)

RTD12 IDENTIFIER (10 Characters) **RTD12NAM** := ____________
(Shown only if RTD12LOC equals OTH)

RTD12 TYPE (PT100, NI100, NI120, CU10) **RTD12TY** := ____________

RTD12 TRIP LEVEL (OFF, 1–250°C) **TRTMP12** := ____________

RTD12 WARN LEVEL (OFF, 1–250°C) **ALTMP12** := ____________

Undervoltage

(All subsequent settings are hidden if there is no 4 ACI/3 AVI, 3 ACI/4 AVI, or 1 ACI/3 AVI card in Slot E)

PHASE UV LEVEL (OFF, 12.50–300.00 V) **27P1P** := ____________
(Hidden and forced to OFF if DELTA_Y := DELTA)

PHASE UV DELAY (0.00–120.00 sec) **27P1D** := ____________
(Hidden if associated pickup is OFF)

PHASE UV LEVEL (OFF, 12.50–300.00 V) **27P2P** := ____________
(Hidden and forced to OFF if DELTA_Y := DELTA)

PHASE UV DELAY (0.00–120.00 sec) **27P2D** := ____________
(Hidden if associated pickup is OFF)

PP UV LEVEL **27PP1P** := ____________
(OFF, 12.50–300.00 V {DELTA_Y := DELTA} OR
12.50–520.00 V {DELTA_Y := WYE})
(Hidden if SINGLEV := Y and DELTA_Y := WYE)

PP UV DELAY (0.00–120.00 sec) **27PP1D** := ____________
(Hidden if associated pickup is OFF)

PP UV LEVEL **27PP2P** := ____________
(OFF, 12.50–300.00 V {DELTA_Y := DELTA} OR
12.50–520.00 V {DELTA_Y := WYE})
(Hidden if SINGLEV :=Y and DELTA_Y := WYE)

PP UV DELAY (0.00–120.00 sec) **27PP2D** := ____________
(Hidden if associated pickup is OFF)

PHASE UVS LEVEL (OFF, 12.50–300.00 V) **27S1P** := ____________
(Shown if Slot E is 3 ACI/4 AVI card and Global setting VS_BAT := VS)

PHASE UVS DELAY (0.00–120.00 sec) **27S1D** := ____________
(Hidden if associated pickup is OFF)

PHASE UVS LEVEL (OFF, 12.50–300.00 V) **27S2P** := ____________________
(Shown if Slot E is 3 ACI/4 AVI card and Global setting VS_BAT := VS)

PHASE UVS DELAY (0.00–120.00 sec) **27S2D** := ____________________
(Hidden if associated pickup is OFF)

Overvoltage

(All subsequent settings are hidden if there is no 4 ACI/3 AVI, 3 ACI/4 AVI, or 1 ACI/3 AVI card in Slot E)

PHASE OV LEVEL (OFF, 12.50–300.00 V) **59P1P** := ____________________
(Hidden and forced to OFF if DELTA_Y := DELTA)

PHASE OV DELAY (0.00–120.00 sec) **59P1D** := ____________________
(Hidden if associated pickup is OFF)

PHASE OV LEVEL (OFF, 12.50–300.00 V) **59P2P** := ____________________
(Hidden and forced to OFF if DELTA_Y := DELTA)

PHASE OV DELAY (0.00–120.00 sec) **59P2D** := ____________________
(Hidden if associated pickup is OFF)

PP OV LEVEL **59PP1P** := ____________________
(OFF, 12.50–300.00 V {DELTA_Y := DELTA} OR
12.50–520.00 {DELTA_Y := WYE})
(Hidden if SINGLEV := Y and if DELTA_Y := WYE)

PP OV DELAY (0.00–120.00 sec) **59PP1D** := ____________________
(Hidden if associated pickup is OFF)

PP OV LEVEL **59PP2P** := ____________________
(OFF, 12.50–300.00 V {DELTA_Y := DELTA} OR
12.50–520.00 V {DELTA_Y := WYE})
(Hidden if SINGLEV := Y and if DELTA_Y := WYE)

PP OV DELAY (0.00–120.00 sec) **59PP2D** := ____________________
(Hidden if associated pickup is OFF)

ZS OV LEVEL (OFF, 12.50–300.00 V) **59G1P** := ____________________
(Hidden if DELTA_Y := DELTA or SINGLEV := Y)

ZS OV DELAY (0.00–120.00 sec) **59G1D** := ____________________
(Hidden if associated pickup is OFF)

ZS OV LEVEL (OFF, 12.50–300.00 V) **59G2P** := ____________________
(Hidden if DELTA_Y := DELTA or SINGLEV := Y)

ZS OV DELAY (0.00–120.00 sec) **59G2D** := ____________________
(Hidden if associated pickup is OFF)

NSEQ OV LEVEL (OFF, 12.50–200.00 V) **59Q1P** := ____________________
(Hidden if SINGLEV := Y)

NSEQ OV DELAY (0.00–120.00 sec) **59Q1D** := ____________________
(Hidden if associated pickup is OFF)

NSEQ OV LEVEL (OFF, 12.50–200.00 V) **59Q2P** := ____________________
(Hidden if SINGLEV := Y)

NSEQ OV DELAY (0.00–120.00 sec) **59Q2D** := ____________________
(Hidden if associated pickup is OFF)

PHASE OVS LEVEL (OFF, 12.50–300.00 V) **59S1P** := ____________________
(Shown if Slot E is 3 ACI/4 AVI card and Global setting VS_VBAT := VS)

PHASE OVS DELAY (0.00–120.00 sec) **59S1D** := ____________________
(Hidden if associated pickup is OFF)

PHASE OVS LEVEL (12.50–300.00 V) **59S2P** := ____________________
(Shown if Slot E is 3 ACI/4 AVI card and Global setting VS_BAT := VS)

PHASE OVS DELAY (0.00–120.00 sec) **59S2D** := ____________
(Hidden if associated pickup is OFF)

27 Inverse-Time Undervoltage

(Shown only if Slot E is 4 ACI/3 AVI, 3 ACI/4 AVI, or 1 ACI/3 AVI)

27I ENABLE (Y, N) **E27I1** := ____________

(The following 27I1 inverse-time undervoltage settings are hidden if E27I1 := N)

OPERATING QTY **27I1OQ** := ____________
(VS option is hidden if Slot E ≠ 3 ACI/4 AVI)
See Table SET.1 for range dependencies.

Table SET.1 Range Dependencies for 27I Operating Quantities

Settings			Operating Quantities Available in 27InOQ Setting Range									
DELTA_Y	VS_VBAT	SINGLEV	VAB	VBC	VCA	VA	VB	VC	V1	VS	MINLL	MINLN
DELTA	VBAT	N	#	#	#	—	—	—	#	—	#	—
DELTA	VBAT	Y	#	—	—	—	—	—	—	—	—	—
DELTA	VS	N	#	#	#	—	—	—	#	#	#	—
DELTA	VS	Y	#	—	—	—	—	—	—	#	—	—
WYE	VS	N	$	$	$	#	#	#	#	#	$	#
WYE	VS	Y	—	—	—	#	—	—	—	#	—	—
WYE	VBAT	N	$	$	$	#	#	#	#	—	$	#
WYE	VBAT	Y	—	—	—	#	—	—	—	—	—	—

= 2.00–300.00 V $ = 2.00–520.00 V — Operating quantity is not available

The "#" and "$" signs indicate the setting range for 27InP (n = 1 or 2).

PICKUP LVL (2.00–300.00 V or 2.00–520.00 V from *Table SET.1*) **27I1P** := ____________

CURVE (CURVEA, CURVEB, COEF) **27I1CRV** := ____________

COEFF A (0.00–3.00) **27I1CFA** := ____________
(Hidden if CURVE is set to CURVEA or CURVEB)

COEFF B (0.00–3.00) **27I1CFB** := ____________
(Hidden if CURVE is set to CURVEA or CURVEB)

COEFF C (0.00–3.00) **27I1CFC** := ____________
(Hidden if CURVE is set to CURVEA or CURVEB)

TIME DIAL (0.00–16.00) **27I1TD** := ____________

RESET TIME (0.00–1.00 s) **27I1TTR** := ____________

TRQ CONTROL (SELOGIC) **27I1TC** := ____________

27I ENABLE (Y, N) **E27I2** := ____________

(The following 27I2 settings are hidden if E27I2 := N)

OPERATING QTY **27I2OQ** := ____________
(VS option is hidden if Slot E ≠ 3 ACI/4 AVI)
See Table SET.1 for range dependencies.

PICKUP LVL (2.00–300.00 V or 2.00–520.00 V from *Table SET.1*) **27I2P** := ____________

CURVE (CURVEA, CURVEB, COEF) **27I2CRV** := ____________

COEFF A (0.00–3.00) **27I2CFA** := ____________
(Hidden if CURVE is set to CURVEA or CURVEB)

COEFF B (0.00–3.00) **27I2CFB** := ___________
(Hidden if CURVE is set to CURVEA or CURVEB)

COEFF C (0.00–3.00) **27I2CFC** := ___________
(Hidden if CURVE is set to CURVEA or CURVEB)

TIME DIAL (0.00–16.00) **27I2TD** := ___________

RESET TIME (0.00–1.00 s) **27I2TTR** := ___________

TRQ CONTROL (SELOGIC) **27I2TC** := ___________

59 Inverse-Time Overvoltage

(Shown only if Slot E is 4 ACI/3 AVI, 3 ACI/4 AVI, or 1 ACI/3 AVI)

59I ENABLE (Y, N) **E59I1** := ___________

(The following 59I1 inverse-time overvoltage settings are hidden if E59I1 := N)

OPERATING QTY **59I1OQ** := ___________
(VS option is hidden if Slot E ≠ 3 ACI/4 AVI)
See Table SET.2 for range dependencies.

Table SET.2 Range Dependencies for 59I Operating Quantities

Settings			Operating Quantities Available in 59InOQ Setting Range											
DELTA_Y	VS_VBAT	SINGLEV	VAB	VBC	VCA	VA	VB	VC	VG	V1	3V2	VS	MAXLL	MAXLN
DELTA	VBAT	N	#	#	#	—	—	—	—	#	#	—	#	—
DELTA	VBAT	Y	#	—	—	—	—	—	—	—	—	—	—	—
DELTA	VS	N	#	#	#	—	—	—	—	#	#	#	#	—
DELTA	VS	Y	#	—	—	—	—	—	—	—	—	#	—	—
WYE	VS	N	$	$	$	#	#	#	#	#	#	#	$	#
WYE	VS	Y	—	—	—	#	—	—	—	—	—	#	—	—
WYE	VBAT	N	$	$	$	#	#	#	#	#	#	—	$	#
WYE	VBAT	Y	—	—	—	#	—	—	—	—	—	—	—	—

= 2.00–300.00 V $ = 2.00–520.00 V — Operating quantity is not available

The "#" and "$" signs indicate the setting range for 59InP (n = 1, 2, 3, or 4).

PICKUP LVL (2.00–300.00 V or 2.00–520.00 V from *Table SET.2*) **59I1P** := ___________

CURVE (CURVEA, CURVEB, COEF) **59I1CR** := ___________

COEFF A (0.00–6.00) **59I1CFA** := ___________
(Hidden if CURVE is set to CURVEA or CURVEB)

COEFF B (0.00–3.00) **59I1CFB** := ___________
(Hidden if CURVE is set to CURVEA or CURVEB)

COEFF C (0.01–3.00) **59I1CFC** := ___________
(Hidden if CURVE is set to CURVEA or CURVEB)

TIME DIAL (0.00–16.00) **59I1TD** := ___________

RESET TIME (0.00–1.00 s) **59I1TTR** := ___________

TRQ CONTROL (SELOGIC) **59I1TC** := ___________

Date ___________
Group___________

59I ENABLE (Y, N) **E59I2** := ____________

(The following 59I2 settings are hidden if E59I2 := N)

OPERATING QTY **59I2OQ** := ____________
(VS option is hidden if Slot E ≠ 3 ACI/4 AVI)
See Table SET.2 for range dependencies.

PICKUP LVL (2.00–300.00 V or 2.00–520.00 V from *Table SET.2*) **59I2P** := ____________

CURVE (CURVEA, CURVEB, COEF) **59I2CRV** := ____________

COEFF A (0.00–6.00) **59I2CFA** := ____________
(Hidden if CURVE is set to CURVEA or CURVEB)

COEFF B (0.00–3.00) **59I2CFB** := ____________
(Hidden if CURVE is set to CURVEA or CURVEB)

COEFF C (0.01–3.00) **59I2CFC** := ____________
(Hidden if CURVE is set to CURVEA or CURVEB)

TIME DIAL (0.00–16.00) **59I2TD** := ____________

RESET TIME (0.00–1.00 s) **59I2TTR** := ____________

TRQ CONTROL (SELOGIC) **59I2TC** := ____________

59I ENABLE (Y, N) **E59I3** := ____________

(The following 59I3 settings are hidden if E59I3 := N)

OPERATING QTY **59I3OQ** := ____________
(VS option is hidden if Slot E ≠ 3 ACI/4 AVI)
See Table SET.2 for range dependencies.

PICKUP LVL (2.00–300.00 V or 2.00–520.00 V from *Table SET.2*) **59I3P** := ____________

CURVE (CURVEA, CURVEB, COEF) **59I3CRV** := ____________

COEFF A (0.00–6.00) **59I3CFA** := ____________
(Hidden if CURVE is set to CURVEA or CURVEB)

COEFF B (0.00–3.00) **59I3CFB** := ____________
(Hidden if CURVE is set to CURVEA or CURVEB)

COEFF C (0.01–3.00) **59I3CFC** := ____________
(Hidden if CURVE is set to CURVEA or CURVEB)

TIME DIAL (0.00–16.00) **59I3TD** := ____________

RESET TIME (0.00–1.00 s) **59I3TTR** := ____________

TRQ CONTROL (SELOGIC) **59I3TC** := ____________

59I ENABLE (Y, N) **E59I4** := ____________

(The following 59I4 settings are hidden if E59I4 := N)

OPERATING QTY **59I4OQ** := ____________
(VS option is hidden if Slot E ≠ 3 ACI/4 AVI)
See Table SET.2 for range dependencies.

PICKUP LVL (2.00–300.00 V or 2.00–520.00 V from *Table SET.2*) **59I4P** := ____________

CURVE (CURVEA, CURVEB, COEF) **59I4CRV** := ____________

COEFF A (0.00–6.00) **59I4CFA** := ____________
(Hidden if CURVE is set to CURVEA or CURVEB)

COEFF B (0.00–3.00) **59I4CFB** := ____________
(Hidden if CURVE is set to CURVEA or CURVEB)

COEFF C (0.01–3.00) **59I4CFC** := ____________
(Hidden if CURVE is set to CURVEA or CURVEB)

TIME DIAL (0.00–16.00) **59I4TD** := ____________________

RESET TIME (0.00–1.00 s) **59I4TTR** := ____________________

TRQ CONTROL (SELOGIC) **59I4TC** := ____________________

Volts/Hertz

(Hidden if no 4 ACI/3 AVI, 3 ACI/4 AVI, or 1 ACI/3 AVI card is present in Slot E)

ENABLE V/HZ PROT (Y, N) **E24** := ____________________
(All subsequent V/HZ settings are hidden if E24 := N)

XFMR WDG CONN (DELTA, WYE) **24WDG** := ____________________

LVL1 V/HZ PICKUP (100%–200%) **24D1P** := ____________________

LVL1 TIME DLY (0.04–400.00 s) **24D1D** := ____________________

LVL2 CURVE SHAPE (OFF, DD, ID, I, U) **24CCS** := ____________________

LVL2 INV-TM PU (100%–200%) **24IP** := ____________________
(Hidden if 24CCS := OFF or DD)

LVL2 INV-TM CURV (0.5, 1.0, 2.0) **24IC** := ____________________
(Hidden if 24CCS := OFF, DD, or U)

LVL2 INV-TM FCTR (0.1–10.0 s) **24ITD** := ____________________
(Hidden if 24CCS := OFF, DD, or U)

LVL2 PICKUP 1 (100%–200%) **24D2P1** := ____________________
(Hidden if 24CCS := OFF, ID, I, or U)

LVL2 TIME DLY 1 (0.04–400.00 s) **24D2D1** := ____________________
(Hidden if 24CCS := OFF, ID, I, or U)

LVL2 PICKUP 2 (101%–200%) **24D2P2** := ____________________
(Hidden if 24CCS := OFF, I, or U)

LVL2 TIME DLY 2 (0.04–400.00 s) **24D2D2** := ____________________
(Hidden if 24CCS := OFF, I, or U)

LVL2 RESET TIME (0.00–400.00 s) **24CR** := ____________________
(Hidden if 24CCS := OFF)

24ELEM TRQ-CNTRL (SELOGIC) **24TC** := ____________________

Loss of Potential (LOP)

(Shown if Slot E card is 4 ACI/3 AVI, 3 ACI/4 AVI, or 1 ACI/3 AVI)

LOP BLOCK (SELOGIC) **LOPBLK** := ____________________

Synchronism Check

(All subsequent settings are hidden if there is no 3 ACI/4 AVI card in Slot E or if the Global setting VS_BAT is set to VBAT)

SYNCH. CHECK (Y, N) **E25** := ____________________
(All subsequent settings are hidden if E25 := N)

VS WINDOW LOW (0.00–300.00 V) **25VLO** := ____________________

VS WINDOW HIGH (0.00–300.00 V) **25VHI** := ____________________

V RATIO COR FAC (0.50–2.00) **25RCF** := ____________________

MAX SLIP FREQ (0.05–0.50 Hz) **25SF** := ____________________

MAX ANGLE 1(0–80 deg) **25ANG1** := ____________________

MAX ANGLE 2 (0–80 deg) **25ANG2** := ____________________

SYNCH PHASE (VA, VB, VC, VAB, VBC, VCA, 0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330) **SYNCPH** := ____________
(Hidden if DELTA_Y := DELTA)

SYNCH PHASE (VAB, VBC, VCA, 0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330) **SYNCPH** := ____________
(Hidden if DELTA_Y := WYE)

BRKR CLOSE TIME (OFF, 1–1000 ms) **TCLOSD** := ____________

BLK SYNCH CHECK (SELOGIC) **BSYNCH** := ____________

Power

(All subsequent settings are hidden if there is no 4 ACI/3 AVI, 3 ACI/4 AVI, or 1 ACI/3 AVI card present in Slot E)

ENABLE PWR ELEM (N, 3P1, 3P2) **EPWR** := ____________
(All subsequent power element settings are hidden if EPWR := N)

3PH PWR ELEM PU (OFF, 0.2–1300.00 VA {1 A PHASE CTS}; OFF, 1.0–6500.0 VA {5 A PHASE CTS}) **3PWR1P** := ____________

PWR ELEM TYPE (+WATTS, –WATTS, +VARS, –VARS) **PWR1T** := ____________
(Hidden if 3PWR1P := OFF)

PWR ELEM DELAY (0.0–240.0 s) **PWR1D** := ____________
(Hidden if 3PWR1P := OFF)

3PH PWR ELEM PU (OFF, 0.2–1300.0 {1 A PHASE CTS}; OFF, 1.0–6500.0 VA {5 A PHASE CTS}) **3PWR2P** := ____________
(Hidden if EPWR := 3P1)

PWR ELEM TYPE (+WATTS, –WATTS, +VARS, –VARS) **PWR2T** := ____________
(Hidden if EPWR := 3P1; hidden if 3PWR2P := OFF)

PWR ELEM DELAY (0.0–240.0 s) **PWR2D** := ____________
(Hidden if EPWR := 3P1; hidden if 3PWR2P := OFF)

Frequency

(All subsequent settings are hidden if there is no 4 ACI/3 AVI, 3 ACI/4 AVI, or 1 ACI/3 AVI card present in Slot E)

FREQ1 TRIP LEVEL (OFF, 15.00–70.00 Hz) **81D1TP** := ____________

FREQ1 TRIP DELAY (0.00–400.00 sec) **81D1TD** := ____________
(Hidden if associated pickup is OFF)

81D1 TRQCTRL (SELOGIC) **81D1TC** := ____________
(Hidden if associated pickup is OFF)

FREQ2 TRIP LEVEL (OFF, 15.00–70.00 Hz) **81D2TP** := ____________

FREQ2 TRIP DELAY (0.00–400.00 sec) **81D2TD** := ____________
(Hidden if associated pickup is OFF)

81D2 TRQCTRL (SELOGIC) **81D2TC** := ____________
(Hidden if associated pickup is OFF)

FREQ3 TRIP LEVEL (OFF, 15.00–70.00 Hz) **81D3TP** := ____________

FREQ3 TRIP DELAY (0.00–400.00 sec) **81D3TD** := ____________
(Hidden if associated pickup is OFF)

81D3 TRQCTRL (SELOGIC) **81D3TC** := ____________
(Hidden if associated pickup is OFF)

FREQ4 TRIP LEVEL (OFF, 15.00–70.00 Hz) **81D4TP** := ____________

FREQ4 TRIP DELAY (0.00–400.00 sec) **81D4TD** := ____________
(Hidden if associated pickup is OFF)

81D4 TRQCTRL (SELOGIC) **81D4TC** := ____________________
(Hidden if associated pickup is OFF)

Demand Metering

ENABLE DEM MTR (OFF, W1, W2, W3, W4, W12, W23, W34) **EDEM** := ____________________
(W3 and W23 are hidden in the range if Slot E is 1 ACI, 1 ACI/3 AVI, an optional I/O card, or is empty; W4 and W34 are hidden in the range if the card in Slot E is not 6 ACI; W3, W23, and W34 are hidden in the range if E87W3 := REF; W12 is hidden in the range if CCW12 := N; W23 is hidden in the range if CCW23 := N; W34 is hidden in the range if CCW34 := N; all subsequent settings are hidden if EDEM := OFF)

DEMAND MTR TYPE (THM, ROL) **DEMTY** := ____________________

DEM TIME CONSTNT (5, 10, 15, 30, 60 min) **DMTC** := ____________________

PH CURR DEM LVL **PHDEMP** := ____________________
(OFF, 0.50–16.00 A {5 A NOM}; 0.10–3.20 A {1 A NOM})

RES CURR DEM LVL **GNDEMP** := ____________________
(OFF, 0.50–16.00 A {5 A NOM}; 0.10–3.20 {1 A NOM})

3I2 CURR DEM LVL **3I2DEMP** := ____________________
(OFF, 0.50–16.00 A {5 A NOM}; 0.10–3.20 A {1 A NOM})

Trip/Close Logic

MIN TRIP TIME (0.0–400.0 sec) **TDURD** := ____________________

CLOSE 1 FAIL DLY (0.0–400.0 sec) **CFD1** := ____________________

CLOSE 2 FAIL DLY (0.0–400.0 sec) **CFD2** := ____________________

CLOSE 3 FAIL DLY (0.0–400.0 sec) **CFD3** := ____________________

CLOSE 4 FAIL DLY (0.0–400.0 sec) **CFD4** := ____________________

TRIP 1 EQUATION (SELOGIC) **TR1** := ____________________

TRIP 2 EQUATION (SELOGIC) **TR2** := ____________________

TRIP 3 EQUATION (SELOGIC) **TR3** := ____________________

TRIP 4 EQUATION (SELOGIC) **TR4** := ____________________

TRIP XFMR EQN (SELOGIC) **TRXFMR** := ____________________

REMOTE TRIP EQN (SELOGIC) **REMTRIP** := ____________________

UNLATCH TRIP 1 (SELOGIC) **ULTRIP1** := ____________________

UNLATCH TRIP 2 (SELOGIC) **ULTRIP2** := ____________________

UNLATCH TRIP 3 (SELOGIC) **ULTRIP3** := ____________________

UNLATCH TRIP 4 (SELOGIC) **ULTRIP4** := ____________________

UNLATCH TRP XFMR (SELOGIC) **ULTRXFMR** := ____________________

BREAKER 1 STATUS (SELOGIC) **52A1** := ____________________

BREAKER 2 STATUS (SELOGIC) **52A2** := ____________________

BREAKER 3 STATUS (SELOGIC) **52A3** := ____________________

BREAKER 4 STATUS (SELOGIC) **52A4** := ____________________

CLOSE 1 EQUATION (SELOGIC) **CL1** := ____________________

CLOSE 2 EQUATION (SELOGIC) **CL2** := ____________

CLOSE 3 EQUATION (SELOGIC) **CL3** := ____________

CLOSE 4 EQUATION (SELOGIC) **CL4** := ____________

UNLATCH CLOSE 1 (SELOGIC) **ULCL1** := ____________

UNLATCH CLOSE 2 (SELOGIC) **ULCL2** := ____________

UNLATCH CLOSE 3 (SELOGIC) **ULCL3** := ____________

UNLATCH CLOSE 4 (SELOGIC) **ULCL4** := ____________

Logic Settings (SET L Command)

SELOGIC Enables

SELOGIC LATCHES (N, 1–32) **ELAT** := ____________

SV/TIMES (N, 1–32) **ESV** := ____________

SELOGIC COUNTERS (N, 1–32) **ESC** := ____________

MATH VARIABLES (N, 1–32) **EMV** := ____________

Latch Bits Equations

SET01 := ____________

RST01 := ____________

SET02 := ____________

RST02 := ____________

SET03 := ____________

RST03 := ____________

SET04 := ____________

RST04 := ____________

SET05 := ____________

RST05 := ____________

SET06 := ____________

RST06 := ____________

SET07 := ____________

RST07 := ____________

SET08 := ____________

RST08 := ____________

SET09	:=	______________________
RST09	:=	______________________
SET10	:=	______________________
RST10	:=	______________________
SET11	:=	______________________
RST11	:=	______________________
SET12	:=	______________________
RST12	:=	______________________
SET13	:=	______________________
RST13	:=	______________________
SET14	:=	______________________
RST14	:=	______________________
SET15	:=	______________________
RST15	:=	______________________
SET16	:=	______________________
RST16	:=	______________________
SET17	:=	______________________
RST17	:=	______________________
SET18	:=	______________________
RST18	:=	______________________
SET19	:=	______________________
RST19	:=	______________________
SET20	:=	______________________
RST20	:=	______________________
SET21	:=	______________________
RST21	:=	______________________
SET22	:=	______________________
RST22	:=	______________________
SET23	:=	______________________
RST23	:=	______________________

Date ____________
Group___________

SET24 := ______________________________

RST24 := ______________________________

SET25 := ______________________________

RST25 := ______________________________

SET26 := ______________________________

RST26 := ______________________________

SET27 := ______________________________

RST27 := ______________________________

SET28 := ______________________________

RST28 := ______________________________

SET29 := ______________________________

RST29 := ______________________________

SET30 := ______________________________

RST30 := ______________________________

SET31 := ______________________________

RST31 := ______________________________

SET32 := ______________________________

RST32 := ______________________________

SV/Timers

SV TIMER PICKUP (0.00–3000.00 sec) **SV01PU** := ______________

SV TIMER DROPOUT (0.00–3000.00 sec) **SV01DO** := ______________

SV INPUT (SELOGIC) **SV01** := ______________

SV TIMER PICKUP (0.00–3000.00 sec) **SV02PU** := ______________

SV TIMER DROPOUT (0.00–3000.00 sec) **SV02DO** := ______________

SV INPUT (SELOGIC) **SV02** := ______________

SV TIMER PICKUP (0.00–3000.00 sec) **SV03PU** := ______________

SV TIMER DROPOUT (0.00–3000.00 sec) **SV03DO** := ______________

SV INPUT (SELOGIC) **SV03** := ______________

SV TIMER PICKUP (0.00–3000.00 sec) **SV04PU** := ______________

SV TIMER DROPOUT (0.00–3000.00 sec)	**SV04DO** := ______________
SV INPUT (SELOGIC)	**SV04** := ______________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV05PU** := ______________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV05DO** := ______________
SV INPUT (SELOGIC)	**SV05** := ______________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV06PU** := ______________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV06DO** := ______________
SV INPUT (SELOGIC)	**SV06** := ______________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV07PU** := ______________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV07DO** := ______________
SV INPUT (SELOGIC)	**SV07** := ______________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV08PU** := ______________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV08DO** := ______________
SV INPUT (SELOGIC)	**SV08** := ______________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV09PU** := ______________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV09DO** := ______________
SV INPUT (SELOGIC)	**SV09** := ______________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV10PU** := ______________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV10DO** := ______________
SV INPUT (SELOGIC)	**SV10** := ______________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV11PU** := ______________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV11DO** := ______________
SV INPUT (SELOGIC)	**SV11** := ______________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV12PU** := ______________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV12DO** := ______________
SV INPUT (SELOGIC)	**SV12** := ______________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV13PU** := ______________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV13DO** := ______________
SV INPUT (SELOGIC)	**SV13** := ______________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV14PU** := ______________

SV TIMER DROPOUT (0.00–3000.00 sec)	**SV14DO** := ________________
SV INPUT (SELOGIC)	**SV14** := ________________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV15PU** := ________________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV15DO** := ________________
SV INPUT (SELOGIC)	**SV15** := ________________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV16PU** := ________________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV16DO** := ________________
SV INPUT (SELOGIC)	**SV16** := ________________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV17PU** := ________________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV17DO** := ________________
SV INPUT (SELOGIC)	**SV17** := ________________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV18PU** := ________________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV18DO** := ________________
SV INPUT (SELOGIC)	**SV18** := ________________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV19PU** := ________________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV19DO** := ________________
SV INPUT (SELOGIC)	**SV19** := ________________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV20PU** := ________________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV20DO** := ________________
SV INPUT (SELOGIC)	**SV20** := ________________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV21PU** := ________________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV21DO** := ________________
SV INPUT (SELOGIC)	**SV21** := ________________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV22PU** := ________________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV22DO** := ________________
SV INPUT (SELOGIC)	**SV22** := ________________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV23PU** := ________________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV23DO** := ________________
SV INPUT (SELOGIC)	**SV23** := ________________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV24PU** := ________________

SV TIMER DROPOUT (0.00–3000.00 sec)	**SV24DO** := ________________
SV INPUT (SELOGIC)	**SV24** := ________________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV25PU** := ________________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV25DO** := ________________
SV INPUT (SELOGIC)	**SV25** := ________________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV26PU** := ________________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV26DO** := ________________
SV INPUT (SELOGIC)	**SV26** := ________________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV27PU** := ________________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV27DO** := ________________
SV INPUT (SELOGIC)	**SV27** := ________________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV28PU** := ________________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV28DO** := ________________
SV INPUT (SELOGIC)	**SV28** := ________________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV29PU** := ________________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV29DO** := ________________
SV INPUT (SELOGIC)	**SV29** := ________________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV30PU** := ________________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV30DO** := ________________
SV INPUT (SELOGIC)	**SV30** := ________________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV31PU** := ________________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV31DO** := ________________
SV INPUT (SELOGIC)	**SV31** := ________________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV32PU** := ________________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV32DO** := ________________
SV INPUT (SELOGIC)	**SV32** := ________________

Counters Equations

SC PRESET VALUE (1–65000)	**SC01PV** := ________________
SC RESET INPUT (SELOGIC)	**SC01R** := ________________
SC LOAD PV INPUT (SELOGIC)	**SC01LD** := ________________

SC CNT UP INPUT (SELOGIC)	**SC01CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC01CD** := ____________
SC PRESET VALUE (1–65000)	**SC02PV** := ____________
SC RESET INPUT (SELOGIC)	**SC02R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC02LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC02CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC02CD** := ____________
SC PRESET VALUE (1–65000)	**SC03PV** := ____________
SC RESET INPUT (SELOGIC)	**SC03R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC03LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC03CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC03CD** := ____________
SC PRESET VALUE (1–65000)	**SC04PV** := ____________
SC RESET INPUT (SELOGIC)	**SC04R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC04LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC04CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC04CD** := ____________
SC PRESET VALUE (1–65000)	**SC05PV** := ____________
SC RESET INPUT (SELOGIC)	**SC05R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC05LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC05CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC05CD** := ____________
SC PRESET VALUE (1–65000)	**SC06PV** := ____________
SC RESET INPUT (SELOGIC)	**SC06R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC06LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC06CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC06CD** := ____________
SC PRESET VALUE (1–65000)	**SC07PV** := ____________
SC RESET INPUT (SELOGIC)	**SC07R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC07LD** := ____________

SC CNT UP INPUT (SELOGIC)	**SC07CU** := ________
SC CNT DN INPUT (SELOGIC)	**SC07CD** := ________
SC PRESET VALUE (1–65000)	**SC08PV** := ________
SC RESET INPUT (SELOGIC)	**SC08R** := ________
SC LOAD PV INPUT (SELOGIC)	**SC08LD** := ________
SC CNT UP INPUT (SELOGIC)	**SC08CU** := ________
SC CNT DN INPUT (SELOGIC)	**SC08CD** := ________
SC PRESET VALUE (1–65000)	**SC09PV** := ________
SC RESET INPUT (SELOGIC)	**SC09R** := ________
SC LOAD PV INPUT (SELOGIC)	**SC09LD** := ________
SC CNT UP INPUT (SELOGIC)	**SC09CU** := ________
SC CNT DN INPUT (SELOGIC)	**SC09CD** := ________
SC PRESET VALUE (1–65000)	**SC010PV** := ________
SC RESET INPUT (SELOGIC)	**SC10R** := ________
SC LOAD PV INPUT (SELOGIC)	**SC10LD** := ________
SC CNT UP INPUT (SELOGIC)	**SC10CU** := ________
SC CNT DN INPUT (SELOGIC)	**SC10CD** := ________
SC PRESET VALUE (1–65000)	**SC11PV** := ________
SC RESET INPUT (SELOGIC)	**SC11R** := ________
SC LOAD PV INPUT (SELOGIC)	**SC11LD** := ________
SC CNT UP INPUT (SELOGIC)	**SC11CU** := ________
SC CNT DN INPUT (SELOGIC)	**SC11CD** := ________
SC PRESET VALUE (1–65000)	**SC12PV** := ________
SC RESET INPUT (SELOGIC)	**SC12R** := ________
SC LOAD PV INPUT (SELOGIC)	**SC12LD** := ________
SC CNT UP INPUT (SELOGIC)	**SC12CU** := ________
SC CNT DN INPUT (SELOGIC)	**SC12CD** := ________
SC PRESET VALUE (1–65000)	**SC13PV** := ________
SC RESET INPUT (SELOGIC)	**SC13R** := ________
SC LOAD PV INPUT (SELOGIC)	**SC13LD** := ________

Date ____________
Group___________

SC CNT UP INPUT (SELOGIC)	**SC13CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC13CD** := ____________
SC PRESET VALUE (1–65000)	**SC14PV** := ____________
SC RESET INPUT (SELOGIC)	**SC14R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC14LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC14CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC14CD** := ____________
SC PRESET VALUE (1–65000)	**SC15PV** := ____________
SC RESET INPUT (SELOGIC)	**SC15R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC15LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC15CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC15CD** := ____________
SC PRESET VALUE (1–65000)	**SC16PV** := ____________
SC RESET INPUT (SELOGIC)	**SC16R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC16LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC16CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC16CD** := ____________
SC PRESET VALUE (1–65000)	**SC17PV** := ____________
SC RESET INPUT (SELOGIC)	**SC17R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC17LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC17CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC17CD** := ____________
SC PRESET VALUE (1–65000)	**SC18PV** := ____________
SC RESET INPUT (SELOGIC)	**SC18R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC18LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC18CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC18CD** := ____________
SC PRESET VALUE (1–65000)	**SC19PV** := ____________
SC RESET INPUT (SELOGIC)	**SC19R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC19LD** := ____________

SC CNT UP INPUT (SELOGIC)	**SC19CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC19CD** := ____________
SC PRESET VALUE (1–65000)	**SC20PV** := ____________
SC RESET INPUT (SELOGIC)	**SC20R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC20LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC20CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC20CD** := ____________
SC PRESET VALUE (1–65000)	**SC21PV** := ____________
SC RESET INPUT (SELOGIC)	**SC21R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC21LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC21CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC21CD** := ____________
SC PRESET VALUE (1–65000)	**SC22PV** := ____________
SC RESET INPUT (SELOGIC)	**SC22R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC22LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC22CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC22CD** := ____________
SC PRESET VALUE (1–65000)	**SC23PV** := ____________
SC RESET INPUT (SELOGIC)	**SC23R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC23LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC23CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC23CD** := ____________
SC PRESET VALUE (1–65000)	**SC24PV** := ____________
SC RESET INPUT (SELOGIC)	**SC24R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC24LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC24CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC24CD** := ____________
SC PRESET VALUE (1–65000)	**SC25PV** := ____________
SC RESET INPUT (SELOGIC)	**SC25R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC25LD** := ____________

SC CNT UP INPUT (SELOGIC)	**SC25CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC25CD** := ____________
SC PRESET VALUE (1–65000)	**SC26PV** := ____________
SC RESET INPUT (SELOGIC)	**SC26R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC26LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC26CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC26CD** := ____________
SC PRESET VALUE (1–65000)	**SC27PV** := ____________
SC RESET INPUT (SELOGIC)	**SC27R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC27LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC27CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC27CD** := ____________
SC PRESET VALUE (1–65000)	**SC28PV** := ____________
SC RESET INPUT (SELOGIC)	**SC28R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC28LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC28CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC28CD** := ____________
SC PRESET VALUE (1–65000)	**SC29PV** := ____________
SC RESET INPUT (SELOGIC)	**SC29R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC29LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC29CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC29CD** := ____________
SC PRESET VALUE (1–65000)	**SC30PV** := ____________
SC RESET INPUT (SELOGIC)	**SC30R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC30LD** := ____________
SC CNT UP INPUT (SELOGIC)	**SC30CU** := ____________
SC CNT DN INPUT (SELOGIC)	**SC30CD** := ____________
SC PRESET VALUE (1–65000)	**SC31PV** := ____________
SC RESET INPUT (SELOGIC)	**SC31R** := ____________
SC LOAD PV INPUT (SELOGIC)	**SC31LD** := ____________

SC CNT UP INPUT (SELOGIC)	**SC31CU** := __________
SC CNT DN INPUT (SELOGIC)	**SC31CD** := __________
SC PRESET VALUE (1–65000)	**SC32PV** := __________
SC RESET INPUT (SELOGIC)	**SC32R** := __________
SC LOAD PV INPUT (SELOGIC)	**SC32LD** := __________
SC CNT UP INPUT (SELOGIC)	**SC32CU** := __________
SC CNT DN INPUT (SELOGIC)	**SC32CD** := __________

Math Variables

MV01 := __________

MV02 := __________

MV03 := __________

MV04 := __________

MV05 := __________

MV06 := __________

MV07 := __________

MV08 := __________

MV09 := __________

MV10 := __________

MV11 := __________

MV12 := __________

MV13 := __________

MV14 := __________

MV15 := __________

MV16 := __________

MV17 := __________

MV18 := __________

MV19 := __________

MV20 := __________

MV21 := __________

Date ____________
Group____________

MV22 := ____________________

MV23 := ____________________

MV24 := ____________________

MV25 := ____________________

MV26 := ____________________

MV27 := ____________________

MV28 := ____________________

MV29 := ____________________

MV30 := ____________________

MV31 := ____________________

MV32 := ____________________

Base Output

OUT101 FAIL-SAFE (Y, N) **OUT101FS** := ____________

OUT101 := ____________________

OUT102 FAIL-SAFE (Y, N) **OUT102FS** := ____________

OUT102 := ____________________

OUT103 FAIL-SAFE (Y, N) **OUT103FS** := ____________

OUT103 := ____________________

Slot C Output

Hidden if an output option is not included in Slot C. The number of outputs depends on the I/O card option.

OUT301 FAIL-SAFE (Y, N) **OUT301FS** := ____________

OUT301 := ____________________

OUT302 FAIL-SAFE (Y, N) **OUT302FS** := ____________

OUT302 := ____________________

OUT303 FAIL-SAFE (Y, N) **OUT303FS** := ____________

OUT303 := ____________________

OUT304 FAIL-SAFE (Y, N) **OUT304FS** := ____________

OUT304 := ____________________

OUT305 FAIL-SAFE (Y, N) **OUT305FS** := ____________

OUT305 := ______________________________

OUT306 FAIL-SAFE (Y, N) **OUT306FS** := ______________

OUT306 := ______________________________

OUT307 FAIL-SAFE (Y, N) **OUT307FS** := ______________

OUT307 := ______________________________

OUT308 FAIL-SAFE (Y, N) **OUT308FS** := ______________

OUT308 := ______________________________

Slot D Output

Hidden if an output option is not included in Slot D. The number of outputs depends on the I/O card option.

OUT401 FAIL-SAFE (Y, N) **OUT401FS** := ______________

OUT401 := ______________________________

OUT402 FAIL-SAFE (Y, N) **OUT402FS** := ______________

OUT402 := ______________________________

OUT403 FAIL-SAFE (Y, N) **OUT403FS** := ______________

OUT403 := ______________________________

OUT404 FAIL-SAFE (Y, N) **OUT404FS** := ______________

OUT404 := ______________________________

OUT405 FAIL-SAFE (Y, N) **OUT405FS** := ______________

OUT405 := ______________________________

OUT406 FAIL-SAFE (Y, N) **OUT406FS** := ______________

OUT406 := ______________________________

OUT407 FAIL-SAFE (Y, N) **OUT407FS** := ______________

OUT407 := ______________________________

OUT408 FAIL-SAFE (Y, N) **OUT408FS** := ______________

OUT408 := ______________________________

Slot E Output

Hidden if an output option is not included in Slot E. The number of outputs depends on the I/O card option.

OUT501 FAIL-SAFE (Y, N) **OUT501FS** := ______________

OUT501 := ______________________________

OUT502 FAIL-SAFE (Y, N) **OUT502FS** := ____________

OUT502 := ________________________________

OUT503 FAIL-SAFE (Y, N) **OUT503FS** := ____________

OUT503 := ________________________________

OUT504 FAIL-SAFE (Y, N) **OUT504FS** := ____________

OUT504 := ________________________________

OUT505 FAIL-SAFE (Y, N) **OUT505FS** := ____________

OUT505 := ________________________________

OUT506 FAIL-SAFE (Y, N) **OUT506FS** := ____________

OUT506 := ________________________________

OUT507 FAIL-SAFE (Y, N) **OUT507FS** := ____________

OUT507 := ________________________________

OUT508 FAIL-SAFE (Y, N) **OUT508FS** := ____________

OUT508 := ________________________________

MIRRORED BITS Transmit SELOGIC Equations

(Hidden if PROTO is not MBxx on any of the communications ports)

TMB1A := ________________________________

TMB2A := ________________________________

TMB3A := ________________________________

TMB4A := ________________________________

TMB5A := ________________________________

TMB6A := ________________________________

TMB7A := ________________________________

TMB8A := ________________________________

TMB1B := ________________________________

TMB2B := ________________________________

TMB3B := ________________________________

TMB4B := ________________________________

TMB5B := ________________________________

TMB6B := ________________________________

TMB7B := ________________

TMB8B := ________________

Global Settings (SET G Command)

General

PHASE ROTATION (ABC, ACB) **PHROT** := ________

RATED FREQ. (50, 60 Hz) **FNOM** := ________

SELECT VS VBAT (VS, VBAT) **VS_VBAT** := ________
(Shown if card in Slot E is 3 ACI/4 AVI)

DATE FORMAT (MDY, YMD, DMY) **DATE_F** := ________

MET CUTOFF THRES (Y, N) **METHRES** := ________

FAULT CONDITION (SELOGIC) **FAULT** := ________

Event Messenger Points

(Only the points enabled by EMP are visible)

EVE MSG PTS ENABLE (N, 1–32) **EMP** := ________

MESSENGER POINT MP01 TRIGGER **MPTR01** := ________
(OFF, 1 Relay Word Bit)
(Hidden if no Event Messenger point selected; applies to all TRIGGER settings for Messenger Points 1–32)

MESSENGER POINT MP01 AQ (NONE, 1 Analog Quantity) **MPAQ01** := ________

MESSENGER POINT MP01 TEXT (148 Characters) **MPTX01** := ________

MESSENGER POINT MP02 TRIGGER **MPTR02** := ________
(OFF, 1 Relay Word Bit)

MESSENGER POINT MP02 AQ (NONE, 1 Analog Quantity) **MPAQ02** := ________

MESSENGER POINT MP02 TEXT (148 Characters) **MPTX02** := ________

MESSENGER POINT MP01 TRIGGER **MPTR03** := ________
(OFF, 1 Relay Word Bit)

MESSENGER POINT MP01 AQ (NONE, 1 Analog Quantity) **MPAQ03** := ________

MESSENGER POINT MP01 TEXT (148 Characters) **MPTX03** := ________

MESSENGER POINT MP02 TRIGGER **MPTR04** := ________
(OFF, 1 Relay Word Bit)

MESSENGER POINT MP02 AQ (NONE, 1 Analog Quantity) **MPAQ04** := ________

MESSENGER POINT MP02 TEXT (148 Characters) **MPTX04** ________

MESSENGER POINT MP01 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR05** := ____________
MESSENGER POINT MP01 AQ (NONE, 1 Analog Quantity)	**MPAQ05** := ____________
MESSENGER POINT MP01 TEXT (148 Characters)	**MPTX05** := ____________
MESSENGER POINT MP02 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR06** := ____________
MESSENGER POINT MP02 AQ (NONE, 1 Analog Quantity)	**MPAQ06** := ____________
MESSENGER POINT MP02 TEXT (148 Characters)	**MPTX06** := ____________
MESSENGER POINT MP01 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR07** := ____________
MESSENGER POINT MP01 AQ (NONE, 1 Analog Quantity)	**MPAQ07** := ____________
MESSENGER POINT MP01 TEXT (148 Characters)	**MPTX07** := ____________
MESSENGER POINT MP02 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR08** := ____________
MESSENGER POINT MP02 AQ (NONE, 1 Analog Quantity)	**MPAQ08** := ____________
MESSENGER POINT MP02 TEXT (148 Characters)	**MPTX08** := ____________
MESSENGER POINT MP01 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR09** := ____________
MESSENGER POINT MP01 AQ (NONE, 1 Analog Quantity)	**MPAQ09** := ____________
MESSENGER POINT MP01 TEXT (148 Characters)	**MPTX09** := ____________
MESSENGER POINT MP02 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR10** := ____________
MESSENGER POINT MP02 AQ (NONE, 1 Analog Quantity)	**MPAQ10** := ____________
MESSENGER POINT MP02 TEXT (148 Characters)	**MPTX10** := ____________
MESSENGER POINT MP01 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR11** := ____________
MESSENGER POINT MP01 AQ (NONE, 1 Analog Quantity)	**MPAQ11** := ____________
MESSENGER POINT MP01 TEXT (148 Characters)	**MPTX11** := ____________
MESSENGER POINT MP02 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR12** := ____________
MESSENGER POINT MP02 AQ (NONE, 1 Analog Quantity)	**MPAQ12** := ____________
MESSENGER POINT MP02 TEXT (148 Characters)	**MPTX12** := ____________
MESSENGER POINT MP01 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR13** := ____________
MESSENGER POINT MP01 AQ (NONE, 1 Analog Quantity)	**MPAQ13** := ____________

MESSENGER POINT MP01 TEXT (148 Characters)	**MPTX13** := ________
MESSENGER POINT MP02 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR14** := ________
MESSENGER POINT MP02 AQ (NONE, 1 Analog Quantity)	**MPAQ14** := ________
MESSENGER POINT MP02 TEXT (148 Characters)	**MPTX14** := ________
MESSENGER POINT MP01 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR15** := ________
MESSENGER POINT MP01 AQ (NONE, 1 Analog Quantity)	**MPAQ15** := ________
MESSENGER POINT MP01 TEXT (148 Characters)	**MPTX15** := ________
MESSENGER POINT MP02 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR16** := ________
MESSENGER POINT MP02 AQ (NONE, 1 Analog Quantity)	**MPAQ16** := ________
MESSENGER POINT MP02 TEXT (148 Characters)	**MPTX16** := ________
MESSENGER POINT MP01 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR17** := ________
MESSENGER POINT MP01 AQ (NONE, 1 Analog Quantity)	**MPAQ17** := ________
MESSENGER POINT MP01 TEXT (148 Characters)	**MPTX17** := ________
MESSENGER POINT MP02 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR18** := ________
MESSENGER POINT MP02 AQ (NONE, 1 Analog Quantity)	**MPAQ18** := ________
MESSENGER POINT MP02 TEXT (148 Characters)	**MPTX18** := ________
MESSENGER POINT MP01 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR19** := ________
MESSENGER POINT MP01 AQ (NONE, 1 Analog Quantity)	**MPAQ19** := ________
MESSENGER POINT MP01 TEXT (148 Characters)	**MPTX19** := ________
MESSENGER POINT MP02 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR20** := ________
MESSENGER POINT MP02 AQ (NONE, 1 Analog Quantity)	**MPAQ20** := ________
MESSENGER POINT MP02 TEXT (148 Characters)	**MPTX20** := ________
MESSENGER POINT MP01 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR21** := ________
MESSENGER POINT MP01 AQ (NONE, 1 Analog Quantity)	**MPAQ21** := ________
MESSENGER POINT MP01 TEXT (148 Characters)	**MPTX21** := ________
MESSENGER POINT MP02 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR22** := ________

MESSENGER POINT MP02 AQ (NONE, 1 Analog Quantity)	**MPAQ22** := ______________
MESSENGER POINT MP02 TEXT (148 Characters)	**MPTX22** := ______________
MESSENGER POINT MP01 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR23** := ______________
MESSENGER POINT MP01 AQ (NONE, 1 Analog Quantity)	**MPAQ23** := ______________
MESSENGER POINT MP01 TEXT (148 Characters)	**MPTX23** := ______________
MESSENGER POINT MP02 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR24** := ______________
MESSENGER POINT MP02 AQ (NONE, 1 Analog Quantity)	**MPAQ24** := ______________
MESSENGER POINT MP02 TEXT (148 Characters)	**MPTX24** := ______________
MESSENGER POINT MP01 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR25** := ______________
MESSENGER POINT MP01 AQ (NONE, 1 Analog Quantity)	**MPAQ25** := ______________
MESSENGER POINT MP01 TEXT (148 Characters)	**MPTX25** := ______________
MESSENGER POINT MP02 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR26** := ______________
MESSENGER POINT MP02 AQ (NONE, 1 Analog Quantity)	**MPAQ26** := ______________
MESSENGER POINT MP02 TEXT (148 Characters)	**MPTX26** := ______________
MESSENGER POINT MP01 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR27** := ______________
MESSENGER POINT MP01 AQ (NONE, 1 Analog Quantity)	**MPAQ27** := ______________
MESSENGER POINT MP01 TEXT (148 Characters)	**MPTX27** := ______________
MESSENGER POINT MP02 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR28** := ______________
MESSENGER POINT MP02 AQ (NONE, 1 Analog Quantity)	**MPAQ28** := ______________
MESSENGER POINT MP02 TEXT (148 Characters)	**MPTX28** := ______________
MESSENGER POINT MP01 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR29** := ______________
MESSENGER POINT MP01 AQ (NONE, 1 Analog Quantity)	**MPAQ29** := ______________
MESSENGER POINT MP01 TEXT (148 Characters)	**MPTX29** := ______________
MESSENGER POINT MP02 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR30** := ______________
MESSENGER POINT MP02 AQ (NONE, 1 Analog Quantity)	**MPAQ30** := ______________
MESSENGER POINT MP02 TEXT (148 Characters)	**MPTX30** := ______________

MESSENGER POINT MP01 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR31** := ____________
MESSENGER POINT MP01 AQ (NONE, 1 Analog Quantity)	**MPAQ31** := ____________
MESSENGER POINT MP01 TEXT (148 Characters)	**MPTX31** := ____________
MESSENGER POINT MP02 TRIGGER (OFF, 1 Relay Word Bit)	**MPTR32** := ____________
MESSENGER POINT MP02 AQ (NONE, 1 Analog Quantity)	**MPAQ32** := ____________
MESSENGER POINT MP02 TEXT (148 Characters)	**MPTX32** := ____________

Group Selection

GRP CHG DELAY (0–400 sec)	**TGR** := ____________
SELECT GROUP1 (SELOGIC)	**SS1** := ____________
SELECT GROUP2 (SELOGIC)	**SS2** := ____________
SELECT GROUP3 (SELOGIC)	**SS3** := ____________
SELECT GROUP4 (SELOGIC)	**SS4** := ____________

LEA Phase Voltage Settings

VA RATIO CORRECT (0.500–1.500) *(Shown if Slot E = (L1 OR L2 OR L8))*	**VARCF** := ____________
VB RATIO CORRECT (0.500–1.500) *(Shown if Slot E = (L1 OR L2 OR L8))*	**VBRCF** := ____________
VC RATIO CORRECT (0.500–1.500 deg) *(Shown if Slot E = (L1 OR L2 OR L8))*	**VCRCF** := ____________
VA ANGLE CORRECT (–10.0 to 10.0 deg) *(Shown if Slot E = (L1 OR L2 OR L8))*	**VAPAC** := ____________
VB ANGLE CORRECT (–10.0 to 10.0 deg) *(Shown if Slot E = (L1 OR L2 OR L8))*	**VBPAC** := ____________
VC ANGLE CORRECT (–10.0 to 10.0) *(Shown if Slot E = (L1 OR L2 OR L8))*	**VCPAC** := ____________

LEA Current Settings

IAW1 RATIO CORRECT (0.900–1.100) *(Shown if Slot Z = L0)*	**IAW1RCF** := ____________
IBW1 RATIO CORRECT (0.900–1.100) *(Shown if Slot Z = L0)*	**IBW1RCF** := ____________
ICW1 RATIO CORRECT (0.900–1.100 deg) *(Shown if Slot Z = L0)*	**ICW1RCF** := ____________
IAW1 ANGLE CORRECT (–10.0 to 10.0 deg) *(Shown if Slot Z = L0)*	**IAW1PAC** := ____________

IBW1 ANGLE CORRECT (–10.0 to 10.0 deg) **IBW1PAC** := ______________________
(Shown if Slot Z = L0)

ICW1 ANGLE CORRECT (–10.0 to 10.0) **ICW1PAC** := ______________________
(Shown if Slot Z = L0)

IAW2 RATIO CORRECT (0.900–1.100) **IAW2RCF** := ______________________
(Shown if Slot Z = L0)

IBW2 RATIO CORRECT (0.900–1.100) **IBW2RCF** := ______________________
(Shown if Slot Z = L0)

ICW2 RATIO CORRECT (0.900–1.100 deg) **ICW2RCF** := ______________________
(Shown if Slot Z = L0)

IAW2 ANGLE CORRECT (–10.0 to 10.0 deg) **IAW2PAC** := ______________________
(Shown if Slot Z = L0)

IBW2 ANGLE CORRECT (–10.0 to 10.0 deg) **IBW2PAC** := ______________________
(Shown if Slot Z = L0)

ICW2 ANGLE CORRECT (–10.0 to 10.0) **ICW2PAC** := ______________________
(Shown if Slot Z = L0)

IAW3 RATIO CORRECT (0.900–1.100) **IAW3RCF** := ______________________
(Shown if Slot E = (L0 OR L1 OR L2))

IBW3 RATIO CORRECT (0.900–1.100) **IBW3RCF** := ______________________
(Shown if Slot E = (L0 OR L1 OR L2))

ICW3 RATIO CORRECT (0.900–1.100 deg) **ICW3RCF** := ______________________
(Shown if Slot E = (L0 OR L1 OR L2))

IAW3 ANGLE CORRECT (–10.0 to 10.0 deg) **IAW3PAC** := ______________________
(Shown if Slot E = (L0 OR L1 OR L2))

IBW3 ANGLE CORRECT (–10.0 to 10.0 deg) **IBW3PAC** := ______________________
(Shown if Slot E = (L0 OR L1 OR L2))

ICW3 ANGLE CORRECT (–10.0 to 10.0) **ICW3PAC** := ______________________
(Shown if Slot E = (L0 OR L1 OR L2))

IAW4 RATIO CORRECT (0.900–1.100) **IAW4RCF** := ______________________
(Shown if Slot E = L0)

IBW4 RATIO CORRECT (0.900–1.100) **IBW4RCF** := ______________________
(Shown if Slot E = L0)

ICW4 RATIO CORRECT (0.900–1.100 deg) **ICW4RCF** := ______________________
(Shown if Slot E = L0)

IAW4 ANGLE CORRECT (–10.0 to 10.0 deg) **IAW4PAC** := ______________________
(Shown if Slot E = L0)

IBW4 ANGLE CORRECT (–10.0 to 10.0 deg) **IBW4PAC** := ______________________
(Shown if Slot E = L0)

ICW4 ANGLE CORRECT (–10.0 to 10.0) **ICW4PAC** := ______________________
(Shown if Slot E = L0)

IN1 RATIO CORRECT (0.900–1.100 deg) **IN1RCF** := ______________________
(Shown if Slot E = (L2 or L6 or L8))

IN1 ANGLE CORRECT (–10.0 to 10.0) **IN1PAC** := ______________________
(Shown if Slot E = (L2 or L6 or L8))

LEA Vsync Settings

VS RATIO CORRECT (0.500–1.500 deg) *(Shown if Slot E = (L1 AND Global setting VS_VBAT ≠ VBAT))*	**VSRCF** := ________
VS ANGLE CORRECT (–10.0 to 10.0) *(Shown if Slot E = (L1 AND Global setting VS_VBAT ≠ VBAT))*	**VSPAC** := ________

Phasor Measurement (PMU)

EN SYNCHRO PHSOR (Y, N) *(All subsequent PMU settings are hidden if EPMU := N)*	**EPMU** := ________
MESSAGES PER SEC (If FNOM := 60 Hz then range is 1, 2, 4, 5, 10, 12, 15, 20, 30, 60; if FNOM := 50 Hz then range is 1, 2, 5, 10, 25, 50)	**MRATE** := ________
PMU APPLICATION (FAST, NARROW)	**PMAPP** := ________
FREQ BASED COMP (Y, N)	**PHCOMP** := ________
STATION NAME (16 Characters)	**PMSTN** := ________
PMU HARDWARE ID (1–65534)	**PMID** := ________
VOLTAGE DATA SET (V1, ALL, NA) *(Hidden if Slot E card is not 3 ACI/4 AVI, 4 ACI/3 AVI, or 1 ACI/3 AVI)*	**PHDATAV** := ________
VOLT COMP ANGLE (–179.99 to 180.00 Deg.) *(Hidden if Slot E card is not 3 ACI/4 AVI, 4 ACI/3 AVI, or 1 ACI/3 AVI)*	**VCOMP** := ________
VS COMP ANGLE (–179.99 to 180.00 Deg.) *(Hidden if Slot E card is not 3 ACI/4 AVI OR VS_BAT := VBAT)*	**VSCOMP** := ________
CURRENT DATA SET (I1, ALL, NA)	**PHDATAI** := ________
CURRENT SOURCE (IW1, IW2, IW3, IW4, ALL) *(Hidden if PHDATAI := NA; IW4 option is hidden if Slot E card is not 6 ACI; show option IW3 in the range if Slot E is 6 ACI, 3 ACI/4 AVI, or 4 ACI/3 AVI)*	**PHCURR** := ________
IW1 COMP ANGLE (–179.99 to 180.00 Deg.) *(Shown if PHCURR := IW1 or ALL AND PHDATAI := I1 or ALL)*	**IW1COMP** := ________
IW2 COMP ANGLE (–179.99 to 180.00 Deg.) *(Shown if PHCURR := IW2 or ALL AND PHDATAI := I1 or ALL)*	**IW2COMP** := ________
IW3 COMP ANGLE (–179.99 to 180.00 Deg.) *(Shown if PHCURR := IW3 or ALL AND PHDATAI := I1 or ALL or if Slot E is 6 ACI, 3 ACI/4 AVI, or 4 ACI/3 AVI)*	**IW3COMP** := ________
IW4 COMP ANGLE (–179.99 to 180.00 Deg.) *(Hidden if Slot E card is not 6 ACI; shown if PHCURR := IW4 or ALL AND PHDATAI := I1 or ALL)*	**IW4COMP** := ________
NUM ANALOGS (0–4)	**NUMANA** := ________
NUM 16BIT DIGTAL (0, 1)	**NUMDSW** := ________
TRIG REASON BIT1 (SELOGIC)	**TREA1** := ________
TRIG REASON BIT2 (SELOGIC)	**TREA2** := ________

TRIG REASON BIT3 (SELOGIC)	**TREA3** := ________________
TRIG REASON BIT4 (SELOGIC)	**TREA4** := ________________
TRIGGER (SELOGIC)	**PMTRIG** := ________________

Time and Date Management

CTRL BITS DEFN (NONE, C37.118)	**IRIGC** := ________________
OFFSET FROM UTC (–24.00 to 24.00, rounded up to nearest 0.25)	**UTC_OFF** := ________________
MONTH TO BEGIN DST (OFF, 1–12) *(All subsequent settings are hidden if DST_BEGM := OFF)*	**DST_BEGM** := ________________
WEEK OF THE MONTH TO BEGIN DST (1–3, L {L = Last week of the month})	**DST_BEGW** := ________________
DAY OF THE WEEK TO BEGIN DST (SUN, MON, TUES, WED, THU, FRI, SAT)	**DST_BEGD** := ________________
LOCAL HOUR TO BEGIN DST (0–23)	**DST_BEGH** := ________________
MONTH TO END DST (1–12)	**DST_ENDM** := ________________
WEEK OF THE MONTH TO END DST (1–3, L {L = Last week of the month})	**DST_ENDW** := ________________
DAY OF THE WEEK TO END DST (SUN, MON, TUES, WED, THU, FRI, SAT)	**DST_ENDD** := ________________
LOCAL HOUR TO END DST (0–23)	**DST_ENDH** := ________________

Breaker Failure

52A INTERLOCK (Y, N)	**52ABF** := ________________
BRKR1 CUR DETECT (0.10–10.00 A {5 A NOM}; 0.02–2.00 A {1 A NOM})	**50BFP1** := ________________
BRK1 RES CUR DET (OFF, 0.50–10.00 A {5 A NOM}; 0.10–2.00 A {1 A NOM})	**50BFG1** := ________________
BRKR1 FAIL DELAY (0.00–2.00 sec)	**BFD1** := ________________
AUX1 TIMER DELAY (OFF, 0.00–2.00 sec)	**ATD1** := ________________
BRKR1 FAIL INIT (SELOGIC)	**BFI1** := ________________
BRK1 SEAL-IN DLY (OFF, 0–2.00 sec)	**BFISID1** := ________________
BRK1 RETRIP DLY (OFF, 0–2.00 sec)	**BFRTD1** := ________________
BF1 TRIP EQN (SELOGIC)	**BFTR1** := ________________
BF1 UNLATCH EQN (SELOGIC)	**BFULTR1** := ________________
BRKR2 CUR DETECT (0.10–10.00 A {5 A NOM}; 0.02–2.00 A {1 A NOM})	**50BFP2** := ________________

BRK2 RES CUR DET (OFF, 0.50–10.00 A {5 A NOM}; 0.10–2.00 A {1 A NOM})	**50BFG2** := ________
BRKR2 FAIL DELAY (0.00–2.00 sec)	**BFD2** := ________
AUX2 TIMER DELAY (OFF, 0.00–2.00 sec)	**ATD2** := ________
BRKR2 FAIL INIT (SELOGIC)	**BFI2** := ________
BRK2 SEAL-IN DLY (OFF, 0–2.00 sec)	**BFISID2** := ________
BRK2 RETRIP DLY (OFF, 0–2.00 sec)	**BFRTD2** := ________
BF2 TRIP EQN (SELOGIC)	**BFTR2** := ________
BF2 UNLATCH EQN (SELOGIC)	**BFULTR2** := ________
BRKR3 CUR DETECT (0.10–10.00 A {5 A NOM}; 0.02–2.00 A {1 A NOM}) *(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI)*	**50BFP3** := ________
BRK3 RES CUR DET (OFF, 0.50–10.00 A {5 A NOM}; 0.10–2.00 A {1 A NOM}) *(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI)*	**50BFG3** := ________
BRKR3 FAIL DELAY (0.00–2.00 sec) *(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI)*	**BFD3** := ________
AUX3 TIMER DELAY (OFF, 0.00–2.00 sec) *(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI)*	**ATD3** := ________
BRKR3 FAIL INIT (SELOGIC) *(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI)*	**BFI3** := ________
BRK3 SEAL-IN DLY (OFF, 0–2.00 sec) *(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI)*	**BFISID3** := ________
BRK3 RETRIP DLY (OFF, 0–2.00 sec) *(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI)*	**BFRTD3** := ________
BF3 TRIP EQN (SELOGIC) *(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI)*	**BFTR3** := ________
BF3 UNLATCH EQN (SELOGIC) *(Shown if Slot E card is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI)*	**BFULTR3** := ________
BRKR4 CUR DETECT (0.10-10.00 A {5 A NOM}; 0.02-2.00 A {1 A NOM}) *(Shown if Slot E card is 6 ACI)*	**50BFP4** := ________
BRK4 RES CUR DET (OFF, 0.50-10.00 A {5 A NOM}; 0.10-2.00 A {1 A NOM}) *(Shown if Slot E card is 6 ACI)*	**50BFG4** := ________
BRKR4 FAIL DELAY (0.00–2.00 sec) *(Shown if Slot E card is 6 ACI)*	**BFD4** := ________
AUX4 TIMER DELAY (OFF, 0.00–2.00 sec) *(Shown if Slot E card is 6 ACI)*	**ATD4** := ________
BRKR4 FAIL INIT (SELOGIC) *(Shown if Slot E card is 6 ACI)*	**BFI4** := ________

BRK4 SEAL-IN DLY (OFF, 0–2.00 sec) **BFISID4** := ____________
(Shown if Slot E card is 6 ACI)

BRK4 RETRIP DLY (OFF, 0–2.00 sec) **BFRTD4** := ____________
(Shown if Slot E card is 6 ACI)

BF4 TRIP EQN (SELOGIC) **BFTR4** := ____________
(Shown if Slot E card is 6 ACI)

BF4 UNLATCH EQN (SELOGIC) **BFULTR4** := ____________
(Shown if Slot E card is 6 ACI)

Through Fault

THR FLT WDG (OFF, 1, 2, 3, 4, 12, 23, 34) **THFLTD** := ____________
(3, 12, and 23 are hidden in the range if Slot E is a 1 ACI, 1 ACI/3 AVI, or optional I/O card, or is empty; 4 and 34 are hidden in the range if Slot E does not have the 6 AVI card)
(All subsequent settings are hidden if THFLTD := OFF)

ENABLE THR FLT (SELOGIC) **ETHRFLT** := ____________

THR FLT ALARM PU (50.0%–900.0%) **THFLTPU** := ____________

XFMR IMPEDANCE (2.0%–40.0%) **XFMRZ** := ____________

Analog Inputs

(For the following settings, x is the card position {3, 4, or 5 in Slot C, D, and E, respectively}; heading and all associated AI card settings for Slot X are hidden if there is no AI card in the corresponding slot)

AIx01

AI*x*01 TAG NAME (8 Characters, 0–9, A–Z) **AI*x*01NAM** := ____________
(This setting must begin with an alpha character A–Z; this setting cannot accept the Analog Quantities or Other AI Names)

AI*x*01 TYPE (I, V) **AI*x*01TYP** := ____________
(The type selection must match the hardware jumper selection on the card)

If AI*x*01TYP = I

AI*x*01 LOW IN VAL (–20.480 to +20.480 mA) **AI*x*01L** := ____________
(Hidden if AIx01TYP := V)

AI*x*01 HI IN VAL (–20.480 to +20.480 mA) **AI*x*01H** := ____________
(Hidden if AIx01TYP := V; setting must not be equal to AIx01L)

If AI*x*01TYP = V

AI*x*01 LOW IN VAL (–10.240 to +10.240 V) **AI*x*01L** := ____________
(Hidden if AIx01TYP := I)

AI*x*01 HI IN VAL (–10.240 to +10.240 V) **AI*x*01H** := ____________
(Hidden if AIx01TYP := I, setting must not be equal to AIx01L)

AI*x*01 ENG UNITS (16 Characters) **AI*x*01EU** := ____________

AI*x*01 EU LOW (–99999.000 to +99999.000) **AI*x*01EL** := ____________

AI*x*01 EU HI (–99999.000 to +99999.000) **AI*x*01EH** := ____________
(Setting must be greater than AIx01EL)

AI*x*01 LO WARN L1 (OFF, –99999.000 to +99999.000) *(The Warn and Alarm settings must be within AIx01EL and AIx01EH setting range)*	**AI*x*01LW1** := ___________
AI*x*01 LO WARN L2 (OFF, –99999.000 to +99999.000)	**AI*x*01LW2** := ___________
AI*x*01 LO ALARM (OFF, –99999.000 to +99999.000)	**AI*x*01LAL** := ___________
AI*x*01 HI WARN L1 (OFF, –99999.000 to +99999.000)	**AI*x*01HW1** := ___________
AI*x*01 HI WARN L2 (OFF, –99999.000 to +99999.000)	**AI*x*01HW2** := ___________
AI*x*01 HI ALARM (OFF, –99999.000 to +99999.000)	**AI*x*01HAL** := ___________

AIx02

AI*x*02 TAG NAME (8 Characters, 0–9, A–Z, _) *(This setting must begin with an alpha character A–Z; this setting cannot accept the Analog Quantities or Other AI Names)*	**AI*x*02NAM** := ___________
AI*x*02 TYPE (I, V) *(The type selection must match the hardware jumper selection on the card)*	**AI*x*02TYP** := ___________
If AI*x*02TYP = I	
AI*x*02 LOW IN VAL (–20.480 to +20.480 mA) *(Hidden if AIx02TYP := V)*	**AI*x*02L** := ___________
AI*x*02 HI IN VAL (–20.480 to +20.480 mA) *(Hidden if AIx02TYP := V; setting must not be equal to AIx02L)*	**AI*x*02H** := ___________
If AI*x*02TYP = V	
AI*x*02 LOW IN VAL (–10.240 to +10.240 V) *(Hidden if AIx02TYP := I)*	**AI*x*02L** := ___________
AI*x*02 HI IN VAL (–10.240 to +10.240 V) *(Hidden if AIx02TYP := I; setting must not be equal to AIx02L)*	**AI*x*02H** := ___________
AI*x*02 ENG UNITS (16 Characters)	**AI*x*02EU** := ___________
AI*x*02 EU LOW (–99999.000 to +99999.000)	**AI*x*02EL** := ___________
AI*x*02 EU HI (–99999.000 to +99999.000) *(Setting must be greater than AIx02EL)*	**AI*x*02EH** := ___________
AI*x*02 LO WARN L1 (OFF, –99999.000 to +99999.000) *(The Warn and Alarm settings must be within AIx02EL and AIx02EH range)*	**AI*x*02LW1** := ___________
AI*x*02 LO WARN L2 (OFF, –99999.000 to +99999.000)	**AI*x*02LW2** := ___________
AI*x*02 LO ALARM (OFF, –99999.000 to +99999.000)	**AI*x*02LAL** := ___________
AI*x*02 HI WARN L1 (OFF, –99999.000 to +99999.000)	**AI*x*02HW1** := ___________
AI*x*02 HI WARN L2 (OFF, –99999.000 to +99999.000)	**AI*x*02HW2** := ___________
AI*x*02 HI ALARM (OFF, –99999.000 to +99999.000)	**AI*x*02HAL** := ___________

AIx03

AI*x*03 TAG NAME (8 Characters, 0–9, A–Z, _) *(This setting must begin with an alpha character A–Z; this setting cannot accept the Analog Quantities or Other AI Names)*	**AI*x*01NAM** := ________________
AI*x*03 TYPE (I, V) *(The type selection must match the hardware jumper selection on the card)*	**AI*x*01TYP** := ________________
If AI*x*03TYP = I	
AI*x*03 LOW IN VAL (–20.480 to +20.480 mA) *(Hidden if AIx03TYP := V)*	**AI*x*03L** := ________________
AI*x*03 HI IN VAL (–20.480 to +20.480 mA) *(Hidden if AIx03TYP := V; setting must not be equal to AIx03L)*	**AI*x*03H** := ________________
If AI*x*03TYP = V	
AI*x*03 LOW IN VAL (–10.240 to +10.240 V) *(Hidden if AIx03TYP := I)*	**AI*x*03L** := ________________
AI*x*03 HI IN VAL (–10.240 to +10.240 V) *(Hidden if AIx03TYP := I; setting must not be equal to AIx03L)*	**AI*x*03H** := ________________
AI*x*03 ENG UNITS (16 Characters)	**AI*x*03EU** := ________________
AI*x*03 EU LOW (–99999.000 to +99999.000)	**AI*x*03EL** := ________________
AI*x*03 EU HI (–99999.000 to +99999.000) *(Setting must be greater than AIx03EL)*	**AI*x*03EH** := ________________
AI*x*03 LO WARN L1 (OFF, –99999.000 to +99999.000) *(The Warn and Alarm settings must be within AIx03EL and AIx03EH setting range)*	**AI*x*03LW1** := ________________
AI*x*03 LO WARN L2 (OFF, –99999.000 to +99999.000)	**AI*x*03LW2** := ________________
AI*x*03 LO ALARM (OFF, –99999.000 to +99999.000)	**AI*x*03LAL** := ________________
AI*x*03 HI WARN L1 (OFF, –99999.000 to +99999.000)	**AI*x*03HW1** := ________________
AI*x*03 HI WARN L2 (OFF, –99999.000 to +99999.000)	**AI*x*03HW2** := ________________
AI*x*03 HI ALARM (OFF, –99999.000 to +99999.000)	**AI*x*03HAL** := ________________

AIx04

AI*x*04 TAG NAME (8 Characters, 0–9, A–Z, _) *(This setting must begin with an alpha character A–Z; this setting cannot accept the Analog Quantities or Other AI Names)*	**AI*x*04NAM** := ________________
AI*x*04 TYPE (I, V) *(The type selection must match the hardware jumper selection on the card)*	**AI*x*04TYP** := ________________
If AI*x*04TYP = I	
AI*x*04 LOW IN VAL (–20.480 to +20.480 mA) *(Hidden if AIx04TYP := V)*	**AI*x*04L** := ________________
AI*x*04 HI IN VAL (–20.480 to +20.480 mA) *(Hidden if AIx04TYP := V; setting must not be equal to AIx04L)*	**AI*x*04H** := ________________

If AI*x*04TYP = V

AI*x*04 LOW IN VAL (–10.240 to +10.240 V) *(Hidden if AIx04TYP := I)*	**AI*x*04L** := ________________
AI*x*04 HI IN VAL (–10.240 to +10.240 V) *(Hidden if AIx04TYP := I; setting must not be equal to AIx04L)*	**AI*x*04H** := ________________
AI*x*04 ENG UNITS (16 Characters)	**AI*x*04EU** := ________________
AI*x*04 EU LOW (–99999.000 to +99999.000)	**AI*x*04EL** := ________________
AI*x*04 EU HI (–99999.000 to +99999.000) *(Setting must be greater than AIx04EL)*	**AI*x*04EH** := ________________
AI*x*04 LO WARN L1 (OFF, –99999.000 to +99999.000) *(The Warn and Alarm settings must be within AIx04EL and AIx04EH setting range)*	**AI*x*04LW1** := ________________
AI*x*04 LO WARN L2 (OFF, –99999.000 to +99999.000)	**AI*x*04LW2** := ________________
AI*x*04 LO ALARM (OFF, –99999.000 to +99999.000)	**AI*x*04LAL** := ________________
AI*x*04 HI WARN L1 (OFF, –99999.000 to +99999.000)	**AI*x*04HW1** := ________________
AI*x*04 HI WARN L2 (OFF, –99999.000 to +99999.000)	**AI*x*04HW2** := ________________
AI*x*04 HI ALARM (OFF, –99999.000 to +99999.000)	**AI*x*04HAL** := ________________

Analog Outputs

(For the following settings, x is the card position {3, 4, or 5 in Slot C, D, and E, respectively}; heading and all associated AO card settings for Slot x are hidden if there is no AO card installed in the corresponding slot)

AOx01

AO*x*01 ANALOG QTY (OFF, 1 Analog Quantity) *(All subsequent settings are hidden when AOx01AQ := OFF)*	**AO*x*01AQ** := ________________
AO*x*01 TYPE (I, V) *(The type selection must match the hardware jumper selection on the card; always hidden for 4 DO/3 DI/1 AO card {internally set Type I})*	**AO*x*01TYP** := ________________
AO*x*01 AQTY LOW (–2147483647 to +2147483647)	**AO*x*01AQL** := ________________
AO*x*01 AQTY HI (–2147483647 to +2147483647) *(Setting must be greater than AOx01AQL)*	**AO*x*01AQH** := ________________

If AO*x*01TYP = I

AO*x*01 LO OUT VAL (–20.480 to +20.480 mA) *(Hidden if AIx01TYP := V; always hidden for 4 DO/3 DI/1 AO card {internally set to default})*	**AO*x*01L** := ________________
AO*x*01 HI OUT VAL (–20.480 to +20.480 mA) *(Hidden if AIx01TYP := V; setting must be greater than AOx01L)*	**AO*x*01H** := ________________

If AO*x*01TYP = V

AO*x*01 LO OUT VAL (–10.240 to +10.240 V) **AO*x*01L** := ______________________
(Hidden if AIx01TYP := I; always hidden for 4 DO/3 DI/1 AO card)

AO*x*01 HI OUT VAL (–10.240 to +10.240 V) **AO*x*01H** := ______________________
(Hidden if AIx01TYP := I; setting must be greater than AOx01L)

AOx02

AO*x*02 ANALOG QTY (OFF, 1 Analog Quantity) **AO*x*02AQ** := ______________________
(All subsequent settings are hidden when AOx02AQ := OFF)

AO*x*02 TYPE (I, V) **AO*x*02TYP** := ______________________
(The type selection must match the hardware jumper selection on the card; always hidden for 4 DO/3 DI/1 AO card (internally set TYPE 1})

AO*x*02 AQTY LOW (–2147483647 to +2147483647) **AO*x*02AQL** := ______________________

AO*x*02 AQTY HI (–2147483647 to +2147483647) **AO*x*02AQH** := ______________________
(Setting must be greater than AOx02AQL)

If AO*x*02TYP = I

AO*x*02 LO OUT VAL (–20.480 to +20.480 mA) **AO*x*02L** := ______________________
(Hidden if AIx02TYP := V; always hidden for 4 DO/3 DI/1 AO card {internally set to default})

AO*x*02 HI OUT VAL (–20.480 to +20.480 mA) **AO*x*02H** := ______________________
(Hidden if AIx02TYP := V; setting must be greater than AOx02L)

If AO*x*02TYP = V

AO*x*02 LO OUT VAL (–10.240 to +10.240 V) **AO*x*02L** := ______________________
(Hidden if AIx02TYP := I; always hidden for 4 DO/3 DI/1 AO card)

AO*x*02 HI OUT VAL (–10.240 to +10.240 V) **AO*x*02H** := ______________________
(Hidden if AIx02TYP := I; setting must be greater than AOx02L)

AOx03

AO*x*03 ANALOG QTY (OFF, 1 Analog Quantity) **AO*x*03AQ** := ______________________
(All subsequent settings are hidden when AOx03AQ := OFF)

AO*x*03 TYPE (I, V) **AO*x*03TYP** := ______________________
(The type selection must match the hardware jumper selection on the card; always hidden for 4 DO/3 DI/ AO card {internally set to default})

AO*x*03 AQTY LOW (–2147483647 to +2147483647) **AO*x*03AQL** := ______________________

AO*x*03 AQTY HI (–2147483647 to +2147483647) **AO*x*03AQH** := ______________________
(Setting must be greater than AOx03AQL)

If AO*x*03TYP = I

AO*x*03 LO OUT VAL (–20.480 to +20.480 mA) **AO*x*03L** := ______________________
(Hidden if AIx03TYP := V; always hidden for 4 DO/3 DI/1 AO {internally set to default})

AO*x*03 HI OUT VAL (–20.480 to +20.480 mA) **AO*x*03H** := ______________________
(Hidden if AIx03TYP := V; setting must be greater than AOx03L)

If AO*x*03TYP = V

AO*x*03 LO OUT VAL (–10.240 to +10.240 V) **AO*x*03L** := ____________
(Hidden if AIx03TYP := I; always hidden for 4 DO/3 DI/1 AO card)

AO*x*03 HI OUT VAL (–10.240 to +10.240 V) **AO*x*03H** := ____________
(Hidden if AIx03TYP := I; setting must be greater than AOx03L)

AOx04

AO*x*04 ANALOG QTY (OFF, 1 Analog Quantity) **AO*x*04AQ** := ____________
(All subsequent settings are hidden when AOx04AQ := OFF)

AO*x*04 TYPE (I, V) **AO*x*04TYP** := ____________
(The type selection must match the hardware jumper selection on the card; always hidden for 4 DO/3 DI/1 AO card {internally set to default})

AO*x*04 AQTY LOW (–2147483647 to +2147483647) **AO*x*04AQL** := ____________

AO*x*04 AQTY HI (–2147483647 to +2147483647) **AO*x*04AQH** := ____________
(Setting must be greater than AOx04AQL)

If AO*x*04TYP = I

AO*x*04 LO OUT VAL (–20.480 to +20.480 mA) **AO*x*04L** := ____________
(Hidden if AIx04TYP := V; always hidden for 4 DO/3 DI/1 AO card {internally set to default})

AO*x*04 HI OUT VAL (–20.480 to +20.480 mA) **AO*x*04H** := ____________
(Hidden if AIx04TYP := V; setting must be greater than AOx04L)

If AO*x*04TYP = V

AO*x*04 LO OUT VAL (–10.240 to +10.240 V) **AO*x*04L** := ____________
(Hidden if AIx04TYP := I; always hidden for 4 DO/3 DI/1 AO card)

AO*x*04 HI OUT VAL (–10.240 to +10.240 V) **AO*x*04H** := ____________
(Hidden if AIx04TYP := I; setting must be greater than AOx04L)

Input Debounce Settings (Base Unit)

IN101 Debounce (AC, 0–65000 ms) **IN101D** := ____________

IN102 Debounce (AC, 0–65000 ms) **IN102D** := ____________

Input Debounce Settings (Slot C)

IN301 Debounce (AC, 0–65000 ms) **IN301D** := ____________
(IN301, IN302, and IN303 are hidden if Slot C is not a 14 DI, 8 DI, 4 DI/4 DO, or 4 DO/3 DI/1 AO card)

IN302 Debounce (AC, 0–65000 ms) **IN302D** := ____________

IN303 Debounce (AC, 0–65000 ms) **IN303D** := ____________

IN304 Debounce (AC, 0–65000 ms) **IN304D** := ____________
(Hidden if Slot C is not a 14 DI, 8 DI, or 4 DI/4 DO card)

IN305 Debounce (AC, 0–65000 ms) **IN305D** := ____________
(IN305D and subsequent settings are hidden if Slot C is not a 14 DI or 8 DI card)

IN306 Debounce (AC, 0–65000 ms) **IN306D** := ____________________

IN307 Debounce (AC, 0–65000 ms) **IN307D** := ____________________

IN308 Debounce (AC, 0–65000 ms) **IN308D** := ____________________

IN309 Debounce (AC, 0–65000 ms) **IN309D** := ____________________
(IN309D and subsequent settings are hidden if Slot C is not a 14 DI card)

IN310 Debounce (AC, 0–65000 ms) **IN310D** := ____________________

IN311 Debounce (AC, 0–65000 ms) **IN311D** := ____________________

IN312 Debounce (AC, 0–65000 ms) **IN312D** := ____________________

IN313 Debounce (AC, 0–65000 ms) **IN313D** := ____________________

IN314 Debounce (AC, 0–65000 ms) **IN314D** := ____________________

Input Debounce Settings (Slot D)

IN401 Debounce (AC, 0–65000 ms) **IN401D** := ____________________
(IN401, IN402, and IN403 are hidden if Slot D is not a 14 DI, 8 DI, 4 DI/4 DO, or 4 DO/3 DI/1 AO card)

IN402 Debounce (AC, 0–65000 ms) **IN402D** := ____________________

IN403 Debounce (AC, 0–65000 ms) **IN403D** := ____________________

IN404 Debounce (AC, 0–65000 ms) **IN404D** := ____________________
(Hidden if Slot D is not 8 DI or 4 DI/4 DO card)

IN405 Debounce (AC, 0–65000 ms) **IN405D** := ____________________
(IN405D and subsequent settings are hidden if Slot D is not a 14 DI or 8 DI card)

IN406 Debounce (AC, 0–65000 ms) **IN406D** := ____________________

IN407 Debounce (AC, 0–65000 ms) **IN407D** := ____________________

IN408 Debounce (AC, 0–65000 ms) **IN408D** := ____________________

IN409 Debounce (AC, 0–65000 ms) **IN409D** := ____________________
(IN409D and subsequent settings are hidden if Slot C is not a 14 DI card)

IN410 Debounce (AC, 0–65000 ms) **IN410D** := ____________________

IN411 Debounce (AC, 0–65000 ms) **IN411D** := ____________________

IN412 Debounce (AC, 0–65000 ms) **IN412D** := ____________________

IN413 Debounce (AC, 0–65000 ms) **IN413D** := ____________________

IN414 Debounce (AC, 0–65000 ms) **IN414D** := ____________________

Input Debounce Settings (Slot E)

IN501 Debounce (AC, 0–65000 ms) **IN501D** := ____________
(IN501, IN502, and IN503 are hidden if Slot D is not a 14 DI, 8 DI, 4 DI/4 DO, or 4 DO/3 DI/1 AO card)

IN502 Debounce (AC, 0–65000 ms) **IN502D** := ____________

IN503 Debounce (AC, 0–65000 ms) **IN503D** := ____________

IN504 Debounce (AC, 0–65000 ms) **IN504D** := ____________
(Hidden if Slot D is not 8 DI or 4 DI/4 DO card)

IN505 Debounce (AC, 0–65000 ms) **IN505D** := ____________
(IN505D and subsequent settings are hidden if Slot D is not a 14 DI or 8 DI card)

IN506 Debounce (AC, 0–65000 ms) **IN506D** := ____________

IN507 Debounce (AC, 0–65000 ms) **IN507D** := ____________

IN508 Debounce (AC, 0–65000 ms) **IN508D** := ____________

IN509 Debounce (AC, 0–65000 ms) **IN509D** := ____________
(IN509D and subsequent settings are hidden if Slot C is not a 14 DI card)

IN510 Debounce (AC, 0–65000 ms) **IN510D** := ____________

IN511 Debounce (AC, 0–65000 ms) **IN511D** := ____________

IN512 Debounce (AC, 0–65000 ms) **IN512D** := ____________

IN513 Debounce (AC, 0–65000 ms) **IN513D** := ____________

IN514 Debounce (AC, 0–65000 ms) **IN514D** := ____________

Breaker Monitor Settings

(Breaker m settings are hidden if EBMONm := N (m = 1, 2, 3, or 4))

Breaker Monitor 1

BRK 1 MONITOR (Y, N) **EBMON1** := ____________

CL/OPN OP SET11 (0–65000) **COSP11** := ____________
(COSP11 must be > COSP12)

CL/OPN OP SET12 (0–65000) **COSP12** := ____________
(COSP12 must be ≥ COSP13; if KASP12 := KASP13, COSP12 must := COSP13)

CL/OPN OP SET13 (0–65000) **COSP13** := ____________

kA PRI INTRPT11 (0.00–999.00 kA) **KASP11** := ____________
(KASP11 must be < KASP12)

kA PRI INTRPT12 (0.00–999.00 kA) **KASP12** := ____________
(KASP12 must be ≤ KASP13)

kA PRI INTRPT13 (0.00–999.00 kA) **KASP13** := ____________________
(KASP13 must be at least 5 times but no more than 100 times more than the KASP11 value)

BRK 1 MON CTRL (SELOGIC) **BKMON1** := ____________________

Breaker Monitor 2

BRK 2 MONITOR (Y, N) **EBMON2** := ____________________

CL/OPN OP SET21 (0–65000) **COSP21** := ____________________
(COSP21 must be > COSP22)

CL/OPN OP SET22 (0–65000) **COSP22** := ____________________
(COSP22 must be ≥ COSP23; if KASP22 := KASP23, COSP22 must := COSP23)

CL/OPN OP SET23 (0–65000) **COSP23** := ____________________

kA PRI INTRPT21 (0.00–999.00 kA) **KASP21** := ____________________
(KASP21 must be < KASP22)

kA PRI INTRPT22 (0.00–999.00 kA) **KASP22** := ____________________
(KASP22 must be ≤ KASP23)

kA PRI INTRPT23 (0.00–999.00 kA) **KASP23** := ____________________
(KASP23 must be at least 5 times but no more than 100 times more than the KASP21 value)

BRK 2 MON CTRL (SELOGIC) **BKMON2** := ____________________

Breaker Monitor 3

(Breaker 3 associated settings are shown if Slot E is 6 ACI, 4 ACI/3 AVI, or 3 ACI/4 AVI)

BRK 3 MONITOR (Y, N) **EBMON3** := ____________________

CL/OPN OP SET31 (0–65000) **COSP31** := ____________________
(COSP31 must be > COSP32)

CL/OPN OP SET32 (0–65000) **COSP32** := ____________________
(COSP32 must be ≥ COSP33; if KASP32 := KASP33, COSP32 must := COSP33)

CL/OPN OP SET33 (0–65000) **COSP33** := ____________________

kA PRI INTRPT31 (0.00–999.00 kA) **KASP31** := ____________________
(KASP31 must be < KASP32)

kA PRI INTRPT32 (0.00–999.00 kA) **KASP32** := ____________________
(KASP32 must be ≤ KASP33)

kA PRI INTRPT33 (0.00–999.00 kA) **KASP33** := ____________________
(KASP33 must be at least 5 times but no more than 100 times more than the KASP31 value)

BRK 3 MON CTRL (SELOGIC) **BKMON3** := ____________________

Breaker Monitor 4

(Breaker 4 associated settings shown if Slot E is 6 ACI)

BRK 4 MONITOR (Y, N) **EBMON4** := ____________________

CL/OPN OP SET41 (0–65000) **COSP41** := ____________________
(COSP41 must be > COSP42)

CL/OPN OP SET42 (0–65000) **COSP42** := ____________________
(COSP42 must be ≥ COSP43; if KASP42 := KASP43, COSP42 must := COSP43)

CL/OPN OP SET43 (0–65000) **COSP43** := ____________________

kA PRI INTRPT41 (0.00–999.00 kA) **KASP41** := ____________________
(KASP41 must be < KASP42)

kA PRI INTRPT42 (0.00–999.00 kA) **KASP42** := ____________________
(KASP42 must be ≤ KASP43)

kA PRI INTRPT43 (0.00–999.00 kA) **KASP43** := ____________________
(KASP43 must be at least 5 times but no more than 100 times more than the KASP41 value)

BRK 4 MON CTRL (SELOGIC) **BKMON4** := ____________________

Station DC Battery Monitor

(Settings are shown only if the card in Slot E is 3 ACI/4 AVI and VS_BAT := VBAT)

DC UNDER VOLT PU (OFF, 20.00–300.00 Vdc) **DCLOP** := ____________________

DC OVER VOLT PU (OFF, 20.00–300.00 Vdc) **DCHIP** := ____________________

Data Reset

RESET TARGETS (SELOGIC) **RSTTRGT** := ____________________

RESET ENERGY (SELOGIC) **RSTENRGY** := ____________________

RESET MAX/MIN (SELOGIC) **RSTMXMN** := ____________________

RESET DEMAND (SELOGIC) **RSTDEM** := ____________________

RESET PK DEMAND (SELOGIC) **RSTPKDEM** := ____________________

Access Control

DISABLE SETTINGS (SELOGIC) **DSABLSET** := ____________________

Time Synchronization Source

IRIG TIME SOURCE (IRIG1, IRIG2) **TIME_SRC** := ____________________
(IRIG1 is IRIG-B/Port 3 input and IRIG2 is Port 2 [Fiber Optic])

Date ___________
Group___________

Two-Position Disconnect

EN 2P DISC (N, 1–16)	**89EN2P** := ____________
2P DISC 1 NAME (16 characters)	**89NM2P1** := ____________
2P DISC 1 MODE (Control, Monitor)	**89MD2P1** := ____________
2P DISC 2 NAME (16 characters)	**89NM2P2** := ____________
2P DISC 2 MODE (Control, Monitor)	**89MD2P2** := ____________
2P DISC 3 NAME (16 characters)	**89NM2P3** := ____________
2P DISC 3 MODE (Control, Monitor)	**89MD2P3** := ____________
2P DISC 4 NAME (16 characters)	**89NM2P4** := ____________
2P DISC 4 MODE (Control, Monitor)	**89MD2P4** := ____________
2P DISC 5 NAME (16 characters)	**89NM2P5** := ____________
2P DISC 5 MODE (Control, Monitor)	**89MD2P5** := ____________
2P DISC 6 NAME (16 characters)	**89NM2P6** := ____________
2P DISC 6 MODE (Control, Monitor)	**89MD2P6** := ____________
2P DISC 7 NAME (16 characters)	**89NM2P7** := ____________
2P DISC 7 MODE (Control, Monitor)	**89MD2P7** := ____________
2P DISC 8 NAME (16 characters)	**89NM2P8** := ____________
2P DISC 8 MODE (Control, Monitor)	**89MD2P8** := ____________
2P DISC 9 NAME (16 characters)	**89NM2P9** := ____________
2P DISC 9 MODE (Control, Monitor)	**89MD2P9** := ____________
2P DISC 10 NAME (16 characters)	**89NM2P10** := ____________
2P DISC 10 MODE (Control, Monitor)	**89MD2P10** := ____________
2P DISC 11 NAME (16 characters)	**89NM2P11** := ____________
2P DISC 11 MODE (Control, Monitor)	**89MD2P11** := ____________
2P DISC 12 NAME (16 characters)	**89NM2P12** := ____________
2P DISC 12 MODE (Control, Monitor)	**89MD2P12** := ____________
2P DISC 13 NAME (16 characters)	**89NM2P13** := ____________
2P DISC 13 MODE (Control, Monitor)	**89MD2P13** := ____________
2P DISC 14 NAME (16 characters)	**89NM2P14** := ____________
2P DISC 14 MODE (Control, Monitor)	**89MD2P14** := ____________

2P DISC 15 NAME (16 characters)	**89NM2P15** := ________
2P DISC 15 MODE (Control, Monitor)	**89MD2P15** := ________
2P DISC 16 NAME (16 characters)	**89NM2P16** := ________
2P DISC 16 MODE (Control, Monitor)	**89MD2P16** := ________
DISC 1 N/O CONT (SELOGIC)	**89A2P1** := ________
DISC 1 N/C CONT (SELOGIC)	**89B2P1** := ________
DISC 1 ALM PU (0.00–300.00 sec)	**89A2P1D** := ________
DISC 1 SEALIN (0.00–300.00 sec)	**89S2P1D** := ________
DISC 1 IMMOBI (0.00–300.00 sec)	**89I2P1D** := ________
DISC 1 CL CONT (SELOGIC)	**89RC2P1** := ________
DISC 1 CL BLK (SELOGIC)	**89CB2P1** := ________
DISC 1 CL RST (SELOGIC)	**89CR2P1** := ________
DISC 1 CL IM RS (SELOGIC)	**89CT2P1** := ________
DISC 1 OP CONT (SELOGIC)	**89RO2P1** := ________
DISC 1 OP BLK (SELOGIC)	**89OB2P1** := ________
DISC 1 OP RST (SELOGIC)	**89OR2P1** := ________
DISC 1 OP IM RS (SELOGIC)	**89OT2P1** := ________
DISC 2 N/O CONT (SELOGIC)	**89A2P2** := ________
DISC 2 N/C CONT (SELOGIC)	**89B2P2** := ________
DISC 2 ALM PU (0.00–300.00 sec)	**89A2P2D** := ________
DISC 2 SEALIN (0.00–300.00 sec)	**89S2P2D** := ________
DISC 2 IMMOBI (0.00–300.00 sec)	**89I2P2D** := ________
DISC 2 CL CONT (SELOGIC)	**89RC2P2** := ________
DISC 2 CL BLK (SELOGIC)	**89CB2P2** := ________
DISC 2 CL RST (SELOGIC)	**89CR2P2** := ________
DISC 2 CL IM RS (SELOGIC)	**89CT2P2** := ________
DISC 2 OP CONT (SELOGIC)	**89RO2P2** := ________
DISC 2 OP BLK (SELOGIC)	**89OB2P2** := ________
DISC 2 OP RST (SELOGIC)	**89OR2P2** := ________
DISC 2 OP IM RS (SELOGIC)	**89OT2P2** := ________

DISC 3 N/O CONT (SELOGIC)	**89A2P3** := ____________
DISC 3 N/C CONT (SELOGIC)	**89B2P3** := ____________
DISC 3 ALM PU (0.00–300.00 sec)	**89A2P3D** := ____________
DISC 3 SEALIN (0.00–300.00 sec)	**89S2P3D** := ____________
DISC 3 IMMOBI (0.00–300.00 sec)	**89I2P3D** := ____________
DISC 3 CL CONT (SELOGIC)	**89RC2P3** := ____________
DISC 3 CL BLK (SELOGIC)	**89CB2P3** := ____________
DISC 3 CL RST (SELOGIC)	**89CR2P3** := ____________
DISC 3 CL IM RS (SELOGIC)	**89CT2P3** := ____________
DISC 3 OP CONT (SELOGIC)	**89RO2P3** := ____________
DISC 3 OP BLK (SELOGIC)	**89OB2P3** := ____________
DISC 3 OP RST (SELOGIC)	**89OR2P3** := ____________
DISC 3 OP IM RS (SELOGIC)	**89OT2P3** := ____________
DISC 4 N/O CONT (SELOGIC)	**89A2P4** := ____________
DISC 4 N/C CONT (SELOGIC)	**89B2P4** := ____________
DISC 4 ALM PU (0.00–300.00 sec)	**89A2P4D** := ____________
DISC 4 SEALIN (0.00–300.00 sec)	**89S2P4D** := ____________
DISC 4 IMMOBI (0.00–300.00 sec)	**89I2P4D** := ____________
DISC 4 CL CONT (SELOGIC)	**89RC2P4** := ____________
DISC 4 CL BLK (SELOGIC)	**89CB2P4** := ____________
DISC 4 CL RST (SELOGIC)	**89CR2P4** := ____________
DISC 4 CL IM RS (SELOGIC)	**89CT2P4** := ____________
DISC 4 OP CONT (SELOGIC)	**89RO2P4** := ____________
DISC 4 OP BLK (SELOGIC)	**89OB2P4** := ____________
DISC 4 OP RST (SELOGIC)	**89OR2P4** := ____________
DISC 4 OP IM RS (SELOGIC)	**89OT2P4** := ____________
DISC 5 N/O CONT (SELOGIC)	**89A2P5** := ____________
DISC 5 N/C CONT (SELOGIC)	**89B2P5** := ____________
DISC 5 ALM PU (0.00–300.00 sec)	**89A2P5D** := ____________
DISC 5 SEALIN (0.00–300.00 sec)	**89S2P5D** := ____________

DISC 5 IMMOBI (0.00–300.00 sec)	**89I2P5D** := ____________
DISC 5 CL CONT (SELOGIC)	**89RC2P5** := ____________
DISC 5 CL BLK (SELOGIC)	**89CB2P5** := ____________
DISC 5 CL RST (SELOGIC)	**89CR2P5** := ____________
DISC 5 CL IM RS (SELOGIC)	**89CT2P5** := ____________
DISC 5 OP CONT (SELOGIC)	**89RO2P5** := ____________
DISC 5 OP BLK (SELOGIC)	**89OB2P5** := ____________
DISC 5 OP RST (SELOGIC)	**89OR2P5** := ____________
DISC 5 OP IM RS (SELOGIC)	**89OT2P5** := ____________
DISC 6 N/O CONT (SELOGIC)	**89A2P6** := ____________
DISC 6 N/C CONT (SELOGIC)	**89B2P6** := ____________
DISC 6 ALM PU (0.00–300.00 sec)	**89A2P6D** := ____________
DISC 6 SEALIN (0.00–300.00 sec)	**89S2P6D** := ____________
DISC 6 IMMOBI (0.00–300.00 sec)	**89I2P6D** := ____________
DISC 6 CL CONT (SELOGIC)	**89RC2P6** := ____________
DISC 6 CL BLK (SELOGIC)	**89CB2P6** := ____________
DISC 6 CL RST (SELOGIC)	**89CR2P6** := ____________
DISC 6 CL IM RS (SELOGIC)	**89CT2P6** := ____________
DISC 6 OP CONT (SELOGIC)	**89RO2P6** := ____________
DISC 6 OP BLK (SELOGIC)	**89OB2P6** := ____________
DISC 6 OP RST (SELOGIC)	**89OR2P6** := ____________
DISC 6 OP IM RS (SELOGIC)	**89OT2P6** := ____________
DISC 7 N/O CONT (SELOGIC)	**89A2P7** := ____________
DISC 7 N/C CONT (SELOGIC)	**89B2P7** := ____________
DISC 7 ALM PU (0.00–300.00 sec)	**89A2P7D** := ____________
DISC 7 SEALIN (0.00–300.00 sec)	**89S2P7D** := ____________
DISC 7 IMMOBI (0.00–300.00 sec)	**89I2P7D** := ____________
DISC 7 CL CONT (SELOGIC)	**89RC2P7** := ____________
DISC 7 CL BLK (SELOGIC)	**89CB2P7** := ____________
DISC 7 CL RST (SELOGIC)	**89CR2P7** := ____________

DISC 7 CL IM RS (SELOGIC)	**89CT2P7** := ____________
DISC 7 OP CONT (SELOGIC)	**89RO2P7** := ____________
DISC 7 OP BLK (SELOGIC)	**89OB2P7** := ____________
DISC 7 OP RST (SELOGIC)	**89OR2P7** := ____________
DISC 7 OP IM RS (SELOGIC)	**89OT2P7** := ____________
DISC 8 N/O CONT (SELOGIC)	**89A2P8** := ____________
DISC 8 N/C CONT (SELOGIC)	**89B2P8** := ____________
DISC 8 ALM PU (0.00–300.00 sec)	**89A2P8D** := ____________
DISC 8 SEALIN (0.00–300.00 sec)	**89S2P8D** := ____________
DISC 8 IMMOBI (0.00–300.00 sec)	**89I2P8D** := ____________
DISC 8 CL CONT (SELOGIC)	**89RC2P8** := ____________
DISC 8 CL BLK (SELOGIC)	**89CB2P8** := ____________
DISC 8 CL RST (SELOGIC)	**89CR2P8** := ____________
DISC 8 CL IM RS (SELOGIC)	**89CT2P8** := ____________
DISC 8 OP CONT (SELOGIC)	**89RO2P8** := ____________
DISC 8 OP BLK (SELOGIC)	**89OB2P8** := ____________
DISC 8 OP RST (SELOGIC)	**89OR2P8** := ____________
DISC 8 OP IM RS (SELOGIC)	**89OT2P8** := ____________
DISC 9 N/O CONT (SELOGIC)	**89A2P9** := ____________
DISC 9 N/C CONT (SELOGIC)	**89B2P9** := ____________
DISC 9 ALM PU (0.00–300.00 sec)	**89A2P9D** := ____________
DISC 9 SEALIN (0.00–300.00 sec)	**89S2P9D** := ____________
DISC 9 IMMOBI (0.00–300.00 sec)	**89I2P9D** := ____________
DISC 9 CL CONT (SELOGIC)	**89RC2P9** := ____________
DISC 9 CL BLK (SELOGIC)	**89CB2P9** := ____________
DISC 9 CL RST (SELOGIC)	**89CR2P9** := ____________
DISC 9 CL IM RS (SELOGIC)	**89CT2P9** := ____________
DISC 9 OP CONT (SELOGIC)	**89RO2P9** := ____________
DISC 9 OP BLK (SELOGIC)	**89OB2P9** := ____________
DISC 9 OP RST (SELOGIC)	**89OR2P9** := ____________

DISC 9 OP IM RS (SELOGIC)	**89OT2P9** := ________
DISC 10 N/O CONT (SELOGIC)	**89A2P10** := ________
DISC 10 N/C CONT (SELOGIC)	**89B2P10** := ________
DISC 10 ALM PU (0.00–300.00 sec)	**89A2P10D** := ________
DISC 10 SEALIN (0.00–300.00 sec)	**89S2P10D** := ________
DISC 10 IMMOBI (0.00–300.00 sec)	**89I2P10D** := ________
DISC 10 CL CONT (SELOGIC)	**89RC2P10** := ________
DISC 10 CL BLK (SELOGIC)	**89CB2P10** := ________
DISC 10 CL RST (SELOGIC)	**89CR2P10** := ________
DISC 10 CL IM RS (SELOGIC)	**89CT2P10** := ________
DISC 10 OP CONT (SELOGIC)	**89RO2P10** := ________
DISC 10 OP BLK (SELOGIC)	**89OB2P10** := ________
DISC 10 OP RST (SELOGIC)	**89OR2P10** := ________
DISC 10 OP IM RS (SELOGIC)	**89OT2P10** := ________
DISC 11 N/O CONT (SELOGIC)	**89A2P11** := ________
DISC 11 N/C CONT (SELOGIC)	**89B2P11** := ________
DISC 11 ALM PU (0.00–300.00 sec)	**89A2P11D** := ________
DISC 11 SEALIN (0.00–300.00 sec)	**89S2P11D** := ________
DISC 11 IMMOBI (0.00–300.00 sec)	**89I2P11D** := ________
DISC 11 CL CONT (SELOGIC)	**89RC2P11** := ________
DISC 11 CL BLK (SELOGIC)	**89CB2P11** := ________
DISC 11 CL RST (SELOGIC)	**89CR2P11** := ________
DISC 11 CL IM RS (SELOGIC)	**89CT2P11** := ________
DISC 11 OP CONT (SELOGIC)	**89RO2P11** := ________
DISC 11 OP BLK (SELOGIC)	**89OB2P11** := ________
DISC 11 OP RST (SELOGIC)	**89OR2P11** := ________
DISC 11 OP IM RS (SELOGIC)	**89OT2P11** := ________
DISC 12 N/O CONT (SELOGIC)	**89A2P12** := ________
DISC 12 N/C CONT (SELOGIC)	**89B2P12** := ________
DISC 12 ALM PU (0.00–300.00 sec)	**89A2P12D** := ________

DISC 12 SEALIN (0.00–300.00 sec)	**89S2P12D** := ________________
DISC 12 IMMOBI (0.00–300.00 sec)	**89I2P12D** := ________________
DISC 12 CL CONT (SELOGIC)	**89RC2P12** := ________________
DISC 12 CL BLK (SELOGIC)	**89CB2P12** := ________________
DISC 12 CL RST (SELOGIC)	**89CR2P12** := ________________
DISC 12 CL IM RS (SELOGIC)	**89CT2P12** := ________________
DISC 12 OP CONT (SELOGIC)	**89RO2P12** := ________________
DISC 12 OP BLK (SELOGIC)	**89OB2P12** := ________________
DISC 12 OP RST (SELOGIC)	**89OR2P12** := ________________
DISC 12 OP IM RS (SELOGIC)	**89OT2P12** := ________________
DISC 13 N/O CONT (SELOGIC)	**89A2P13** := ________________
DISC 13 N/C CONT (SELOGIC)	**89B2P13** := ________________
DISC 13 ALM PU (0.00–300.00 sec)	**89A2P13D** := ________________
DISC 13 SEALIN (0.00–300.00 sec)	**89S2P13D** := ________________
DISC 13 IMMOBI (0.00–300.00 sec)	**89I2P13D** := ________________
DISC 13 CL CONT (SELOGIC)	**89RC2P13** := ________________
DISC 13 CL BLK (SELOGIC)	**89CB2P13** := ________________
DISC 13 CL RST (SELOGIC)	**89CR2P13** := ________________
DISC 13 CL IM RS (SELOGIC)	**89CT2P13** := ________________
DISC 13 OP CONT (SELOGIC)	**89RO2P13** := ________________
DISC 13 OP BLK (SELOGIC)	**89OB2P13** := ________________
DISC 13 OP RST (SELOGIC)	**89OR2P13** := ________________
DISC 13 OP IM RS (SELOGIC)	**89OT2P13** := ________________
DISC 14 N/O CONT (SELOGIC)	**89A2P14** := ________________
DISC 14 N/C CONT (SELOGIC)	**89B2P14** := ________________
DISC 14 ALM PU (0.00–300.00 sec)	**89A2P14D** := ________________
DISC 14 SEALIN (0.00–300.00 sec)	**89S2P14D** := ________________
DISC 14 IMMOBI (0.00–300.00 sec)	**89I2P14D** := ________________
DISC 14 CL CONT (SELOGIC)	**89RC2P14** := ________________
DISC 14 CL BLK (SELOGIC)	**89CB2P14** := ________________

DISC 14 CL RST (SELOGIC)	**89CR2P14** := ________
DISC 14 CL IM RS (SELOGIC)	**89CT2P14** := ________
DISC 14 OP CONT (SELOGIC)	**89RO2P14** := ________
DISC 14 OP BLK (SELOGIC)	**89OB2P14** := ________
DISC 14 OP RST (SELOGIC)	**89OR2P14** := ________
DISC 14 OP IM RS (SELOGIC)	**89OT2P14** := ________
DISC 15 N/O CONT (SELOGIC)	**89A2P15** := ________
DISC 15 N/C CONT (SELOGIC)	**89B2P15** := ________
DISC 15 ALM PU (0.00–300.00 sec)	**89A2P15D** := ________
DISC 15 SEALIN (0.00–300.00 sec)	**89S2P15D** := ________
DISC 15 IMMOBI (0.00–300.00 sec)	**89I2P15D** := ________
DISC 15 CL CONT (SELOGIC)	**89RC2P15** := ________
DISC 15 CL BLK (SELOGIC)	**89CB2P15** := ________
DISC 15 CL RST (SELOGIC)	**89CR2P15** := ________
DISC 15 CL IM RS (SELOGIC)	**89CT2P15** := ________
DISC 15 OP CONT (SELOGIC)	**89RO2P15** := ________
DISC 15 OP BLK (SELOGIC)	**89OB2P15** := ________
DISC 15 OP RST (SELOGIC)	**89OR2P15** := ________
DISC 15 OP IM RS (SELOGIC)	**89OT2P15** := ________
DISC 16 N/O CONT (SELOGIC)	**89A2P16** := ________
DISC 16 N/C CONT (SELOGIC)	**89B2P16** := ________
DISC 16 ALM PU (0.00–300.00 sec)	**89A2P16D** := ________
DISC 16 SEALIN (0.00–300.00 sec)	**89S2P16D** := ________
DISC 16 IMMOBI (0.00–300.00 sec)	**89I2P16D** := ________
DISC 16 CL CONT (SELOGIC)	**89RC2P16** := ________
DISC 16 CL BLK (SELOGIC)	**89CB2P16** := ________
DISC 16 CL RST (SELOGIC)	**89CR2P16** := ________
DISC 16 CL IM RS (SELOGIC)	**89CT2P16** := ________
DISC 16 OP CONT (SELOGIC)	**89RO2P16** := ________
DISC 16 OP BLK (SELOGIC)	**89OB2P16** := ________

Date ___________
Group___________

DISC 16 OP RST (SELOGIC)	**89OR2P16** := ________
DISC 16 OP IM RS (SELOGIC)	**89OT2P16** := ________

Three-Position Disconnect

EN 3P DISC (N, 1–2)	**89EN3P** := ________

In-Line Disconnect Settings

LDISC 1 N/O CONT (SELOGIC)	**89A3PL1** := ________
LDISC 1 N/C CONT (SELOGIC)	**89B3PL1** := ________
LDISC 1 ALM PU CONT (0.00–300.00 sec)	**89A3PL1D** := ________
LDISC 1 SEALIN (0.00–300.00 sec)	**89S3PL1D** := ________
LDISC 1 IMMOBI (0.00–300.00 sec)	**89I3PL1D** := ________
LDISC 1 CL CONT (SELOGIC)	**89RC3PL1** := ________
LDISC 1 CL BLK (SELOGIC)	**89CB3PL1** := ________
LDISC 1 CL RST (SELOGIC)	**89CR3PL1** := ________
LDISC 1 CL IM RS (SELOGIC)	**89CT3PL1** := ________
LDISC 1 OP CONT (SELOGIC)	**89RO3PL1** := ________
LDISC 1 OP BLK (SELOGIC)	**89OB3PL1** := ________
LDISC 1 OP RST (SELOGIC)	**89OR3PL1** := ________
LDISC 1 OP IM RS (SELOGIC)	**89OT3PL1** := ________
LDISC 2 N/O CONT (SELOGIC)	**89A3PL2** := ________
LDISC 2 N/C CONT (SELOGIC)	**89B3PL2** := ________
LDISC 2 ALM PU CONT (0.00–300.00 sec)	**89A3PL2D** := ________
LDISC 2 SEALIN (0.00–300.00 sec)	**89S3PL2D** := ________
LDISC 2 IMMOBI (0.00–300.00 sec)	**89I3PL2D** := ________
LDISC 2 CL CONT (SELOGIC)	**89RC3PL2** := ________
LDISC 2 CL BLK (SELOGIC)	**89CB3PL2** := ________
LDISC 2 CL RST (SELOGIC)	**89CR3PL2** := ________
LDISC 2 CL IM RS (SELOGIC)	**89CT3PL2** := ________
LDISC 2 OP CONT (SELOGIC)	**89RO3PL2** := ________
LDISC 2 OP BLK (SELOGIC)	**89OB3PL2** := ________

LDISC 2 OP RST (SELOGIC)	**89OR3PL2** := ________
LDISC 2 OP IM RS (SELOGIC)	**89OT3PL2** := ________

Earthing Disconnect Settings

EDISC 1 N/O CONT (SELOGIC)	**89A3PE1** := ________
EDISC 1 N/C CONT (SELOGIC)	**89B3PE1** := ________
EDISC 1 ALM PU CONT (0.00–300.00 sec)	**89A3PE1D** := ________
EDISC 1 SEALIN (0.00–300.00 sec)	**89S3PE1D** := ________
EDISC 1 IMMOBI (0.00–300.00 sec)	**89I3PE1D** := ________
EDISC 1 CL CONT (SELOGIC)	**89RC3PE1** := ________
EDISC 1 CL BLK (SELOGIC)	**89CB3PE1** := ________
EDISC 1 CL RST (SELOGIC)	**89CR3PE1** := ________
EDISC 1 CL IM RS (SELOGIC)	**89CT3PE1** := ________
EDISC 1 OP CONT (SELOGIC)	**89RO3PE1** := ________
EDISC 1 OP BLK (SELOGIC)	**89OB3PE1** := ________
EDISC 1 OP RST (SELOGIC)	**89OR3PE1** := ________
EDISC 1 OP IM RS (SELOGIC)	**89OT3PE1** := ________
EDISC 2 N/O CONT (SELOGIC)	**89A3PE2** := ________
EDISC 2 N/C CONT (SELOGIC)	**89B3PE2** := ________
EDISC 2 ALM PU CONT (0.00–300.00 sec)	**89A3PE2D** := ________
EDISC 2 SEALIN (0.00–300.00 sec)	**89S3PE2D** := ________
EDISC 2 IMMOBI (0.00–300.00 sec)	**89I3PE2D** := ________
EDISC 2 CL CONT (SELOGIC)	**89RC3PE2** := ________
EDISC 2 CL BLK (SELOGIC)	**89CB3PE2** := ________
EDISC 2 CL RST (SELOGIC)	**89CR3PE2** := ________
EDISC 2 CL IM RS (SELOGIC)	**89CT3PE2** := ________
EDISC 2 OP CONT (SELOGIC)	**89RO3PE2** := ________
EDISC 2 OP BLK (SELOGIC)	**89OB3PE2** := ________
EDISC 2 OP RST (SELOGIC)	**89OR3PE2** := ________
EDISC 2 OP IM RS (SELOGIC)	**89OT3PE2** := ________

Control Configuration

ENABLE LOC REM CON (Y, N)	**EN_LRC** := ________
LOCAL CONTROL (SELOGIC)	**LOCAL** := ________

IEC 61850 Mode Control

(Hidden when IEC 61850 is not supported)

CONTROL FOR IEC 61850 BLOCKED MODE (SELOGIC)	**SC850BM** := ________
CONTROL FOR IEC 61850 TEST MODE (SELOGIC)	**SC850TM** := ________

IEC 61850 Simulation Mode

(Hidden when IEC 61850 is not supported)

SELOGIC CONTROL FOR IEC 61850 SIMULATION MODE (SELOGIC)	**SC850SM** := ________

IEC 61850 Local Remote

(Hidden when IEC 61850 is not supported)

SELOGIC CONTROL FOR CONTROL AUTHORITY AT STATION LEVEL (SELOGIC)	**SC850LS** := ________
SELOGIC CONTROL FOR CONTROL AUTHORITY AT LOCAL/BAY LEVEL (SELOGIC)	**LOC** := ________
SELOGIC CONTROL FOR MULTILEVEL MODE OF CONTROL AUTHORITY (SELOGIC)	**MLTLEV** := ________

IEC 61850

(Hidden when IEC 61850 is not supported)

SELOGIC CONTROL FOR BREAKER1 OPEN SUPERVISION (SELOGIC)	**SCBK1BO** := ________
SELOGIC CONTROL FOR BREAKER1 CLOSE SUPERVISION (SELOGIC)	**SCBK1BC** := ________
SELOGIC CONTROL FOR BREAKER2 OPEN SUPERVISION (SELOGIC)	**SCBK2BO** := ________
SELOGIC CONTROL FOR BREAKER2 CLOSE SUPERVISION (SELOGIC)	**SCBK2BC** := ________
SELOGIC CONTROL FOR BREAKER3 OPEN SUPERVISION (SELOGIC)	**SCBK3BO** := ________
SELOGIC CONTROL FOR BREAKER3 CLOSE SUPERVISION (SELOGIC)	**SCBK3BC** := ________
SELOGIC CONTROL FOR BREAKER4 OPEN SUPERVISION (SELOGIC)	**SCBK4BO** := ________
SELOGIC CONTROL FOR BREAKER4 CLOSE SUPERVISION (SELOGIC)	**SCBK4BC** := ________

SET PORT p (p = F, 1, 2, 3, or 4) Command

Port F

ENABLE PORT (Y, N)	**EPORT** := ____________
PROTOCOL (SEL, MOD, EVMSG, PMU)	**PROTO** := ____________
MAXIMUM ACCESS LEVEL (1, 2, C)	**MAXACC** := ____________

Communications

SPEED (300, 1200, 2400, 4800, 9600, 19200, 38400 bps)	**SPEED** := ____________
DATA BITS (7, 8 bits) *(Hidden if PROTO := MOD, EVMSG, or PMU)*	**BITS** := ____________
PARITY (O, E, N) *(Hidden if PROTO := EVMSG or PMU)*	**PARITY** := ____________
STOP BITS (1, 2 bits) *(Hidden if PROTO := MOD or EVMSG)*	**STOP** := ____________
PORT TIME-OUT (0–30 min) *(Hidden and forced to 0 if PROTO := MOD, EVMSG, or PMU)*	**T_OUT** := ____________
HDWR HANDSHAKING (Y, N) *(Hidden if PROTO := MOD or EVMSG)*	**RTSCTS** := ____________

SEL Protocol

LANGUAGE (ENGLISH, SPANISH)	**LANG** := ____________
SEND AUTOMESSAGE (Y, N) *(Hidden and forced to N if PROTO := MOD, EVMSG, or PMU)*	**AUTO** := ____________

Modbus Protocol

MODBUS SLAVE ID (1–247) *(Hidden if PROTO := SEL, EVMSG, or PMU)*	**SLAVEID** := ____________

Port 1

(Ethernet Port in Slot B; all Ethernet settings are hidden if an Ethernet option is not available; IP addresses are entered using zzz = 1–126, 128–223; yyy = 0–255; xxx = 0–255; www = 0–255)

ENABLE PORT (Y, N)	**EPORT** := ____________
ENABLE ETHERNET FIRMWARE UPGRADE (Y, N)	**EETHFWU** := ____________
IP ADDRESS (zzz.yyy.xxx.www) (15 characters)	**IPADDR** := ____________
SUBNET MASK (zzz.yyy.xxx.www) (15 characters)	**SUBNETM** := ____________
DEFAULT ROUTER (zzz.yyy.xxx.www) (15 characters) *(NOTE: Settings DEFRTR := 0.0.0.0 disables the default router)*	**DEFRTR** := ____________
ENABLE TCP KEEP-ALIVE (Y, N)	**ETCPKA** := ____________

TCP KEEP-ALIVE IDLE RANGE (1–20 sec) *(Hidden if ETCPKA := N; KAIDLE ≥ KAINTV)*	**KAIDLE** := ____________
TCP KEEP-ALIVE INTERVAL RANGE (1–20 sec) *(Hidden if ETCPKA := N; KAIDLE ≥ KAINTV)*	**KAINTV** := ____________
TCP KEEP-ALIVE COUNT RANGE (1–20) *(Hidden if ETCPKA := N)*	**KACNT** := ____________
OPERATING MODE (FIXED, FAILOVER, SWITCHED, PRP) *(Hidden when the dual redundant Ethernet port option is not included)*	**NETMODE** := ____________
FAILOVER TIMEOUT (OFF, 0.10–65.00 sec) *(Hidden when the dual redundant Ethernet port option is not included or if NETMODE ≠ FAILOVER)*	**FTIME** := ____________
PRIMARY NETPORT (A, B) *(Hidden when the dual redundant Ethernet port option is not included)*	**NETPORT** := ____________
PRP ENTRY TIMEOUT (400–10000 ms) *(Hidden when the dual redundant Ethernet port option is not included or if NETMODE ≠ PRP)*	**PRPTOUT** := ____________
PRP DESTINATION ADDR LSB (0–255) *(Hidden when the dual redundant Ethernet port option is not included or if NETMODE ≠ PRP)*	**PRPADDR** := ____________
PRP SUPERVISION TX INTERVAL (1–10 sec) *(Hidden when the dual redundant Ethernet port option is not included or if NETMODE ≠ PRP)*	**PRPINTV** := ____________
NETWRK PORTA SPD (AUTO, 10, 100 Mbps) *(Hidden when the dual redundant Ethernet port option is not included)*	**NETASPD** := ____________
NETWRK PORTB SPD (AUTO, 10, 100 Mbps) *(Hidden when the dual redundant Ethernet port option is not included)*	**NETBSPD** := ____________
ENABLE TELNET (Y, N)	**ETELNET** := ____________
MAXIMUM ACCESS LEVEL (1, 2, C)	**MAXACC** := ____________
LANGUAGE (ENGLISH, SPANISH)	**LANG** := ____________
TELNET PORT (23, 1025–65534) *(NOTE: See Table SET.3 and the note at the end of Port 1 settings)*	**TPORT** := ____________
TELNET CONNECT BANNER (254 characters)	**TCBAN** := ____________
TELNET TIME-OUT (1–30 min)	**TIDLE** := ____________
FAST OP MESSAGES (Y, N) *Note: The FAST OP MESSAGES setting only functions when using SEL Fast Operate protocol to operate/set/pulse breaker bits and remote bits. This setting has no effect on the other protocols.*	**FASTOP** := ____________
ENABLE FTP (Y, N)	**EFTPSERV** := ____________
FTP MAXIMUM ACCESS LEVEL (1, 2 C)	**FTPACC** := ____________
FTP USER NAME (20 Characters)	**FTPUSER** := ____________
FTP CONNECT BANNER (254 characters)	**FTPCBAN** := ____________

FTP IDLE TIME-OUT (5–255 min) **FTPIDLE** := ____________________

ENABLE IEC 61850 PROTOCOL (Y, N) **E61850** := ____________________
(Hidden when IEC 61850 is not supported)

ENABLE IEC 61850 GSE (Y, N) **EGSE** := ____________________
(Hidden and forced to N if E61850 := N)

ENABLE MMS FILE SERVICES (Y, N) **EMMSFS** := ____________________

ENABLE 61850 MODE/BEHAVIOR CONTROL (Y, N) **E850MBC** := ____________________

ENABLE GOOSE TX IN OFF MODE (Y, N) **EOFFMTX** := ____________________

ENABLE MODBUS SESSIONS (0–2) **EMOD** := ____________________

MODBUS MASTER IP ADDRESS (zzz.yyy.xxx.www) **MODIP1** := ____________________
(Hidden if EMOD := 0)

MODBUS MASTER IP ADDRESS (zzz.yyy.xxx.www) **MODIP2** := ____________________
(Hidden if EMOD := 0 or 1)

NOTE: MODIP1 and MODIP2 cannot share an address and must be unique (except when 0.0.0.0, which effectively disables security and allows any master to communicate).

MODBUS TCP PORT1 (1–65534)* **MODNUM1** := ____________________
(Hidden if EMOD := 0)
(NOTE: See Table SET.3 and the note at the end of Port 1 settings)

MODBUS TCP PORT2 (1–65534)* **MODNUM2** := ____________________
(Hidden if EMOD := 0 or 1)
(NOTE: See Table SET.3 and the note at the end of Port 1 settings)

MODBUS TIMEOUT 1 (15–900 sec) **MTIMEO1** := ____________________
(Hidden if EMOD := 0)

MODBUS TIMEOUT 2 (15–900 sec) **MTIMEO2** := ____________________
(Hidden if EMOD := 0 or 1)

ENABLE HTTP SERVER (Y, N) **EHTTP** := ____________________

HTTP MAXIMUM ACCESS LEVEL (1, 2) **HTTPACC** := ____________________
(Hidden if EHTTP := N)

HTTP SERVER TCP/IP PORT NUMBER (1–65534) **HTTPPORT** := ____________________
(Hidden if EHTTP := N)
(See Table SET.3 and the note at the end of Port 1 settings.)

HTTP CONNECT BANNER (254 ASCII printable characters) **HTTPBAN** := ____________________
(Hidden if EHTTP := N)

HTTP WEB SERVER TIMEOUT (1–60 min) **HTTPIDLE** := ____________________
(Hidden if EHTTP := N)

ENABLE RSTP (Y, N) **ERSTP** := ____________________
(Hidden when the dual redundant Ethernet port option is not included or if NETMODE ≠ SWITCHED)

BRIDGE PRIORITY (0–61440) **BRDGPRI** := ____________________
(Hidden if ERSTP := N; input must be set in increments of 4096)

PORTA PRIORITY (0–240) **PORTAPRI** := ____________________
(Hidden if ERSTP := N; input must be set in increments of 16)

PORTB PRIORITY (0–240) **PORTBPRI** := ____________________
(Hidden if ERSTP := N; input must be set in increments of 16)

SEL Synchrophasor Protocol Settings

(The following synchrophasor protocol settings are hidden if the Global setting EPMU := N)

Enable PMU Processing (0–2) **EPMIP** := ____________________

PMU OUTPUT 1 TRANSPORT SCHEME (OFF, TCP, UDP_S, UDP_T, UDP_U) **PMOTS1** := ____________________
(Hidden if EPMIP := 0)

PMU Output 1 Client IP Address [zzz.yyy.xxx.www] (15 characters) **PMOIPA1** := ____________________
(Hidden if PMOTS1 := OFF) (PMOIPA1 cannot be set to the same address as IPADDR. IP address 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.)

PMU Output 1 TCP/IP Port Number (1–65534) **PMOTCP1** := ____________________
(Shown only when EPMIP is not equal to 0 and PMOTS1 is not equal to UDP_S; PMOTCP1 cannot be set to the same number as PMOTCP2)
(See Table SET.3 and the note at the end of Port 1 settings.)

PMU Output 1 UDP/IP Data Port Number (1–65534) **PMOUDP1** := ____________________
(Shown only when EPMIP is not equal to 0 and PMOTS1 is not equal to TCP)

PMU Output 2 Transport Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U) **PMOTS2** := ____________________
(Hidden if EPMIP := 0 or 1)

PMU Output 2 Client IP Address (zzz.yyy.xxx.www) (15 characters) **PMOIPA2** := ____________________
(Hidden if PMOTS2 := OFF) (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.)

PMU Output 2 TCP/IP Port Number (1–65534) **PMOTCP2** := ____________________
(Shown only when EPMIP := 2 and PMOTS2 is not equal to UDP_S; PMOTCP2 cannot be set to the same number as PMOTCP1)
(See Table SET.3 and the note at the end of Port 1 settings.)

PMU Output 2 UDP/IP Data Port Number (1–65534) **PMOUDP2** := ____________________
(Shown only when EPMIP = 2 and PMOTS2 is not equal to TCP)

DNP3 Protocol

(The following DNP3 settings are hidden if DNP3 is not an option)

Enable DNP3 Sessions (0–5) **EDNP** := ____________________
(The following DNP3 settings are hidden if EDNP := 0)

DNP TCP and UDP Port (1–65534) **DNPNUM** := ____________________
(NOTE: See Table SET.3 and the note at the end of Port 1 settings)

DNP Address (0–65519) **DNPADR** := ____________________

Session 1

(NOTE: The DNP IP address of each session (DNPIP1, DNPIP2, etc.) must be unique.)

DNP Master IP Address {zzz.yyy.xxx.www} (15 Characters) **DNPIP1** := ____________________

Transport Protocol (UDP, TCP) **DNPTR1** := ____________________

UDP Response Port (REQ, 1–65534)	**DNPUDP1** := ________
DNP Address to Report to (0–65519)	**REPADR1** := ________
DNP Map (1–3)	**DNPMAP1** := ________
Analog Input Default Variation (1–6) *(Only applies to objects 30 and 32)*	**DVARAI1** := ________
Class for Binary Event Data (0–3)	**ECLASSB1** := ________
Class for Counter Event Data (0–3)	**ECLASSC1** := ________
Class for Analog Event Data (0–3)	**ECLASSA1** := ________
Currents Scaling Decimal Places (0–3)	**DECPLA1** := ________
Voltages Scaling Decimal Places (0–3)	**DECPLV1** := ________
Misc Data Scaling Decimal Places (0–3)	**DECPLM1** := ________
Amps Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0)*	**ANADBA1** := ________
Volts Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0)*	**ANADBV1** := ________
Misc Data Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0 and ECLASSC1 := 0)*	**ANADBM1** := ________
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ1** := ________
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO1** := ________
Seconds to send Data Link Heartbeat (0–7200) *(Hidden if DNPTR1 := UDP)*	**DNPINA1** := ________
Event Message Confirm Time-Out (1–50 sec)	**ETIMEO1** := ________
Enable Unsolicited Reporting (Y, N) *(Hidden and forced to N if ECLASSA1 := 0, ECLASSB1 := 0, and ECLASSC1 := 0)* *(All subsequent settings are hidden and forced to N if UNSOL1 := N)*	**UNSOL1** := ________
Enable Unsolicited Reporting at Power-Up (Y, N)	**PUNSOL1** := ________
Number of Events to Transmit On (1–200)	**NUMEVE1** := ________
Oldest Event to Tx On (0.0–99999.0 sec)	**AGEEVE1** := ________
Unsolicited Message Max Retry Attempts (2–10)	**URETRY1** := ________
Unsolicited Message Offline Time-Out (1–5000 sec)	**UTIMEO1** := ________

Session 2

(All Session 2 settings are hidden if EDNP < 2)

DNP Master IP Address {zzz.yyy.xxx.www} (15 Characters)	**DNPIP2** := ________
Transport Protocol (UDP, TCP)	**DNPTR2** := ________

UDP Response Port (REQ, 1–65534)	**DNPUDP2** := ________
DNP Address to Report to (0–65519)	**REPADR2** := ________
DNP Map (1–3)	**DNPMAP2** := ________
Analog Input Default Variation (1–6)	**DVARAI2** := ________
Class for Binary Event Data (0–3)	**ECLASSB2** := ________
Class for Counter Event Data (0–3)	**ECLASSC2** := ________
Class for Analog Even Data (0–3)	**ECLASSA2** := ________
Currents Scaling Decimal Places (0–3)	**DECPLA2** := ________
Voltages Scaling Decimal Places (0–3)	**DECPLV2** := ________
Misc Data Scaling Decimal Places (0–3)	**DECPLM2** := ________
Amps Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA2 := 0)*	**ANADBA2** := ________
Volts Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA2 := 0)*	**ANADBV2** := ________
Misc Data Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA2 := 0 and ECLASSC2 := 0)*	**ANADBM2** := ________
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ2** := ________
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO2** := ________
Seconds to send Data Link Heartbeat (0–7200) *(Hidden if DNPTR2 := UDP)*	**DNPINA2** := ________
Event Message Confirm Time-Out (1–50 sec)	**ETIMEO2** := ________
Enable Unsolicited Reporting (Y, N) *(Hidden and forced to N if ECLASSA2 := 0, ECLASSB2 := 0, ECLASSC2 := 0, and ECLASSV2 := 0)* *(All subsequent settings are hidden and forced to N if UNSOL2 := N)*	**UNSOL2** := ________
Enable Unsolicited Reporting at Power-Up (Y, N)	**PUNSOL2** := ________
Number of Event to Transmit On (1–200)	**NUMEVE2** := ________
Oldest Even to Tx On (0.0–99999.0 sec)	**AGEEVE2** := ________
Unsolicited Message Max Retry Attempts (2–10)	**URETRY2** := ________
Unsolicited Message Offline Time-Out (1–5000 sec)	**UTIMEO2** := ________

Session 3

(All Session 3 settings are hidden if EDNP < 3)

DNP Master IP Address {zzz.yyy.xxx.www} (15 Characters)	**DNPIP3** := ________
Transport Protocol (UDP, TCP)	**DNPTR3** := ________
UDP Response Port (REQ, 1–65534)	**DNPUDP3** := ________

DNP Address to Report to (0–65519)	**REPADR3** := ____________
DNP Map (1–3)	**DNPMAP3** := ____________
Analog Input Default Variation (1–6)	**DVARAI3** := ____________
Class for Binary Event Data (0–3)	**ECLASSB3** := ____________
Class for Counter Event Data (0–3)	**ECLASSC3** := ____________
Class for Analog Even Data (0–3)	**ECLASSA3** := ____________
Currents Scaling Decimal Places (0–3)	**DECPLA3** := ____________
Voltages Scaling Decimal Places (0–3)	**DECPLV3** := ____________
Misc Data Scaling Decimal Places (0–3)	**DECPLM3** := ____________
Amps Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA3 := 0)*	**ANADBA3** := ____________
Volts Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA3 := 0)*	**ANADBV3** := ____________
Misc Data Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA3 := 0 and ECLASSC3 := 0)*	**ANADBM3** := ____________
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ3** := ____________
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO3** := ____________
Seconds to Send Data Link Heartbeat (0–7200) *(Hidden if DNPTR3 := UDP)*	**DNPINA3** := ____________
Event Message Confirm Time-Out (1–50 sec)	**ETIMEO3** := ____________
Enable Unsolicited Reporting (Y, N) *(Hidden and forced to N if ECLASSA3 := 0, ECLASSB3 := 0, ECLASSC3 := 0, and ECLASSV3 := 0)* *(All subsequent settings are hidden and forced to N if UNSOL3 := N)*	**UNSOL3** := ____________
Enable Unsolicited Reporting at Power-Up (Y, N)	**PUNSOL3** := ____________
Number of Event to Transmit On (1–200)	**NUMEVE3** := ____________
Oldest Event to Tx On (0.0–99999.0 sec)	**AGEEVE3** := ____________
Unsolicited Message Max Retry Attempts (2–10)	**URETRY3** := ____________
Unsolicited Message Offline Time-Out (1–5000 sec)	**UTIMEO3** := ____________

Session 4

(All Session 4 settings are hidden if EDNP < 4)

DNP Master IP Address {zzz.yyy.xxx.www} (15 Characters)	**DNPIP4** := ____________
Transport Protocol (UDP, TCP)	**DNPTR4** := ____________
UDP Response Port (REQ, 1–65534)	**DNPUDP4** := ____________
DNP Address to Report to (0–65519)	**REPADR4** := ____________

DNP Map (1–3)	**DNPMAP4** := ____________
Analog Input Default Variation (1–6)	**DVARAI4** := ____________
Class for Binary Event Data (0–3)	**ECLASSB4** := ____________
Class for Counter Event Data (0–3)	**ECLASSC4** := ____________
Class for Analog Even Data (0–3)	**ECLASSA4** := ____________
Currents Scaling Decimal Places (0–3)	**DECPLA4** := ____________
Voltages Scaling Decimal Places (0–3)	**DECPLV4** := ____________
Misc Data Scaling Decimal Places (0–3)	**DECPLM4** := ____________
Amps Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA4 := 0)*	**ANADBA4** := ____________
Volts Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA4 := 0)*	**ANADBV4** := ____________
Misc Data Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA4 := 0 and ECLASSC4 := 0)*	**ANADBM4** := ____________
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ4** := ____________
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO4** := ____________
Seconds to Send Data Link Heartbeat (0–7200) *(Hidden if DNPTR4 := UDP)*	**DNPINA4** := ____________
Event Message Confirm Time-Out (1–50 sec)	**ETIMEO4** := ____________
Enable Unsolicited Reporting (Y, N) *(Hidden and forced to N if ECLASSA4 := 0, ECLASSB4 := 0, ECLASSC4 := 0, and ECLASSV4 := 0)* *(All subsequent settings are hidden and forced to N if UNSOL4 := N)*	**UNSOL4** := ____________
Enable Unsolicited Reporting at Power-Up (Y, N)	**PUNSOL4** := ____________
Number of Event to Transmit On (1–200)	**NUMEVE4** := ____________
Oldest Event to Tx On (0.0–99999.0 sec)	**AGEEVE4** := ____________
Unsolicited Message Max Retry Attempts (2–10)	**URETRY4** := ____________
Unsolicited Message Offline Time-Out (1–5000 sec)	**UTIMEO4** := ____________

Session 5

(All Session 5 settings are hidden if EDNP < 5)

DNP Master IP Address {zzz.yyy.xxx.www} (15 Characters)	**DNPIP5** := ____________
Transport Protocol (UDP, TCP)	**DNPTR5** := ____________
UDP Response Port (REQ, 1–65534)	**DNPUDP5** := ____________
DNP Address to Report to (0–65519)	**REPADR5** := ____________
DNP Map (1–3)	**DNPMAP5** := ____________

Analog Input Default Variation (1–6)	**DVARAI5** := ____________
Class for Binary Event Data (0–3)	**ECLASSB5** := ____________
Class for Counter Event Data (0–3)	**ECLASSC5** := ____________
Class for Analog Even Data (0–3)	**ECLASSA5** := ____________
Currents Scaling Decimal Places (0–3)	**DECPLA5** := ____________
Voltages Scaling Decimal Places (0–3)	**DECPLV5** := ____________
Misc Data Scaling Decimal Places (0–3)	**DECPLM5** := ____________
Amps Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA5 := 0)*	**ANADBA5** := ____________
Volts Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA5 := 0)*	**ANADBV5** := ____________
Misc Data Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA5 := 0 and ECLASSC5 := 0)*	**ANADBM5** := ____________
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ5** := ____________
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO5** := ____________
Seconds to Send Data Link Heartbeat (0–7200) *(Hidden if DNPTR5 := UDP)*	**DNPINA5** := ____________
Event Message Confirm Time-Out (1–50 sec)	**ETIMEO5** := ____________
Enable Unsolicited Reporting (Y, N) *(Hidden and forced to N if ECLASSA5 := 0, ECLASSB5 := 0, ECLASSC5 := 0, and ECLASSV5 := 0)* *(All subsequent settings are hidden and forced to N if UNSOL5 := N)*	**UNSOL5** := ____________
Enable Unsolicited Reporting at Power-Up (Y, N)	**PUNSOL5** := ____________
Number of Event to Transmit On (1–200)	**NUMEVE5** := ____________
Oldest Event to Tx On (0.0–99999.0 sec)	**AGEEVE5** := ____________
Unsolicited Message Max Retry Attempts (2–10)	**URETRY5** := ____________
Unsolicited Message Offline Time-Out (1–5000 sec)	**UTIMEO5** := ____________

SNTP Client Protocol Settings

Enable SNTP Client (OFF, UNICAST, MANYCAST, BROADCAST) *(All subsequent category settings are hidden if ESNTP := OFF)*	**ESNTP** := ____________

Make the following settings when ESNTP ≠ MANYCAST

Primary Server IP Address (zzz.yyy.xxx.www) *(NOTE: To accept updates from any server when ESNTP := BROADCAST, set SNTPPSIP to 0.0.0.0.* *NOTE: Only IP addresses in the range 224.0.0.1 through 239.255.255.255 are valid when ESNTP = MANYCAST.)*	**SNTPPSIP** := ____________

Make the following setting when ESNTP := UNICAST

Backup Server IP Address (zzz.yyy.xxx.www) *(Hidden if ESNTP ≠ UNICAST)*	**SNTPBSIP** := ______________
SNTP IP (Local) Port Number (1–65534) *(NOTE: See Table SET.3 and the note at the end of Port 1 settings.)*	**SNTPPORT** := ______________
SNTP Update Rate (15–3600 sec)	**SNTPRATE** := ______________

Make the following setting when ESNTP := UNICAST or MANYCAST

SNTP Timeout (5–20 sec) *(Hidden and forced to 5 if ESNTP := BROADCAST NOTE: SNTPTO must be less than setting SNTPRATE.)*	**SNTPTO** := ______________

PTP Settings

ENABLE PTP (Y, N) *(All subsequent category settings are hidden if EPTP := N)* *(Hidden and forced to N if NETMODE := SWITCHED)*	**EPTP** := ______________
PTP PROFILE (DEFAULT, C37.238) *(Hidden and forced to C37.238 if NETMODE := PRP)*	**PTPPRO** := ______________
PTP TRANSPORT MECHANISM (UDP, LAYER2) *(Hidden and forced to LAYER2 if PTPPRO := C37.238 or if NETMODE := PRP)*	**PTPTR** := ______________
PTP DOMAIN NUMBER (0–255)	**DOMNUM** := ______________
PTP PATH DELAY MECHANISM (P2P, E2E, OFF) *(Hidden and forced to P2P if PTPPRO := C37.238 or if NETMODE := PRP)*	**PTHDLY** := ______________
PEER DELAY REQUEST INTERVAL (1, 2, 4, 8, 16, 32, 64 seconds) *(Hidden if PTHDLY ≠ P2P, PTPPRO ≠ C37.238, and NETMODE ≠ PRP)*	**PDINT** := ______________
PTP NUMBER OF ACCEPTABLE MASTERS (OFF, 1–5)	**AMNUM** := ______________
PTP ACCEPTABLE MASTER *n* IP (zzz.yyy.xxx.www) *(Hidden if n > AMNUM, AMNUM := OFF, PTPTR := LAYER2, NETMODE := PRP, or PTPPRO := C37.238)*	**AMIP*n*** := ______________
PTP ACCEPTABLE MASTER *n* MAC (xx:xx:xx:xx:xx:xx) *(Hidden if AMNUM := OFF or if NETMODE ≠ PRP and if PTPTR ≠ LAYER2 and if PTPPRO ≠ C37.238)*	**AMMAC*n*** := ______________
PTP ALTERNATE PRIORITY1 FOR MASTER *n* (0–255) *(Hidden if n > AMNUM or if AMNUM := OFF)*	**ALTPRI*n*** := ______________
PTP VLAN IDENTIFIER (1–4094) *(Hidden if NETMODE ≠ PRP and PTPPRO ≠ C37.238)*	**PVLAN** := ______________
PTP VLAN PRIORITY (0–7) *(Hidden if NETMODE ≠ PRP and PTPPRO ≠ C37.238)*	**PVLANPR** := ______________

EtherNet/IP Settings

ENABLE ETHERNET IP (Y, N)	**EEIP** := ______________
CONFIGURATION ID (0–255)	**CONFIGID** := ______________

MAJOR EDS REVISION (1–255) **MAJOREDS** := ________________

MINOR EDS REVISION (1–255) **MINOREDS** := ________________

NUMBER OF IP ADDRESSES FOR EIP SCANNER (OFF, 1–8) **NUMIP** := ________________
(OFF allows anonymous clients)

IP ADDRESS (zzz.yyy.xxx.www) **EIPIP*n*** := ________________
(Hidden if NUMIP := OFF; n > NUMIP)
(Note: EIPIPn settings shall not be equal to the value of IPADDR setting. EIPIP1, EIPIP2, EIPIP3, ..., EIPIP8 must be unique.)

NUMBER OF IO CONNECTIONS (1–6) **NUMCONN** := ________________

APPLICATION TYPE (EXCLUSIVE_OWNER, INPUT_ONLY) **APPTYP*n*** := ________________
(Note: At most 3 exclusive owner types shall be allowed.)

INPUT ASSEMBLY (IA1, IA2, IA3, OA1, OA2, OA3) **INASSM*n*** := ________________

OUTPUT ASSEMBLY (OA1, OA2, OA3) **OUTASSM*n*** := ________________
(Hidden if APPTYPn := INPUT_ONLY)

Port Number Settings Must be Unique

When making the SEL-787 Port 1 settings, port number settings cannot be used for more than one protocol. The relay checks all of the settings shown in *Table SET.3* before saving changes. If a port number is used more than once, or if it matches any of the fixed port numbers (20, 21, 23, 102, 502), the relay displays an error message and returns to the first setting that is in error or contains a duplicate value.

Table SET.3 Port Number Settings That Must be Unique

Setting	Name	Setting Required When
TPORT	Telnet Port	Always
MODNUM1[a]	Modbus TCP Port 1	EMOD > 0
MODNUM2[a]	Modbus TCP Port 2	EMOD > 1
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
DNPNUM	DNPTCP and UDP Port	EDNP > 0
SNTPPORT	SNTPIP (Local) Port Number	ESNTP ≠ OFF
EPTP	Enable PTP	PTPPRO = DEFAULT and PTPTR = UDP (Ports 319 and 320 are reserved)
EEIP	Enable EtherNet/IP	EEIP ≠ N (Ports 2222 and 44818 are reserved)

[a] MODNUM1 and MODNUM2 can have the same port number. The relay displays an error message if this number matches with the port numbers of the other protocols.

Port 2

(Fiber-optic serial port in Slot B; the following settings are autoset and hidden if E49RTD := EXT)

ENABLE PORT (Y, N)	**EPORT** := ________
PROTOCOL (SEL, DNP, MOD, EVMSG, PMU, MBA, MBB, MB8A, MB8B, MBTA, MBTB, 103)	**PROTO** := ________
MAXIMUM ACCESS LEVEL (1, 2, C)	**MAXACC** := ________

Communications

SPEED (300, 1200, 2400, 4800, 9600, 19200, 38400 bps)	**SPEED** := ________
DATA BITS (7, 8 bits) *(Hidden if PROTO := MOD, DNP, PMU, EVMSG, 103, or MB_)*	**BITS** := ________
PARITY (O, E, N) *(Hidden if PROTO := EVMSG, PMU, or MB_)*	**PARITY** := ________
STOP BITS (1, 2 bits) *(Hidden if PROTO := MOD, EVMSG, or MB_)*	**STOP** := ________
PORT TIME-OUT (0–30 min) *(Hidden and forced to 0 if PROTO := MOD, EVMSG, PMU, 103, or MB_)*	**T_OUT** := ________
HDWR HANDSHAKING (Y, N) *(Hidden and forced to N if PROTO := MOD, EVMSG, DNP, SEL, or MB_)*	**RTSCTS** := ________
LANGUAGE (ENGLISH, SPANISH)	**LANG** := ________
SEND AUTOMESSAGE (Y, N) *(Hidden and forced to N if PROTO := MOD, DNP, PMU, EVMSG, 103, or MB_)*	**AUTO** := ________
FAST OP MESSAGES (Y, N) *(Hidden if PROTO := MOD, EVMSG, DNP, PMU, 103, or MB_)*	**FASTOP** := ________

Modbus

MODBUS SLAVE ID (1–247) *(Hidden if PROTO := SEL, EVMSG, MB_, 103, or DNP)*	**SLAVEID** := ________

DNP3 Protocol

(Hidden if PROTO := SEL, EVMSG, MB, PMU, 103, or MOD)

DNP Address (0–65519)	**DNPADR** := ________
DNP Address to Report to (0–65519)	**REPADR1** := ________
DNP Map (1–3)	**DNPMAP1** := ________
Analog Input Default Variation (1–6)	**DVARAI1** := ________
Class for Binary Event Data (0–3)	**ECLASSB1** := ________
Class for Counter Event Data (0–3)	**ECLASSC1** := ________
Class for Analog Event Data (0–3)	**ECLASSA1** := ________
Current Scaling Decimal Places (0–3)	**DECPLA1** := ________

Voltages Scaling Decimal Places (0–3)	**DECPLV1** := ________
Misc Data Scaling Decimal Places (0–3)	**DECPLM1** := ________
Amps Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0)*	**ANADBA1** := ________
Volts Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0)*	**ANADBV1** := ________
Misc Data Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0 and ECLASSC1 := 0*	**ANADBM1** := ________
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ1** := ________
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO1** := ________
Data Link Retries (0–51)	**DRETRY1** := ________
Seconds to Data Link Time-Out (0–5 sec) *(Hidden if DRETRY1 := 0)*	**DTIMEO1** := ________
Event Message Confirm Time-Out (1–50 sec)	**ETIMEO1** := ________
Enable Unsolicited Reporting (Y, N) *(Hidden and forced to N if ECLASSA1 := 0, ECLASSB1 := 0, and ECLASSC1 := 0)* *(All subsequent settings are hidden and forced to N if UNSOL1 := N)*	**UNSOL1** := ________
Enable Unsolicited Reporting at Power-Up (Y, N)	**PUNSOL1** := ________
Number of Events to Transmit On (1–200)	**NUMEVE1** := ________
Oldest Event to Tx On (0.0–99999.0 sec)	**AGEEVE1** := ________
Unsolicited Message Max Retry Attempts (2–10)	**URETRY1** := ________
Unsolicited Message Offline Time-Out (1–5000 sec)	**UTIMEO1** := ________

MIRRORED BITS Protocol

(All subsequent settings are hidden if PROTO := SEL, DNP, PMU, EVMSG, 103, or MOD)

MB Transmit Identifier (1–4)	**TXID** := ________
MB Receive Identifier (1–4)	**RXID** := ________
MB RX Bad Pickup Time (0–10000 sec)	**RBADPU** := ________
MB Channel Bad Pickup (1–10000 ppm)	**CBADPU** := ________
MB Receive Default State (8 Characters)	**RXDFLT** := ________
RMB1 Pickup Debounce Messages (1–8)	**RMB1PU** := ________
RMB1 Dropout Debounce Messages (1–8)	**RMB1DO** := ________
RMB2 Pickup Debounce Messages (1–8)	**RMB2PU** := ________
RMB2 Dropout Debounce Messages (1–8)	**RMB2DO** := ________
RMB3 Pickup Debounce Messages (1–8)	**RMB3PU** := ________

RMB3 Dropout Debounce Messages (1–8)	**RMB3DO** := ____________
RMB4 Pickup Debounce Messages (1–8)	**RMB4PU** := ____________
RMB4 Dropout Debounce Messages (1–8)	**RMB4DO** := ____________
RMB5 Pickup Debounce Messages (1–8)	**RMB5PU** := ____________
RMB5 Dropout Debounce Messages (1–8)	**RMB5DO** := ____________
RMB6 Pickup Debounce Messages (1–8)	**RMB6PU** := ____________
RMB6 Dropout Debounce Messages (1–8)	**RMB6DO** := ____________
RMB7 Pickup Debounce Messages (1–8)	**RMB7PU** := ____________
RMB7 Dropout Debounce Messages (1–8)	**RMB7DO** := ____________
RMB8 Pickup Debounce Messages (1–8)	**RMB8PU** := ____________
RMB8 Dropout Debounce Messages (1–8)	**RMB8DO** := ____________

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(Hidden unless serial port with PROTO := 103)

103 DEVICE ADDRESS (0–254)	**103ADDR** := ____________
CYCLIC DATA REPORTING PERIOD (1–3600 sec)	**103CYC** := ____________
ACCUMULATOR REPORTING PERIOD (OFF, 1–3600 sec)	**103ACYC** := ____________
ACCUMULATOR REPORTING TRIGGER (1 Relay Word Bit)	**103ATRI** := ____________
ENABLE TIME SYNCHRONIZATION (Y, N)	**103TIME** := ____________

Port 3

(EIA-232 or EIA-485 Port in Slot B)

ENABLE PORT (Y, N)	**EPORT** := ____________
PROTOCOL (SEL, DNP, MOD, EVMSG, PMU, MBA, MBB, MB8A, MB8B, MBTA, MBTB, 103)	**PROTO** := ____________
MAXIMUM ACCESS LEVEL (1, 2, C)	**MAXACC** := ____________

Communications

SPEED (300, 1200, 2400, 4800, 9600, 19200, 38400 bps)	**SPEED** := ____________
DATA BITS (7, 8 bits) *(Hidden if PROTO := MOD, DNP, PMU, EVMSG, 103, or MB_)*	**BITS** := ____________
PARITY (O, E, N) *(Hidden if PROTO := EVMSG, PMU, or MB_)*	**PARITY** := ____________
STOP BITS (1, 2 bits) *(Hidden if PROTO := MOD, EVMSG, or MB_)*	**STOP** := ____________
PORT TIME-OUT (0–30 min) *(Hidden and forced to 0 if PROTO := MOD, PMU, EVMSG, 103, or MB_)*	**T_OUT** := ____________

HDWR HANDSHAKING (Y, N) **RTSCTS** := ______________
(Hidden and forced to N if EIA-485 Port or PROTO := MOD, DNP, EVMSG, or MB_)

LANGUAGE (ENGLISH, SPANISH) **LANG** := ______________

SEND AUTOMESSAGE (Y, N) **AUTO** := ______________
(Hidden and forced to N if PROTO := MOD, DNP, PMU, EVMSG, 103, or MB_)

FAST OP MESSAGES (Y, N) **FASTOP** := ______________
(Hidden if PROTO := MOD, DNP, PMU, EVMSG, 103, or MB_)

MINIMUM SECONDS FROM DCD TO TX (0.00–1.00 sec) **MINDLY** := ______________
(Hidden if PROTO ≠ DNP)

MAXIMUM SECONDS FROM DCD TO TX (0.0–1.00 sec) **MAXDLY** := ______________
(Hidden if PROTO ≠ DNP)

SETTLE TIME FROM RTS ON TO TX (OFF, 0.00–30.00 sec) **PREDLY** := ______________
(Hidden if PROTO ≠ DNP or 103)

SETTLE TIME FROM TX TO RTD OFF (0.00–30.00 sec) **PSTDLY** := ______________
(Hidden if PROTO ≠ DNP or 103)

Modbus

MODBUS SLAVE ID (1–247) **SLAVEID** := ______________
(Hidden if PROTO := SEL, EVMSG, 103, DNP, or MB_)

DNP3 Protocol

(Hidden if PROTO := SEL, EVMSG, MB, PMU, 103, or MOD)

DNP Address (0–65519) **DNPADR** := ______________

DNP Address to Report to (0–65519) **REPADR1** := ______________

DNP Map (1–3) **DNPMAP1** := ______________

Analog Input Default Variation (1–6) **DVARAI1** := ______________

Class for Binary Event Data (0–3) **ECLASSB1** := ______________

Class for Counter Event Data (0–3) **ECLASSC1** := ______________

Class for Analog Event Data (0–3) **ECLASSA1** := ______________

Current Scaling Decimal Places (0–3) **DECPLA1** := ______________

Voltages Scaling Decimal Places (0–3) **DECPLV1** := ______________

Misc Data Scaling Decimal Places (0–3) **DECPLM1** := ______________

Amps Reporting Deadband Counts (0–32767) **ANADBA1** := ______________
(Hidden if ECLASSA1 := 0)

Volts Reporting Deadband Counts (0–32767) **ANADBV1** := ______________
(Hidden if ECLASSA1 := 0)

Misc Data Reporting Deadband Counts (0–32767) **ANADBM1** := ______________
(Hidden if ECLASSA1 := 0 and ECLASSC1 := 0)

Minutes for Request Interval (I, M, 1–32767) **TIMERQ1** := ______________

Seconds to Select/Operate Time-Out (0.0–30.0 sec) **STIMEO1** := ______________

Data Link Retries (0–15) **DRETRY1** := ______________

Seconds to Data Link Time-Out (0–5 sec) **DTIMEO1** := ______________
(Hidden if DRETRY1 := 0)

Event Message Confirm Time-Out (1–50 sec) **ETIMEO1** := ______________

Enable Unsolicited Reporting (Y, N) **UNSOL1** := ______________
(Hidden and forced to N if ECLASSA1 := 0, ECLASSB1 := 0, and ECLASSC1 := 0)
(All subsequent settings are hidden and forced to N when UNSOL1 := N)

Enable Unsolicited Reporting at Power-Up (Y, N) **PUNSOL1** := ______________

Number of Events to Transmit On (1–200) **NUMEVE1** := ______________

Oldest Event to Tx On (0.0–99999.0 sec) **AGEEVE1** := ______________

Unsolicited Message Max Retry Attempts (2–10) **URETRY1** := ______________

Unsolicited Message Offline Time-Out (1–5000 sec) **UTIMEO1** := ______________

Modem Protocol

(For DNP3 session and EIA-232 port only)

Modem Connected to Port (Y, N) **MODEM** := ______________

Modem Startup String (30 Characters) **MSTR** := ______________

Phone Number for Dial-Out (30 Characters) **PH_NUM1** := ______________

Phone Number for Dial-Out (30 Characters) **PH_NUM2** := ______________

Retry Attempts for Phone 1 Dial-Out (1–20) **RETRY1** := ______________

Retry Attempts for Phone 2 Dial-Out (1–20) **RETRY2** := ______________

Time to Attempt Dial (5–300 sec) **MDTIME** := ______________

Time Between Dial-Out Attempts (5–3600 sec) **MDRET** := ______________

MIRRORED BITS Protocol

(Hidden if PROTO := SEL, DNP, PMU, EVMSG, 103, or MOD)

MB Transmit Identifier (1–4) **TXID** := ______________

MB Receive Identifier (1–4) **RXID** := ______________

MB RX Bad Pickup Time (0–10000 sec) **RBADPU** := ______________

MB Channel Bad Pickup (1–10000 ppm) **CBADPU** := ______________

MB Receive Default State (8 Characters) **RXDFLT** := ______________

RMB1 Pickup Debounce Messages (1–8) **RMB1PU** := ______________

RMB1 Dropout Debounce Messages (1–8) **RMB1DO** := ______________

RMB2 Pickup Debounce Messages (1–8)	**RMB2PU** := ________
RMB2 Dropout Debounce Messages (1–8)	**RMB2DO** := ________
RMB3 Pickup Debounce Messages (1–8)	**RMB3PU** := ________
RMB3 Dropout Debounce Messages (1–8)	**RMB3DO** := ________
RMB4 Pickup Debounce Messages (1–8)	**RMB4PU** := ________
RMB4 Dropout Debounce Messages (1–8)	**RMB4DO** := ________
RMB5 Pickup Debounce Messages (1–8)	**RMB5PU** := ________
RMB5 Dropout Debounce Messages (1–8)	**RMB5DO** := ________
RMB6 Pickup Debounce Messages (1–8)	**RMB6PU** := ________
RMB6 Dropout Debounce Messages (1–8)	**RMB6DO** := ________
RMB7 Pickup Debounce Messages (1–8)	**RMB7PU** := ________
RMB7 Dropout Debounce Messages (1–8)	**RMB7DO** := ________
RMB8 Pickup Debounce Messages (1–8)	**RMB8PU** := ________
RMB8 Dropout Debounce Messages (1–8)	**RMB8DO** := ________

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(Hidden if the serial port setting PROTO ≠ 103)

103 DEVICE ADDRESS (0–254)	**103ADDR** := ________
CYCLIC DATA REPORTING PERIOD (1–3600 sec)	**103CYC** := ________
ACCUMULATOR REPORTING PERIOD (OFF, 1–3600 sec)	**103ACYC** := ________
ACCUMULATOR REPORTING TRIGGER (1 Relay Word Bit)	**103ATRI** := ________
ENABLE TIME SYNCHRONIZATION (Y, N)	**103TIME** := ________

Port 4

(EIA-232/485 port or DeviceNet port in Slot C)

ENABLE PORT (Y, N)	**EPORT** := ________
PROTOCOL (SEL, DNP, MOD, DNET, EVMSG, PMU, MBA, MBB, MB8A, MB8B, MBTA, MBTB, 103)	**PROTO** := ________
MAXIMUM ACCESS LEVEL (1, 2, C)	**MAXACC** := ________

Interface Select

(Hidden if PROTO := DNET)

COMM INTERFACE (232, 485)	**COMMINF** := ________

Communications

SPEED (300, 1200, 2400, 4800, 9600, 19200, 38400 bps) **SPEED** := ____________
(Hidden if PROTO := DNET)

DATA BITS (7, 8 bits) **BITS** := ____________
(Hidden if PROTO := DNP, MOD, PMU, EVMSG, MB_, 103, or DNET)

PARITY (O, E, N) **PARITY** := ____________
(Hidden and forced to 0 if PROTO := DNET, EVMSG, PMU, or MB_)

STOP BITS (1, 2 bits) **STOP** := ____________
(Hidden if PROTO := MOD, EVMSG, MB_, or DNET)

PORT TIME-OUT (0–30 min) **T_OUT** := ____________
(Hidden if PROTO := MOD, EVMSG, MB_, PMU, 103, or DNET)

HDWR HANDSHAKING (Y, N) **RTSCTS** := ____________
(Hidden and forced to N if COMMINF := 485 or PROTO := MOD, DNP, EVMSG, MB_, or DNET)

LANGUAGE (ENGLISH, SPANISH) **LANG** := ____________

SEND AUTOMESSAGE (Y, N) **AUTO** := ____________
(Hidden and forced to N if PROTO := DNP, MOD, EVMSG, MB_, PMU, 103, or DNET)

FAST OP MESSAGES (Y, N) **FASTOP** := ____________
(Hidden if PROTO := DNP, MOD, EVMSG, MB_, PMU, 103, or DNET)

MINIMUM SECONDS FROM DCD TO TX (0.00–1.00) **MINDLY** := ____________
(Hidden if PROTO ≠ DNP)

MAXIMUM SECONDS FROM DCD TO TX (0.0–1.00) **MAXDLY** := ____________
(Hidden if PROTO ≠ DNP)

SETTLE TIME FROM RTD ON TO TX (OFF, 0.00–30.00 sec) **PREDLY** := ____________
(Hidden if PROTO ≠ DNP or 103)

SETTLE TIME FROM TX TO RTS OFF (0.00–30.00 sec) **PSTDLY** := ____________
(Hidden if PROTO ≠ DNP or 103)

Modbus

MODBUS SLAVE ID (1–247) **SLAVEID** := ____________
(Hidden if PROTO := SEL, EVMSG, MB_, 103, or DNET)

DNP3

(Hidden if PROTO := SEL, EVMSG, MB, PMU, DNET, 103, or MOD)

DNP Address (0–65519) **DNPADR** := ____________

DNP Address to Report to (0–65519) **REPADR1** := ____________

DNP Map (1–3) **DNPMAP1** := ____________

Analog Input Default Variation (1–6) **DVARAI1** := ____________

Class for Binary Event Data (0–3) **ECLASSB1** := ____________

Class for Counter Event Data (0–3) **ECLASSC1** := ____________

Class for Analog Event Data (0–3) **ECLASSA1** := ____________

Current Scaling Decimal Places (0–3)	**DECPLA1** := ____________
Voltages Scaling Decimal Places (0–3)	**DECPLV1** := ____________
Misc Data Scaling Decimal Places (0–3)	**DECPLM1** := ____________
Amps Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0)*	**ANADBA1** := ____________
Volts Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0)*	**ANADBV1** := ____________
Misc Data Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0 and ECLASSC1 := 0)*	**ANADBM1** := ____________
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ1** := ____________
Seconds to Select/Operate Time-Out (0.0–30.0 sec)	**STIMEO1** := ____________
Data Link Retries (0–15)	**DRETRY1** := ____________
Seconds to Data Link Time-Out (0–5 sec) *(Hidden if DRETRY := 0)*	**DTIMEO1** := ____________
Event Message Confirm Time-Out (1–50 sec)	**ETIMEO1** := ____________
Enable Unsolicited Reporting (Y, N) *(Hidden and forced to N if ECLASSA1 := 0, ECLASSB1 := 0, ECLASSC1 := 0, and ECLASSV1 := 0)* *(All subsequent settings are hidden and forced to N when UNSOL1 := N)*	**UNSOL1** := ____________
Enable Unsolicited Reporting at Power-Up (Y, N)	**PUNSOL1** := ____________
Number of Event to Transmit On (1–200)	**NUMEVE1** := ____________
Oldest Event on Tx On (0.0–99999.0 sec)	**AGEEVE1** := ____________
Unsolicited Message Max Retry Attempts (2–10)	**URETRY1** := ____________
Unsolicited Message Offline Time-Out (1–5000 sec) *(Hidden if UNSOL1 := N)*	**UTIMEO1** := ____________

Modem Protocol

(For DNP3 session and EIA-232 port only)

Modem Connected to Port (Y, N)	**MODEM** := ____________
Modem Startup String (30 Characters)	**MSTR** := ____________
Phone Number for Dial-Out (30 Characters)	**PH_NUM1** := ____________
Phone Number for Dial-Out (30 Characters)	**PH_NUM2** := ____________
Retry Attempts for Phone 1 Dial-Out (1–20)	**RETRY1** := ____________
Retry Attempts for Phone 2 Dial-Out (1–20)	**RETRY2** := ____________
Time to Attempt Dial (5–300 sec)	**MDTIME** := ____________
Time Between Dial-Out Attempts (5–3600 sec)	**MDRET** := ____________

MIRRORED BITS Protocol

(Hidden if PROTO := SEL, EVMSG, DNP, PMU, DNET, 103, or MOD)

MB Transmit Identifier (1–4)	**TXID** := ____________
MB Receive Identifier (1–4)	**RXID** := ____________
MB RX Bad Pickup Time (0–10000 sec)	**RBADPU** := ____________
MB Channel Bad Pickup (1–10000 ppm)	**CBADPU** := ____________
MB Receive Default State (8 Characters)	**RXDFLT** := ____________
RMB1 Pickup Debounce Messages (1–8)	**RMB1PU** := ____________
RMB1 Dropout Debounce Messages (1–8)	**RMB1DO** := ____________
RMB2 Pickup Debounce Messages (1–8)	**RMB2PU** := ____________
RMB2 Dropout Debounce Messages (1–8)	**RMB2DO** := ____________
RMB3 Pickup Debounce Messages (1–8)	**RMB3PU** := ____________
RMB3 Dropout Debounce Messages (1–8)	**RMB3DO** := ____________
RMB4 Pickup Debounce Messages (1–8)	**RMB4PU** := ____________
RMB4 Dropout Debounce Messages (1–8)	**RMB4DO** := ____________
RMB5 Pickup Debounce Messages (1–8)	**RMB5PU** := ____________
RMB5 Dropout Debounce Messages (1–8)	**RMB5DO** := ____________
RMB6 Pickup Debounce Messages (1–8)	**RMB6PU** := ____________
RMB6 Dropout Debounce Messages (1–8)	**RMB6DO** := ____________
RMB7 Pickup Debounce Messages (1–8)	**RMB7PU** := ____________
RMB7 Dropout Debounce Messages (1–8)	**RMB7DO** := ____________
RMB8 Pickup Debounce Messages (1–8)	**RMB8PU** := ____________
RMB8 Dropout Debounce Messages (1–8)	**RMB8DO** := ____________

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(Hidden unless serial port with PROTO := 103)

103 DEVICE ADDRESS (0–254)	**103ADDR** := ____________
CYCLIC DATA REPORTING PERIOD (1–3600 sec)	**103CYC** := ____________
ACCUMULATOR REPORTING PERIOD (OFF, 1–3600 sec)	**103ACYC** := ____________
ACCUMULATOR REPORTING TRIGGER (1 Relay Word Bit)	**103ATRI** := ____________
ENABLE TIME SYNCHRONIZATION (Y, N)	**103TIME** := ____________

Front-Panel Settings (SET F Command)

General

DISPLY PTS ENABL (N, 1–32) *(Hidden and forced to N if the front-panel MOT option is A)*	**EDP** := ____________
LOCAL BITS ENABL (N, 1–32)	**ELB** := ____________
LCD TIMEOUT (OFF, 1–30 min) *(Hidden and forced to N if the front-panel MOT option is A)*	**FP_TO** := ____________
LCD CONTRAST (1–8) *(Hidden if the front-panel MOT option is A)*	**FP_CONT** := ____________
FP AUTOMESSAGES (OVERRIDE, ROTATING) *(Hidden if the front-panel MOT option is A)*	**FP_AUTO** := ____________
CLOSE RESET LEDS (Y, N)	**RSTLED** := ____________
ENA_LED COLOR (R, G, A) *(Hidden if the front-panel MOT option is A)*	**LEDENAC** := ____________
TRIP_LED COLOR (R, G, A)	**LEDTRPC** := ____________
MAXIMUM ACCESS LEVEL (1, 2) *(Hidden if the front-panel MOT option is A)*	**MAXACC** := ____________

Target LED

(R = Red, G = Green, A = Amber)

TRIP LATCH T_LED (Y, N)	**T01LEDL** := ____________
TARGET T_LED ASSERTED COLOR (R, G, A)	**T01LEDC** := ____________
LED1 EQUATION (SELOGIC)	**T01_LED** := ____________
TRIP LATCH T_LED (Y, N)	**T02LEDL** := ____________
TARGET T_LED ASSERTED COLOR (R, G, A)	**T02LEDC** := ____________
LED1 EQUATION (SELOGIC)	**T02_LED** := ____________
TRIP LATCH T_LED (Y, N)	**T03LEDL** := ____________
TARGET T_LED ASSERTED COLOR (R, G, A)	**T03LEDC** := ____________
LED1 EQUATION (SELOGIC)	**T03_LED** := ____________
TRIP LATCH T_LED (Y, N)	**T04LEDL** := ____________
TARGET T_LED ASSERTED COLOR (R, G, A)	**T04LEDC** := ____________
LED1 EQUATION (SELOGIC)	**T04_LED** := ____________
TRIP LATCH T_LED (Y, N)	**T05LEDL** := ____________
TARGET T_LED ASSERTED COLOR (R, G, A)	**T05LEDC** := ____________

Date ____________
Group___________

LED1 EQUATION (SELOGIC)	**T05_LED** := ____________
TRIP LATCH T_LED (Y, N)	**T06LEDL** := ____________
TARGET T_LED ASSERTED COLOR (R, G, A)	**T06LEDC** := ____________
LED1 EQUATION (SELOGIC)	**T06_LED** := ____________

Operator Control LED

(Asserted/deasserted color choices: R = Red, G = Green, A = Amber, O = Off; asserted and deasserted colors must be different)

PB_LED ASSERTED/DEASSRTED COLORS (AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO)	**PB1ALEDC** := ____________
PB1A_LED EQUATION (SELOGIC)	**PB1A_LED** := ____________
PB_LED ASSERTED/DEASSRTED COLORS (AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO)	**PB1BLEDC** := ____________
PB1B_LED EQUATION (SELOGIC)	**PB1B_LED** := ____________
PB_LED ASSERTED/DEASSRTED COLORS (AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO)	**PB2ALEDC** := ____________
PB1A_LED EQUATION (SELOGIC)	**PB2A_LED** := ____________
PB_LED ASSERTED/DEASSRTED COLORS (AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO)	**PB2BLEDC** := ____________
PB1B_LED EQUATION (SELOGIC)	**PB2B_LED** := ____________
PB_LED ASSERTED/DEASSRTED COLORS (AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO)	**PB3ALEDC** := ____________
PB1A_LED EQUATION (SELOGIC)	**PB3A_LED** := ____________
PB_LED ASSERTED/DEASSRTED COLORS (AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO)	**PB3BLEDC** := ____________
PB1B_LED EQUATION (SELOGIC)	**PB3B_LED** := ____________
PB_LED ASSERTED/DEASSRTED COLORS (AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO)	**PB4ALEDC** := ____________
PB1A_LED EQUATION (SELOGIC)	**PB4A_LED** := ____________
PB_LED ASSERTED/DEASSRTED COLORS (AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO)	**PB4BLEDC** := ____________
PB1B_LED EQUATION (SELOGIC)	**PB4B_LED** := ____________
PB_LED ASSERTED/DEASSRTED COLORS (AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO)	**PB5ALEDC** := ____________
PB1A_LED EQUATION (SELOGIC)	**PB5A_LED** := ____________
PB_LED ASSERTED/DEASSRTED COLORS (AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO)	**PB5BLEDC** := ____________
PB1B_LED EQUATION (SELOGIC)	**PB5B_LED** := ____________

PB_LED ASSERTED/DEASSRTED COLORS (AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO) **PB6ALEDC** := ____________________

PB1A_LED EQUATION (SELOGIC) **PB6A_LED** := ____________________

PB_LED ASSERTED/DEASSRTED COLORS (AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO) **PB6BLEDC** := ____________________

PB1B_LED EQUATION (SELOGIC) **PB6B_LED** := ____________________

PB_LED ASSERTED/DEASSRTED COLORS (AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO) **PB7ALEDC** := ____________________

PB1A_LED EQUATION (SELOGIC) **PB7A_LED** := ____________________

PB_LED ASSERTED/DEASSRTED COLORS (AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO) **PB7BLEDC** := ____________________

PB1B_LED EQUATION (SELOGIC) **PB7B_LED** := ____________________

PB_LED ASSERTED/DEASSRTED COLORS (AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO) **PB8ALEDC** := ____________________

PB1A_LED EQUATION (SELOGIC) **PB8A_LED** := ____________________

PB_LED ASSERTED/DEASSRTED COLORS (AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO) **PB8BLEDC** := ____________________

PB1B_LED EQUATION (SELOGIC) **PB8B_LED** := ____________________

Display Points

(The following display point settings are hidden if the front-panel MOT option is A)

Display Point Settings (maximum 60 characters):
(Boolean): Relay Word bit name, "Alias", "Set String", "Clear String"
(Analog): Analog Quantity name, "User Text and Formatting"

DISPLAY POINT DP01 (60 characters) **DP01** := ____________________

DISPLAY POINT DP02 (60 characters) **DP02** := ____________________

DISPLAY POINT DP03 (60 characters) **DP03** := ____________________

DISPLAY POINT DP04 (60 characters) **DP04** := ____________________

DISPLAY POINT DP05 (60 characters) **DP05** := ____________________

DISPLAY POINT DP06 (60 characters) **DP06** := ____________________

DISPLAY POINT DP07 (60 characters) **DP07** := ____________________

DISPLAY POINT DP08 (60 characters) **DP08** := ____________________

DISPLAY POINT DP09 (60 characters) **DP09** := ____________________

DISPLAY POINT DP10 (60 characters) **DP10** := ____________________

DISPLAY POINT DP11 (60 characters) **DP11** := ____________________

DISPLAY POINT DP12 (60 characters) **DP12** := ____________________

DISPLAY POINT DP13 (60 characters)	**DP13** := ____________
DISPLAY POINT DP14 (60 characters)	**DP14** := ____________
DISPLAY POINT DP15 (60 characters)	**DP15** := ____________
DISPLAY POINT DP16 (60 characters)	**DP16** := ____________
DISPLAY POINT DP17 (60 characters)	**DP17** := ____________
DISPLAY POINT DP18 (60 characters)	**DP18** := ____________
DISPLAY POINT DP19 (60 characters)	**DP19** := ____________
DISPLAY POINT DP20 (60 characters)	**DP20** := ____________
DISPLAY POINT DP21 (60 characters)	**DP21** := ____________
DISPLAY POINT DP22 (60 characters)	**DP22** := ____________
DISPLAY POINT DP23 (60 characters)	**DP23** := ____________
DISPLAY POINT DP24 (60 characters)	**DP24** := ____________
DISPLAY POINT DP25 (60 characters)	**DP25** := ____________
DISPLAY POINT DP26 (60 characters)	**DP26** := ____________
DISPLAY POINT DP27 (60 characters)	**DP27** := ____________
DISPLAY POINT DP28 (60 characters)	**DP28** := ____________
DISPLAY POINT DP29 (60 characters)	**DP29** := ____________
DISPLAY POINT DP30 (60 characters)	**DP30** := ____________
DISPLAY POINT DP31 (60 characters)	**DP31** := ____________
DISPLAY POINT DP32 (60 characters)	**DP32** := ____________

Local Bits Labels

LB_NAME (14 characters)	**NLB01** := ____________
CLEAR LB_LABEL (7 characters)	**CLB01** := ____________
SET LB_LABEL (7 characters)	**SLB01** := ____________
PULSE LB_LABEL (7 characters)	**PLB01** := ____________
LB_NAME (14 characters)	**NLB02** := ____________
CLEAR LB_LABEL (7 characters)	**CLB02** := ____________
SET LB_LABEL (7 characters)	**SLB02** := ____________
PULSE LB_LABEL (7 characters)	**PLB02** := ____________
LB_NAME (14 characters)	**NLB03** := ____________

CLEAR LB_LABEL (7 characters)	**CLB03** := __________
SET LB_LABEL (7 characters)	**SLB03** := __________
PULSE LB_LABEL (7 characters)	**PLB03** := __________
LB_NAME (14 characters)	**NLB04** := __________
CLEAR LB_LABEL (7 characters)	**CLB04** := __________
SET LB_LABEL (7 characters)	**SLB04** := __________
PULSE LB_LABEL (7 characters)	**PLB04** := __________
LB_NAME (14 characters)	**NLB05** := __________
CLEAR LB_LABEL (7 characters)	**CLB05** := __________
SET LB_LABEL (7 characters)	**SLB05** := __________
PULSE LB_LABEL (7 characters)	**PLB05** := __________
LB_NAME (14 characters)	**NLB06** := __________
CLEAR LB_LABEL (7 characters)	**CLB06** := __________
SET LB_LABEL (7 characters)	**SLB06** := __________
PULSE LB_LABEL (7 characters)	**PLB06** := __________
LB_NAME (14 characters)	**NLB07** := __________
CLEAR LB_LABEL (7 characters)	**CLB07** := __________
SET LB_LABEL (7 characters)	**SLB07** := __________
PULSE LB_LABEL (7 characters)	**PLB07** := __________
LB_NAME (14 characters)	**NLB08** := __________
CLEAR LB_LABEL (7 characters)	**CLB08** := __________
SET LB_LABEL (7 characters)	**SLB08** := __________
PULSE LB_LABEL (7 characters)	**PLB08** := __________
LB_NAME (14 characters)	**NLB09** := __________
CLEAR LB_LABEL (7 characters)	**CLB09** := __________
SET LB_LABEL (7 characters)	**SLB09** := __________
PULSE LB_LABEL (7 characters)	**PLB09** := __________
LB_NAME (14 characters)	**NLB10** := __________
CLEAR LB_LABEL (7 characters)	**CLB10** := __________
SET LB_LABEL (7 characters)	**SLB10** := __________

Date ____________
Group____________

PULSE LB_LABEL (7 characters)	**PLB10** := ____________
LB_NAME (14 characters)	**NLB11** := ____________
CLEAR LB_LABEL (7 characters)	**CLB11** := ____________
SET LB_LABEL (7 characters)	**SLB11** := ____________
PULSE LB_LABEL (7 characters)	**PLB11** := ____________
LB_NAME (14 characters)	**NLB12** := ____________
CLEAR LB_LABEL (7 characters)	**CLB12** := ____________
SET LB_LABEL (7 characters)	**SLB12** := ____________
PULSE LB_LABEL (7 characters)	**PLB12** := ____________
LB_NAME (14 characters)	**NLB13** := ____________
CLEAR LB_LABEL (7 characters)	**CLB13** := ____________
SET LB_LABEL (7 characters)	**SLB13** := ____________
PULSE LB_LABEL (7 characters)	**PLB13** := ____________
LB_NAME (14 characters)	**NLB14** := ____________
CLEAR LB_LABEL (7 characters)	**CLB14** := ____________
SET LB_LABEL (7 characters)	**SLB14** := ____________
PULSE LB_LABEL (7 characters)	**PLB14** := ____________
LB_NAME (14 characters)	**NLB15** := ____________
CLEAR LB_LABEL (7 characters)	**CLB15** := ____________
SET LB_LABEL (7 characters)	**SLB15** := ____________
PULSE LB_LABEL (7 characters)	**PLB15** := ____________
LB_NAME (14 characters)	**NLB16** := ____________
CLEAR LB_LABEL (7 characters)	**CLB16** := ____________
SET LB_LABEL (7 characters)	**SLB16** := ____________
PULSE LB_LABEL (7 characters)	**PLB16** := ____________
LB_NAME (14 characters)	**NLB17** := ____________
CLEAR LB_LABEL (7 characters)	**CLB17** := ____________
SET LB_LABEL (7 characters)	**SLB17** := ____________
PULSE LB_LABEL (7 characters)	**PLB17** := ____________
LB_NAME (14 characters)	**NLB18** := ____________

CLEAR LB_LABEL (7 characters)	**CLB18** := ________
SET LB_LABEL (7 characters)	**SLB18** := ________
PULSE LB_LABEL (7 characters)	**PLB18** := ________
LB_NAME (14 characters)	**NLB19** := ________
CLEAR LB_LABEL (7 characters)	**CLB19** := ________
SET LB_LABEL (7 characters)	**SLB19** := ________
PULSE LB_LABEL (7 characters)	**PLB19** := ________
LB_NAME (14 characters)	**NLB20** := ________
CLEAR LB_LABEL (7 characters)	**CLB20** := ________
SET LB_LABEL (7 characters)	**SLB20** := ________
PULSE LB_LABEL (7 characters)	**PLB20** := ________
LB_NAME (14 characters)	**NLB21** := ________
CLEAR LB_LABEL (7 characters)	**CLB21** := ________
SET LB_LABEL (7 characters)	**SLB21** := ________
PULSE LB_LABEL (7 characters)	**PLB21** := ________
LB_NAME (14 characters)	**NLB22** := ________
CLEAR LB_LABEL (7 characters)	**CLB22** := ________
SET LB_LABEL (7 characters)	**SLB22** := ________
PULSE LB_LABEL (7 characters)	**PLB22** := ________
LB_NAME (14 characters)	**NLB23** := ________
CLEAR LB_LABEL (7 characters)	**CLB23** := ________
SET LB_LABEL (7 characters)	**SLB23** := ________
PULSE LB_LABEL (7 characters)	**PLB23** := ________
LB_NAME (14 characters)	**NLB24** := ________
CLEAR LB_LABEL (7 characters)	**CLB24** := ________
SET LB_LABEL (7 characters)	**SLB24** := ________
PULSE LB_LABEL (7 characters)	**PLB24** := ________
LB_NAME (14 characters)	**NLB25** := ________
CLEAR LB_LABEL (7 characters)	**CLB25** := ________
SET LB_LABEL (7 characters)	**SLB25** := ________

PULSE LB_LABEL (7 characters)	**PLB25** := ______________________
LB_NAME (14 characters)	**NLB26** := ______________________
CLEAR LB_LABEL (7 characters)	**CLB26** := ______________________
SET LB_LABEL (7 characters)	**SLB26** := ______________________
PULSE LB_LABEL (7 characters)	**PLB26** := ______________________
LB_NAME (14 characters)	**NLB27** := ______________________
CLEAR LB_LABEL (7 characters)	**CLB27** := ______________________
SET LB_LABEL (7 characters)	**SLB27** := ______________________
PULSE LB_LABEL (7 characters)	**PLB27** := ______________________
LB_NAME (14 characters)	**NLB28** := ______________________
CLEAR LB_LABEL (7 characters)	**CLB28** := ______________________
SET LB_LABEL (7 characters)	**SLB28** := ______________________
PULSE LB_LABEL (7 characters)	**PLB28** := ______________________
LB_NAME (14 characters)	**NLB29** := ______________________
CLEAR LB_LABEL (7 characters)	**CLB29** := ______________________
SET LB_LABEL (7 characters)	**SLB29** := ______________________
PULSE LB_LABEL (7 characters)	**PLB29** := ______________________
LB_NAME (14 characters)	**NLB30** := ______________________
CLEAR LB_LABEL (7 characters)	**CLB30** := ______________________
SET LB_LABEL (7 characters)	**SLB30** := ______________________
PULSE LB_LABEL (7 characters)	**PLB30** := ______________________
LB_NAME (14 characters)	**NLB31** := ______________________
CLEAR LB_LABEL (7 characters)	**CLB31** := ______________________
SET LB_LABEL (7 characters)	**SLB31** := ______________________
PULSE LB_LABEL (7 characters)	**PLB31** := ______________________
LB_NAME (14 characters)	**NLB32** := ______________________
CLEAR LB_LABEL (7 characters)	**CLB32** := ______________________
SET LB_LABEL (7 characters)	**SLB32** := ______________________
PULSE LB_LABEL (7 characters)	**PLB32** := ______________________

Touchscreen Settings

(Shown if the front-panel MOT option is A)
(Note: The Touchscreen settings category is only available in QuickSet, with the exception of the settings FPTO, FPDUR, and FPBAB, which are also available to set via the touchscreen display.)

Touchscreen Configuration

DISPLAY HOME SCREEN (Refer to *Table 8.17* for setting range)	**FPHOME**	____________
DISPLAY TIME-OUT (1–30 min)	**FPTO**	____________
ROTATING DISPLAY TRANSITION TIME (3–15 sec)	**FPDUR**	____________
BACKLIGHT ACTIVE BRIGHTNESS (1–10)	**FPBAB**	____________

Rotating Display

(Refer to Table 8.17 for the setting range)

ROTATING DISPLAY 01	**FPRD01** :=	____________
ROTATING DISPLAY 02	**FPRD02** :=	____________
ROTATING DISPLAY 03	**FPRD03** :=	____________
ROTATING DISPLAY 04	**FPRD04** :=	____________
ROTATING DISPLAY 05	**FPRD05** :=	____________
ROTATING DISPLAY 06	**FPRD06** :=	____________
ROTATING DISPLAY 07	**FPRD07** :=	____________
ROTATING DISPLAY 08	**FPRD08** :=	____________
ROTATING DISPLAY 09	**FPRD09** :=	____________
ROTATING DISPLAY 10	**FPRD10** :=	____________
ROTATING DISPLAY 11	**FPRD11** :=	____________
ROTATING DISPLAY 12	**FPRD12** :=	____________
ROTATING DISPLAY 13	**FPRD13** :=	____________
ROTATING DISPLAY 14	**FPRD14** :=	____________
ROTATING DISPLAY 15	**FPRD15** :=	____________
ROTATING DISPLAY 16	**FPRD16** :=	____________

Pushbuttons

(OFF, refer to Table 8.17 for the setting range)

PUSHBUTTON 01 HMI SCREEN	**FPPB01** :=	____________
PUSHBUTTON 02 HMI SCREEN	**FPPB02** :=	____________

PUSHBUTTON 03 HMI SCREEN	**FPPB03** := ____________
PUSHBUTTON 04 HMI SCREEN	**FPPB04** := ____________
PUSHBUTTON 05 HMI SCREEN	**FPPB05** := ____________
PUSHBUTTON 06 HMI SCREEN	**FPPB06** := ____________
PUSHBUTTON 07 HMI SCREEN	**FPPB07** := ____________
PUSHBUTTON 08 HMI SCREEN	**FPPB08** := ____________

Bay Control Breaker

BREAKER TRIP TYPE (3)	**BK01TTY** := ____________
BREAKER MODE (CONTROL, MONITOR)	**BK01MOD** := ____________
BREAKER CLOSE STATUS (Relay Word bit)	**BK01CS** := ____________
BREAKER OPEN STATUS (Relay Word bit)	**BK01OS** := ____________
BREAKER ALARM STATUS (Relay Word bit)	**BK01AS** := ____________
BREAKER HMI CLOSE COMMAND (Relay Word bit)	**BK01CLC** := ____________
BREAKER HMI OPEN COMMAND (Relay Word bit)	**BK01OPC** := ____________
BREAKER TRIP TYPE (3)	**BK02TTY** := ____________
BREAKER MODE (CONTROL, MONITOR)	**BK02MOD** := ____________
BREAKER CLOSE STATUS (Relay Word bit)	**BK02CS** := ____________
BREAKER OPEN STATUS (Relay Word bit)	**BK02OS** := ____________
BREAKER ALARM STATUS (Relay Word bit)	**BK02AS** := ____________
BREAKER HMI CLOSE COMMAND (Relay Word bit)	**BK02CLC** := ____________
BREAKER HMI OPEN COMMAND (Relay Word bit)	**BK02OPC** := ____________
BREAKER TRIP TYPE (3)	**BK03TTY** := ____________
BREAKER MODE (CONTROL, MONITOR)	**BK03MOD** := ____________
BREAKER CLOSE STATUS (Relay Word bit)	**BK03CS** := ____________
BREAKER OPEN STATUS (Relay Word bit)	**BK03OS** := ____________
BREAKER ALARM STATUS (Relay Word bit)	**BK03AS** := ____________
BREAKER HMI CLOSE COMMAND (Relay Word bit)	**BK03CLC** := ____________
BREAKER HMI OPEN COMMAND (Relay Word bit)	**BK03OPC** := ____________
BREAKER TRIP TYPE (3)	**BK04TTY** := ____________
BREAKER MODE (CONTROL, MONITOR)	**BK04MOD** := ____________

BREAKER CLOSE STATUS (Relay Word bit)	**BK04CS** :=	________________
BREAKER OPEN STATUS (Relay Word bit)	**BK04OS** :=	________________
BREAKER ALARM STATUS (Relay Word bit)	**BK04AS** :=	________________
BREAKER HMI CLOSE COMMAND (Relay Word bit)	**BK04CLC** :=	________________
BREAKER HMI OPEN COMMAND (Relay Word bit)	**BK04OPC** :=	________________

Bay Control Two-Position Disconnect

TWO-POSITION DISCONNECT MODE (CONTROL, MONITOR)	**2D01MOD** :=	________________
TWO-POSITION DISCONNECT CLOSE STATUS (Relay Word bit)	**2DS01CS** :=	________________
TWO-POSITION DISCONNECT OPEN STATUS (Relay Word bit)	**2DS01OS** :=	________________
TWO-POSITION DISCONNECT IN-PROGRESS STATUS (Relay Word bit)	**2DS01IS** :=	________________
TWO-POSITION DISCONNECT ALARM STATUS (Relay Word bit)	**2DS01AS** :=	________________
TWO-POSITION DISCONNECT HMI CLOSE COMMAND (Relay Word bit)	**2DS01CL** :=	________________
TWO-POSITION DISCONNECT HMI OPEN COMMAND (Relay Word bit)	**2DS01OP** :=	________________
TWO-POSITION DISCONNECT MODE (CONTROL, MONITOR)	**2D02MOD** :=	________________
TWO-POSITION DISCONNECT CLOSE STATUS (Relay Word bit)	**2DS02CS** :=	________________
TWO-POSITION DISCONNECT OPEN STATUS (Relay Word bit)	**2DS02OS** :=	________________
TWO-POSITION DISCONNECT IN-PROGRESS STATUS (Relay Word bit)	**2DS02IS** :=	________________
TWO-POSITION DISCONNECT ALARM STATUS (Relay Word bit)	**2DS02AS** :=	________________
TWO-POSITION DISCONNECT HMI CLOSE COMMAND (Relay Word bit)	**2DS02CL** :=	________________
TWO-POSITION DISCONNECT HMI OPEN COMMAND (Relay Word bit)	**2DS02OP** :=	________________
TWO-POSITION DISCONNECT MODE (CONTROL, MONITOR)	**2D03MOD** :=	________________
TWO-POSITION DISCONNECT CLOSE STATUS (Relay Word bit)	**2DS03CS** :=	________________
TWO-POSITION DISCONNECT OPEN STATUS (Relay Word bit)	**2DS03OS** :=	________________
TWO-POSITION DISCONNECT IN-PROGRESS STATUS (Relay Word bit)	**2DS03IS** :=	________________
TWO-POSITION DISCONNECT ALARM STATUS (Relay Word bit)	**2DS03AS** :=	________________
TWO-POSITION DISCONNECT HMI CLOSE COMMAND (Relay Word bit)	**2DS03CL** :=	________________

TWO-POSITION DISCONNECT HMI OPEN COMMAND (Relay Word bit)	**2DS03OP** := ______________
TWO-POSITION DISCONNECT MODE (CONTROL, MONITOR)	**2D04MOD** := ______________
TWO-POSITION DISCONNECT CLOSE STATUS (Relay Word bit)	**2DS04CS** := ______________
TWO-POSITION DISCONNECT OPEN STATUS (Relay Word bit)	**2DS04OS** := ______________
TWO-POSITION DISCONNECT IN-PROGRESS STATUS (Relay Word bit)	**2DS04IS** := ______________
TWO-POSITION DISCONNECT ALARM STATUS (Relay Word bit)	**2DS04AS** := ______________
TWO-POSITION DISCONNECT HMI CLOSE COMMAND (Relay Word bit)	**2DS04CL** := ______________
TWO-POSITION DISCONNECT HMI OPEN COMMAND (Relay Word bit)	**2DS04OP** := ______________
TWO-POSITION DISCONNECT MODE (CONTROL, MONITOR)	**2D05MOD** := ______________
TWO-POSITION DISCONNECT CLOSE STATUS (Relay Word bit)	**2DS05CS** := ______________
TWO-POSITION DISCONNECT OPEN STATUS (Relay Word bit)	**2DS05OS** := ______________
TWO-POSITION DISCONNECT IN-PROGRESS STATUS (Relay Word bit)	**2DS05IS** := ______________
TWO-POSITION DISCONNECT ALARM STATUS (Relay Word bit)	**2DS05AS** := ______________
TWO-POSITION DISCONNECT HMI CLOSE COMMAND (Relay Word bit)	**2DS05CL** := ______________
TWO-POSITION DISCONNECT HMI OPEN COMMAND (Relay Word bit)	**2DS05OP** := ______________
TWO-POSITION DISCONNECT MODE (CONTROL, MONITOR)	**2D06MOD** := ______________
TWO-POSITION DISCONNECT CLOSE STATUS (Relay Word bit)	**2DS06CS** := ______________
TWO-POSITION DISCONNECT OPEN STATUS (Relay Word bit)	**2DS06OS** := ______________
TWO-POSITION DISCONNECT IN-PROGRESS STATUS (Relay Word bit)	**2DS06IS** := ______________
TWO-POSITION DISCONNECT ALARM STATUS (Relay Word bit)	**2DS06AS** := ______________
TWO-POSITION DISCONNECT HMI CLOSE COMMAND (Relay Word bit)	**2DS06CL** := ______________
TWO-POSITION DISCONNECT HMI OPEN COMMAND (Relay Word bit)	**2DS06OP** := ______________
TWO-POSITION DISCONNECT MODE (CONTROL, MONITOR)	**2D07MOD** := ______________
TWO-POSITION DISCONNECT CLOSE STATUS (Relay Word bit)	**2DS07CS** := ______________
TWO-POSITION DISCONNECT OPEN STATUS (Relay Word bit)	**2DS07OS** := ______________

TWO-POSITION DISCONNECT IN-PROGRESS STATUS (Relay Word bit) **2DS07IS** := ____________

TWO-POSITION DISCONNECT ALARM STATUS (Relay Word bit) **2DS07AS** := ____________

TWO-POSITION DISCONNECT HMI CLOSE COMMAND (Relay Word bit) **2DS07CL** := ____________

TWO-POSITION DISCONNECT HMI OPEN COMMAND (Relay Word bit) **2DS07OP** := ____________

TWO-POSITION DISCONNECT MODE (CONTROL, MONITOR) **2D08MOD** := ____________

TWO-POSITION DISCONNECT CLOSE STATUS (Relay Word bit) **2DS08CS** := ____________

TWO-POSITION DISCONNECT OPEN STATUS (Relay Word bit) **2DS08OS** := ____________

TWO-POSITION DISCONNECT IN-PROGRESS STATUS (Relay Word bit) **2DS08IS** := ____________

TWO-POSITION DISCONNECT ALARM STATUS (Relay Word bit) **2DS08AS** := ____________

TWO-POSITION DISCONNECT HMI CLOSE COMMAND (Relay Word bit) **2DS08CL** := ____________

TWO-POSITION DISCONNECT HMI OPEN COMMAND (Relay Word bit) **2DS08OP** := ____________

TWO-POSITION DISCONNECT MODE (CONTROL, MONITOR) **2D09MOD** := ____________

TWO-POSITION DISCONNECT CLOSE STATUS (Relay Word bit) **2DS09CS** := ____________

TWO-POSITION DISCONNECT OPEN STATUS (Relay Word bit) **2DS09OS** := ____________

TWO-POSITION DISCONNECT IN-PROGRESS STATUS (Relay Word bit) **2DS09IS** := ____________

TWO-POSITION DISCONNECT ALARM STATUS (Relay Word bit) **2DS09AS** := ____________

TWO-POSITION DISCONNECT HMI CLOSE COMMAND (Relay Word bit) **2DS09CL** := ____________

TWO-POSITION DISCONNECT HMI OPEN COMMAND (Relay Word bit) **2DS09OP** := ____________

TWO-POSITION DISCONNECT MODE (CONTROL, MONITOR) **2D10MOD** := ____________

TWO-POSITION DISCONNECT CLOSE STATUS (Relay Word bit) **2DS10CS** := ____________

TWO-POSITION DISCONNECT OPEN STATUS (Relay Word bit) **2DS10OS** := ____________

TWO-POSITION DISCONNECT IN-PROGRESS STATUS (Relay Word bit) **2DS10IS** := ____________

TWO-POSITION DISCONNECT ALARM STATUS (Relay Word bit) **2DS10AS** := ____________

TWO-POSITION DISCONNECT HMI CLOSE COMMAND (Relay Word bit) **2DS10CL** := ____________

TWO-POSITION DISCONNECT HMI OPEN COMMAND (Relay Word bit) **2DS10OP** := ____________

TWO-POSITION DISCONNECT MODE (CONTROL, MONITOR)	**2D11MOD** :=	____________________
TWO-POSITION DISCONNECT CLOSE STATUS (Relay Word bit)	**2DS11CS** :=	____________________
TWO-POSITION DISCONNECT OPEN STATUS (Relay Word bit)	**2DS11OS** :=	____________________
TWO-POSITION DISCONNECT IN-PROGRESS STATUS (Relay Word bit)	**2DS11IS** :=	____________________
TWO-POSITION DISCONNECT ALARM STATUS (Relay Word bit)	**2DS11AS** :=	____________________
TWO-POSITION DISCONNECT HMI CLOSE COMMAND (Relay Word bit)	**2DS11CL** :=	____________________
TWO-POSITION DISCONNECT HMI OPEN COMMAND (Relay Word bit)	**2DS11OP** :=	____________________
TWO-POSITION DISCONNECT MODE (CONTROL, MONITOR)	**2D12MOD** :=	____________________
TWO-POSITION DISCONNECT CLOSE STATUS (Relay Word bit)	**2DS12CS** :=	____________________
TWO-POSITION DISCONNECT OPEN STATUS (Relay Word bit)	**2DS12OS** :=	____________________
TWO-POSITION DISCONNECT IN-PROGRESS STATUS (Relay Word bit)	**2DS12IS** :=	____________________
TWO-POSITION DISCONNECT ALARM STATUS (Relay Word bit)	**2DS12AS** :=	____________________
TWO-POSITION DISCONNECT HMI CLOSE COMMAND (Relay Word bit)	**2DS12CL** :=	____________________
TWO-POSITION DISCONNECT HMI OPEN COMMAND (Relay Word bit)	**2DS12OP** :=	____________________
TWO-POSITION DISCONNECT MODE (CONTROL, MONITOR)	**2D13MOD** :=	____________________
TWO-POSITION DISCONNECT CLOSE STATUS (Relay Word bit)	**2DS13CS** :=	____________________
TWO-POSITION DISCONNECT OPEN STATUS (Relay Word bit)	**2DS13OS** :=	____________________
TWO-POSITION DISCONNECT IN-PROGRESS STATUS (Relay Word bit)	**2DS13IS** :=	____________________
TWO-POSITION DISCONNECT ALARM STATUS (Relay Word bit)	**2DS13AS** :=	____________________
TWO-POSITION DISCONNECT HMI CLOSE COMMAND (Relay Word bit)	**2DS13CL** :=	____________________
TWO-POSITION DISCONNECT HMI OPEN COMMAND (Relay Word bit)	**2DS13OP** :=	____________________
TWO-POSITION DISCONNECT MODE (CONTROL, MONITOR)	**2D14MOD** :=	____________________
TWO-POSITION DISCONNECT CLOSE STATUS (Relay Word bit)	**2DS14CS** :=	____________________
TWO-POSITION DISCONNECT OPEN STATUS (Relay Word bit)	**2DS14OS** :=	____________________
TWO-POSITION DISCONNECT IN-PROGRESS STATUS (Relay Word bit)	**2DS14IS** :=	____________________
TWO-POSITION DISCONNECT ALARM STATUS (Relay Word bit)	**2DS14AS** :=	____________________

TWO-POSITION DISCONNECT HMI CLOSE COMMAND (Relay Word bit)	**2DS14CL** :=	____________________
TWO-POSITION DISCONNECT HMI OPEN COMMAND (Relay Word bit)	**2DS14OP** :=	____________________
TWO-POSITION DISCONNECT MODE (CONTROL, MONITOR)	**2D15MOD** :=	____________________
TWO-POSITION DISCONNECT CLOSE STATUS (Relay Word bit)	**2DS15CS** :=	____________________
TWO-POSITION DISCONNECT OPEN STATUS (Relay Word bit)	**2DS15OS** :=	____________________
TWO-POSITION DISCONNECT IN-PROGRESS STATUS (Relay Word bit)	**2DS15IS** :=	____________________
TWO-POSITION DISCONNECT ALARM STATUS (Relay Word bit)	**2DS15AS** :=	____________________
TWO-POSITION DISCONNECT HMI CLOSE COMMAND (Relay Word bit)	**2DS15CL** :=	____________________
TWO-POSITION DISCONNECT HMI OPEN COMMAND (Relay Word bit)	**2DS15OP** :=	____________________
TWO-POSITION DISCONNECT MODE (CONTROL, MONITOR)	**2D16MOD** :=	____________________
TWO-POSITION DISCONNECT CLOSE STATUS (Relay Word bit)	**2DS16CS** :=	____________________
TWO-POSITION DISCONNECT OPEN STATUS (Relay Word bit)	**2DS16OS** :=	____________________
TWO-POSITION DISCONNECT IN-PROGRESS STATUS (Relay Word bit)	**2DS16IS** :=	____________________
TWO-POSITION DISCONNECT ALARM STATUS (Relay Word bit)	**2DS16AS** :=	____________________
TWO-POSITION DISCONNECT HMI CLOSE COMMAND (Relay Word bit)	**2DS16CL** :=	____________________
TWO-POSITION DISCONNECT HMI OPEN COMMAND (Relay Word bit)	**2DS16OP** :=	____________________

Bay Control Three-Position Disconnect

THREE-POSITION DISCONNECT MODE (CONTROL, MONITOR)	**3D01MOD** :=	____________________
THREE-POSITION IN-LINE DISCONNECT CLOSE STATUS (Relay Word bit)	**3ID01CS** :=	____________________
THREE-POSITION IN-LINE DISCONNECT OPEN STATUS (Relay Word bit)	**3ID01OS** :=	____________________
THREE-POSITION IN-LINE DISCONNECT IN-PROGRESS STATUS (Relay Word bit)	**3ID01IS** :=	____________________
THREE-POSITION IN-LINE DISCONNECT ALARM STATUS (Relay Word bit)	**3ID01AS** :=	____________________
THREE-POSITION IN-LINE DISCONNECT HMI CLOSE COMMAND (Relay Word bit)	**3ID01CL** :=	____________________

THREE-POSITION IN-LINE DISCONNECT HMI OPEN COMMAND (Relay Word bit)	**3ID01OP** := ____________
THREE-POSITION EARTHING DISCONNECT CLOSE STATUS (Relay Word bit)	**3ED01CS** := ____________
THREE-POSITION EARTHING DISCONNECT OPEN STATUS (Relay Word bit)	**3ED01OS** := ____________
THREE-POSITION EARTHING DISCONNECT IN-PROGRESS STATUS (Relay Word bit)	**3ED01IS** := ____________
THREE-POSITION EARTHING DISCONNECT ALARM STATUS (Relay Word bit)	**3ED01AS** := ____________
THREE-POSITION EARTHING DISCONNECT HMI CLOSE COMMAND (Relay Word bit)	**3ED01CL** := ____________
THREE-POSITION EARTHING DISCONNECT HMI OPEN COMMAND (Relay Word bit)	**3ED01OP** := ____________
THREE-POSITION DISCONNECT MODE (CONTROL, MONITOR)	**3D02MOD** := ____________
THREE-POSITION IN-LINE DISCONNECT CLOSE STATUS (Relay Word bit)	**3ID02CS** := ____________
THREE-POSITION IN-LINE DISCONNECT OPEN STATUS (Relay Word bit)	**3ID02OS** := ____________
THREE-POSITION IN-LINE DISCONNECT IN-PROGRESS STATUS (Relay Word bit)	**3ID02IS** := ____________
THREE-POSITION IN-LINE DISCONNECT ALARM STATUS (Relay Word bit)	**3ID02AS** := ____________
THREE-POSITION IN-LINE DISCONNECT HMI CLOSE COMMAND (Relay Word bit)	**3ID02CL** := ____________
THREE-POSITION IN-LINE DISCONNECT HMI OPEN COMMAND (Relay Word bit)	**3ID02OP** := ____________
THREE-POSITION EARTHING DISCONNECT CLOSE STATUS (Relay Word bit)	**3ED02CS** := ____________
THREE-POSITION EARTHING DISCONNECT OPEN STATUS (Relay Word bit)	**3ED02OS** := ____________
THREE-POSITION EARTHING DISCONNECT IN-PROGRESS STATUS (Relay Word bit)	**3ED02IS** := ____________
THREE-POSITION EARTHING DISCONNECT ALARM STATUS (Relay Word bit)	**3ED02AS** := ____________
THREE-POSITION EARTHING DISCONNECT HMI CLOSE COMMAND (Relay Word bit)	**3ED02CL** := ____________
THREE-POSITION EARTHING DISCONNECT HMI OPEN COMMAND (Relay Word bit)	**3ED02OP** := ____________

Analog Label

ANALOG QUANTITY **ALAB01** := ______________________

ANALOG QUANTITY **ALAB02** := ______________________

ANALOG QUANTITY **ALAB03** := ______________________

ANALOG QUANTITY **ALAB04** := ______________________

ANALOG QUANTITY **ALAB05** := ______________________

ANALOG QUANTITY **ALAB06** := ______________________

ANALOG QUANTITY **ALAB07** := ______________________

ANALOG QUANTITY **ALAB08** := ______________________

ANALOG QUANTITY **ALAB09** := ______________________

ANALOG QUANTITY **ALAB10** := ______________________

ANALOG QUANTITY **ALAB11** := ______________________

ANALOG QUANTITY **ALAB12** := ______________________

ANALOG QUANTITY **ALAB13** := ______________________

ANALOG QUANTITY **ALAB14** := ______________________

ANALOG QUANTITY **ALAB15** := ______________________

ANALOG QUANTITY **ALAB16** := ______________________

ANALOG QUANTITY **ALAB17** := ______________________

ANALOG QUANTITY **ALAB18** := ______________________

ANALOG QUANTITY **ALAB19** := ______________________

ANALOG QUANTITY **ALAB20** := ______________________

ANALOG QUANTITY **ALAB21** := ______________________

ANALOG QUANTITY **ALAB22** := ______________________

ANALOG QUANTITY **ALAB23** := ______________________

ANALOG QUANTITY **ALAB24** := ______________________

ANALOG QUANTITY **ALAB25** := ______________________

ANALOG QUANTITY **ALAB26** := ______________________

ANALOG QUANTITY **ALAB27** := ______________________

ANALOG QUANTITY **ALAB28** := ______________________

ANALOG QUANTITY **ALAB29** := ______________________

ANALOG QUANTITY	**ALAB30** := ____________________
ANALOG QUANTITY	**ALAB31** := ____________________
ANALOG QUANTITY	**ALAB32** := ____________________

Digital Label

RELAY WORD BIT	**DLAB01** := ____________________
RELAY WORD BIT	**DLAB02** := ____________________
RELAY WORD BIT	**DLAB03** := ____________________
RELAY WORD BIT	**DLAB04** := ____________________
RELAY WORD BIT	**DLAB05** := ____________________
RELAY WORD BIT	**DLAB06** := ____________________
RELAY WORD BIT	**DLAB07** := ____________________
RELAY WORD BIT	**DLAB08** := ____________________
RELAY WORD BIT	**DLAB09** := ____________________
RELAY WORD BIT	**DLAB10** := ____________________
RELAY WORD BIT	**DLAB11** := ____________________
RELAY WORD BIT	**DLAB12** := ____________________
RELAY WORD BIT	**DLAB13** := ____________________
RELAY WORD BIT	**DLAB14** := ____________________
RELAY WORD BIT	**DLAB15** := ____________________
RELAY WORD BIT	**DLAB16** := ____________________
RELAY WORD BIT	**DLAB17** := ____________________
RELAY WORD BIT	**DLAB18** := ____________________
RELAY WORD BIT	**DLAB19** := ____________________
RELAY WORD BIT	**DLAB20** := ____________________
RELAY WORD BIT	**DLAB21** := ____________________
RELAY WORD BIT	**DLAB22** := ____________________
RELAY WORD BIT	**DLAB23** := ____________________
RELAY WORD BIT	**DLAB24** := ____________________
RELAY WORD BIT	**DLAB25** := ____________________
RELAY WORD BIT	**DLAB26** := ____________________

RELAY WORD BIT	**DLAB27** := ____________
RELAY WORD BIT	**DLAB28** := ____________
RELAY WORD BIT	**DLAB29** := ____________
RELAY WORD BIT	**DLAB30** := ____________
RELAY WORD BIT	**DLAB31** := ____________
RELAY WORD BIT	**DLAB32** := ____________

Report Settings (SET R Command)

SER Chatter Criteria

Auto-Removal Enable (Y, N)	**ESERDEL** := ____________
Number of Counts (2–20 counts) *(Hidden if ESERDEL := N)*	**SRDLCNT** := ____________
Removal Time (0.1–90.0 sec) *(Hidden if ESERDEL := N)*	**SRDLTIM** := ____________

SER Trigger Lists

(SERn = as many as 24 Relay Word elements separated by spaces or commas; use NA to disable setting)

SER1 := ________________________________

SER2 := ________________________________

SER3 := ________________________________

SER4 := ________________________________

Relay Word Bit Aliases

(ALIASn = 'RW Bit'(space)'Alias'(space)'Asserted Text'(space)'Deasserted Text')
(Alias, Asserted, and Deasserted text strings can be as long as 15 characters; use NA to disable setting)

Enable ALIAS Settings (N, 1–32) *(All subsequent ALIAS settings are hidden if EALIAS := N)*	**EALIAS** := ____________
ALIAS 1	**ALIAS1** := ____________
ALIAS 2	**ALIAS2** := ____________
ALIAS 3	**ALIAS3** := ____________
ALIAS 4	**ALIAS4** := ____________
ALIAS 5	**ALIAS5** := ____________
ALIAS 6	**ALIAS6** := ____________
ALIAS 7	**ALIAS7** := ____________

ALIAS 8	**ALIAS8** := ________________
ALIAS 9	**ALIAS9** := ________________
ALIAS 10	**ALIAS10** := ________________
ALIAS 11	**ALIAS11** := ________________
ALIAS 12	**ALIAS12** := ________________
ALIAS 13	**ALIAS13** := ________________
ALIAS 14	**ALIAS14** := ________________
ALIAS 15	**ALIAS15** := ________________
ALIAS 16	**ALIAS16** := ________________
ALIAS 17	**ALIAS17** := ________________
ALIAS 18	**ALIAS18** := ________________
ALIAS 19	**ALIAS19** := ________________
ALIAS 20	**ALIAS20** := ________________
ALIAS 21	**ALIAS21** := ________________
ALIAS 22	**ALIAS22** := ________________
ALIAS 23	**ALIAS23** := ________________
ALIAS 24	**ALIAS24** := ________________
ALIAS 25	**ALIAS25** := ________________
ALIAS 26	**ALIAS26** := ________________
ALIAS 27	**ALIAS27** := ________________
ALIAS 28	**ALIAS28** := ________________
ALIAS 29	**ALIAS29** := ________________
ALIAS 30	**ALIAS30** := ________________
ALIAS 31	**ALIAS31** := ________________
ALIAS 32	**ALIAS32** := ________________

Event Report

EVENT TRIGGER (SELOGIC)	**ER** := ________________
EVENT LENGTH (15, 64, 180 cyc)	**LER** := ________________
PREFAULT LENGTH (1–10 cyc if LER := 15; 1–59 cyc if LER := 64; 1–175 cyc if LER := 180)	**PRE** := ________________

Fast Message Read Settings

(FMRnNAM = any valid string {no spaces allowed; should be different from other FMRxNAM})
(FMRn = as many as 24 analog quantities separated by spaces or commas {analog quantities listed here will be included in the Fast Message read request})
(Use NA to disable setting)

FMR1 Name (9 characters) **FMR1NAM** := ______________

Fast Message Read FMR1 (24 analog quantities) **FMR1** := ______________

FMR2 Name (9 characters) **FMR2NAM** := ______________

Fast Message Read FMR2 (24 analog quantities) **FMR2** := ______________

FMR3 Name (9 characters) **FMR3NAM** := ______________

Fast Message Read FMR3 (24 analog quantities) **FMR3** := ______________

FMR4 Name (9 characters) **FMR4NAM** := ______________

Fast Message Read FMR4 (24 analog quantities) **FMR4** := ______________

Fast Message Remote Analog Settings

(I = Integer, F = Float, L = Long)

Remote Analog Value Type (I, F, L) **RA01TYPE** := ______________

Remote Analog Value Type (I, F, L) **RA02TYPE** := ______________

Remote Analog Value Type (I, F, L) **RA03TYPE** := ______________

Remote Analog Value Type (I, F, L) **RA04TYPE** := ______________

Remote Analog Value Type (I, F, L) **RA05TYPE** := ______________

Remote Analog Value Type (I, F, L) **RA06TYPE** := ______________

Remote Analog Value Type (I, F, L) **RA07TYPE** := ______________

Remote Analog Value Type (I, F, L) **RA08TYPE** := ______________

Remote Analog Value Type (I, F, L) **RA09TYPE** := ______________

Remote Analog Value Type (I, F, L) **RA10TYPE** := ______________

Remote Analog Value Type (I, F, L) **RA11TYPE** := ______________

Remote Analog Value Type (I, F, L) **RA12TYPE** := ______________

Remote Analog Value Type (I, F, L) **RA13TYPE** := ______________

Remote Analog Value Type (I, F, L) **RA14TYPE** := ______________

Remote Analog Value Type (I, F, L) **RA15TYPE** := ______________

Remote Analog Value Type (I, F, L) **RA16TYPE** := ______________

Remote Analog Value Type (I, F, L) **RA17TYPE** := ______________

Date ____________
Group____________

Remote Analog Value Type (I, F, L)	**RA18TYPE** := ____________
Remote Analog Value Type (I, F, L)	**RA19TYPE** := ____________
Remote Analog Value Type (I, F, L)	**RA20TYPE** := ____________
Remote Analog Value Type (I, F, L)	**RA21TYPE** := ____________
Remote Analog Value Type (I, F, L)	**RA22TYPE** := ____________
Remote Analog Value Type (I, F, L)	**RA22TYPE** := ____________
Remote Analog Value Type (I, F, L)	**RA23TYPE** := ____________
Remote Analog Value Type (I, F, L)	**RA24TYPE** := ____________
Remote Analog Value Type (I, F, L)	**RA25TYPE** := ____________
Remote Analog Value Type (I, F, L)	**RA26TYPE** := ____________
Remote Analog Value Type (I, F, L)	**RA27TYPE** := ____________
Remote Analog Value Type (I, F, L)	**RA28TYPE** := ____________
Remote Analog Value Type (I, F, L)	**RA29TYPE** := ____________
Remote Analog Value Type (I, F, L)	**RA30TYPE** := ____________
Remote Analog Value Type (I, F, L)	**RA31TYPE** := ____________
Remote Analog Value Type (I, F, L)	**RA32TYPE** := ____________

Load Profile

LDLIST (NA, as many as 17 analog quantities)	**LDLIST** := ____________
LDP ACQ RATE (5, 10, 15, 30, 60 min)	**LDAR** := ____________

Modbus Map Settings (SET M Command)

Modbus User Map

(See Appendix E: Modbus RTU Communications for additional details)

User Map Register Label Name (8 characters)	**MOD_001** := ____________
User Map Register Label Name (8 characters)	**MOD_002** := ____________
User Map Register Label Name (8 characters)	**MOD_003** := ____________
User Map Register Label Name (8 characters)	**MOD_004** := ____________
User Map Register Label Name (8 characters)	**MOD_005** := ____________
User Map Register Label Name (8 characters)	**MOD_006** := ____________
User Map Register Label Name (8 characters)	**MOD_007** := ____________

User Map Register Label Name (8 characters)	**MOD_008** := ____________
User Map Register Label Name (8 characters)	**MOD_009** := ____________
User Map Register Label Name (8 characters)	**MOD_010** := ____________
User Map Register Label Name (8 characters)	**MOD_011** := ____________
User Map Register Label Name (8 characters)	**MOD_012** := ____________
User Map Register Label Name (8 characters)	**MOD_013** := ____________
User Map Register Label Name (8 characters)	**MOD_014** := ____________
User Map Register Label Name (8 characters)	**MOD_015** := ____________
User Map Register Label Name (8 characters)	**MOD_016** := ____________
User Map Register Label Name (8 characters)	**MOD_017** := ____________
User Map Register Label Name (8 characters)	**MOD_018** := ____________
User Map Register Label Name (8 characters)	**MOD_019** := ____________
User Map Register Label Name (8 characters)	**MOD_020** := ____________
User Map Register Label Name (8 characters)	**MOD_021** := ____________
User Map Register Label Name (8 characters)	**MOD_022** := ____________
User Map Register Label Name (8 characters)	**MOD_023** := ____________
User Map Register Label Name (8 characters)	**MOD_024** := ____________
User Map Register Label Name (8 characters)	**MOD_025** := ____________
User Map Register Label Name (8 characters)	**MOD_026** := ____________
User Map Register Label Name (8 characters)	**MOD_027** := ____________
User Map Register Label Name (8 characters)	**MOD_028** := ____________
User Map Register Label Name (8 characters)	**MOD_029** := ____________
User Map Register Label Name (8 characters)	**MOD_030** := ____________
User Map Register Label Name (8 characters)	**MOD_031** := ____________
User Map Register Label Name (8 characters)	**MOD_032** := ____________
User Map Register Label Name (8 characters)	**MOD_033** := ____________
User Map Register Label Name (8 characters)	**MOD_034** := ____________
User Map Register Label Name (8 characters)	**MOD_035** := ____________
User Map Register Label Name (8 characters)	**MOD_036** := ____________
User Map Register Label Name (8 characters)	**MOD_037** := ____________

User Map Register Label Name (8 characters)	**MOD_038** := ________
User Map Register Label Name (8 characters)	**MOD_039** := ________
User Map Register Label Name (8 characters)	**MOD_040** := ________
User Map Register Label Name (8 characters)	**MOD_041** := ________
User Map Register Label Name (8 characters)	**MOD_042** := ________
User Map Register Label Name (8 characters)	**MOD_043** := ________
User Map Register Label Name (8 characters)	**MOD_044** := ________
User Map Register Label Name (8 characters)	**MOD_045** := ________
User Map Register Label Name (8 characters)	**MOD_046** := ________
User Map Register Label Name (8 characters)	**MOD_047** := ________
User Map Register Label Name (8 characters)	**MOD_048** := ________
User Map Register Label Name (8 characters)	**MOD_049** := ________
User Map Register Label Name (8 characters)	**MOD_050** := ________
User Map Register Label Name (8 characters)	**MOD_051** := ________
User Map Register Label Name (8 characters)	**MOD_052** := ________
User Map Register Label Name (8 characters)	**MOD_053** := ________
User Map Register Label Name (8 characters)	**MOD_054** := ________
User Map Register Label Name (8 characters)	**MOD_055** := ________
User Map Register Label Name (8 characters)	**MOD_056** := ________
User Map Register Label Name (8 characters)	**MOD_057** := ________
User Map Register Label Name (8 characters)	**MOD_058** := ________
User Map Register Label Name (8 characters)	**MOD_059** := ________
User Map Register Label Name (8 characters)	**MOD_060** := ________
User Map Register Label Name (8 characters)	**MOD_061** := ________
User Map Register Label Name (8 characters)	**MOD_062** := ________
User Map Register Label Name (8 characters)	**MOD_063** := ________
User Map Register Label Name (8 characters)	**MOD_064** := ________
User Map Register Label Name (8 characters)	**MOD_065** := ________
User Map Register Label Name (8 characters)	**MOD_066** := ________
User Map Register Label Name (8 characters)	**MOD_067** := ________

User Map Register Label Name (8 characters) **MOD_068** := ______________________
User Map Register Label Name (8 characters) **MOD_069** := ______________________
User Map Register Label Name (8 characters) **MOD_070** := ______________________
User Map Register Label Name (8 characters) **MOD_071** := ______________________
User Map Register Label Name (8 characters) **MOD_072** := ______________________
User Map Register Label Name (8 characters) **MOD_073** := ______________________
User Map Register Label Name (8 characters) **MOD_074** := ______________________
User Map Register Label Name (8 characters) **MOD_075** := ______________________
User Map Register Label Name (8 characters) **MOD_076** := ______________________
User Map Register Label Name (8 characters) **MOD_077** := ______________________
User Map Register Label Name (8 characters) **MOD_078** := ______________________
User Map Register Label Name (8 characters) **MOD_079** := ______________________
User Map Register Label Name (8 characters) **MOD_080** := ______________________
User Map Register Label Name (8 characters) **MOD_081** := ______________________
User Map Register Label Name (8 characters) **MOD_082** := ______________________
User Map Register Label Name (8 characters) **MOD_083** := ______________________
User Map Register Label Name (8 characters) **MOD_084** := ______________________
User Map Register Label Name (8 characters) **MOD_085** := ______________________
User Map Register Label Name (8 characters) **MOD_086** := ______________________
User Map Register Label Name (8 characters) **MOD_087** := ______________________
User Map Register Label Name (8 characters) **MOD_088** := ______________________
User Map Register Label Name (8 characters) **MOD_089** := ______________________
User Map Register Label Name (8 characters) **MOD_090** := ______________________
User Map Register Label Name (8 characters) **MOD_091** := ______________________
User Map Register Label Name (8 characters) **MOD_092** := ______________________
User Map Register Label Name (8 characters) **MOD_093** := ______________________
User Map Register Label Name (8 characters) **MOD_094** := ______________________
User Map Register Label Name (8 characters) **MOD_095** := ______________________
User Map Register Label Name (8 characters) **MOD_096** := ______________________
User Map Register Label Name (8 characters) **MOD_097** := ______________________

Date ____________
Group___________

User Map Register Label Name (8 characters)	**MOD_098** := ______________
User Map Register Label Name (8 characters)	**MOD_099** := ______________
User Map Register Label Name (8 characters)	**MOD_100** := ______________
User Map Register Label Name (8 characters)	**MOD_101** := ______________
User Map Register Label Name (8 characters)	**MOD_102** := ______________
User Map Register Label Name (8 characters)	**MOD_103** := ______________
User Map Register Label Name (8 characters)	**MOD_104** := ______________
User Map Register Label Name (8 characters)	**MOD_105** := ______________
User Map Register Label Name (8 characters)	**MOD_106** := ______________
User Map Register Label Name (8 characters)	**MOD_107** := ______________
User Map Register Label Name (8 characters)	**MOD_108** := ______________
User Map Register Label Name (8 characters)	**MOD_109** := ______________
User Map Register Label Name (8 characters)	**MOD_110** := ______________
User Map Register Label Name (8 characters)	**MOD_111** := ______________
User Map Register Label Name (8 characters)	**MOD_112** := ______________
User Map Register Label Name (8 characters)	**MOD_113** := ______________
User Map Register Label Name (8 characters)	**MOD_114** := ______________
User Map Register Label Name (8 characters)	**MOD_115** := ______________
User Map Register Label Name (8 characters)	**MOD_116** := ______________
User Map Register Label Name (8 characters)	**MOD_117** := ______________
User Map Register Label Name (8 characters)	**MOD_118** := ______________
User Map Register Label Name (8 characters)	**MOD_119** := ______________
User Map Register Label Name (8 characters)	**MOD_120** := ______________
User Map Register Label Name (8 characters)	**MOD_121** := ______________
User Map Register Label Name (8 characters)	**MOD_122** := ______________
User Map Register Label Name (8 characters)	**MOD_123** := ______________
User Map Register Label Name (8 characters)	**MOD_124** := ______________
User Map Register Label Name (8 characters)	**MOD_125** := ______________

EtherNet/IP Assembly Map Settings (SET E Command)

EtherNet/IP Assembly Map

(See Appendix F: EtherNet/IP Communications for additional details)
(EtherNet/IP Assembly Map settings are hidden if EtherNet/IP is not included)
(Use SET E n command where n = 1, 2, or 3 to create as many as three EtherNet/IP Assembly Maps)
(This is EtherNet/IP Assembly Map 1 (EtherNet/IP Assembly Map 2 and EtherNet/IP Assembly Map 3 are identical to EtherNet/IP Assembly Map 1))

Input Assembly (IA) Binary

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_00** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_01** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_02** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_03** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_04** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_05** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_06** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_07** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_08** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_09** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_10** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_11** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_12** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_13** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_14** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_15** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_16** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_17** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_18** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_19** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_20** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_21** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_22** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_23** := ________________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_24** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_25** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_26** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_27** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_28** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_29** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_30** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_31** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_32** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_33** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_34** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_35** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_36** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_37** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_38** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_39** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_40** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_41** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_42** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_43** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_44** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_45** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_46** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_47** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_48** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_49** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_50** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_51** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_52** :=	____________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_53** :=	____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_54** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_55** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_56** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_57** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_58** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_59** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_60** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_61** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_62** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_63** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_64** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_65** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_66** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_67** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_68** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_69** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_70** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_71** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_72** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_73** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_74** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_75** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_76** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_77** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_78** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_79** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_80** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_81** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_82** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters) **IAB_83** := ____________

EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_84** := ______________________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_85** := ______________________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_86** := ______________________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_87** := ______________________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_88** := ______________________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_89** := ______________________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_90** := ______________________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_91** := ______________________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_92** := ______________________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_93** := ______________________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_94** := ______________________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_95** := ______________________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_96** := ______________________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_97** := ______________________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_98** := ______________________
EIP INPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**IAB_99** := ______________________

Input Assembly (IA) Analog

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_00** := ______________________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_01** := ______________________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_02** := ______________________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_03** := ______________________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_04** := ______________________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_05** := ______________________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_06** := ______________________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_07** := ______________________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_08** := ______________________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_09** := ______________________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_10** := ______________________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_11** := ______________________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_12** := ______________________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_13** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_14** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_15** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_16** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_17** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_18** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_19** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_20** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_21** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_22** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_23** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_24** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_25** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_26** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_27** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_28** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_29** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_30** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_31** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_32** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_33** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_34** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_35** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_36** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_37** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_38** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_39** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_40** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_41** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_42** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_43** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_44** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_45** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_46** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_47** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_48** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_49** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_50** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_51** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_52** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_53** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_54** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_55** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_56** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_57** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_58** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_59** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_60** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_61** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_62** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_63** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_64** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_65** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_66** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_67** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_68** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_69** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_70** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_71** := ______________
EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**IAA_72** := ______________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_73** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_74** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_75** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_76** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_77** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_78** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_79** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_80** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_81** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_82** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_83** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_84** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_85** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_86** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_87** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_88** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_89** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_90** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_91** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_92** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_93** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_94** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_95** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_96** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_97** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_98** := ____________

EIP INPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **IAA_99** := ____________

Output Assembly (OA) Binary

EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters) **OAB_00** := ____________

EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters) **OAB_01** := ____________

Date ____________
Group ___________

EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_02** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_03** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_04** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_05** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_06** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_07** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_08** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_09** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_10** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_11** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_12** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_13** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_14** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_15** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_16** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_17** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_18** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_19** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_20** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_21** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_22** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_23** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_24** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_25** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_26** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_27** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_28** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_29** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_30** := ______________
EIP OUTPUT ASSEMBLY BINARY LABEL NAME (10 characters)	**OAB_31** := ______________

Output Assembly (OA) Analog

EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_00** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_01** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_02** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_03** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_04** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_05** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_06** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_07** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_08** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_09** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_10** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_11** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_12** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_13** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_14** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_15** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_16** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_17** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_18** :=	______________
EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters)	**OAA_19** :=	______________

EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **OAA_20** := ______________________

EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **OAA_21** := ______________________

EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **OAA_22** := ______________________

EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **OAA_23** := ______________________

EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **OAA_24** := ______________________

EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **OAA_25** := ______________________

EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **OAA_26** := ______________________

EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **OAA_27** := ______________________

EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **OAA_28** := ______________________

EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **OAA_29** := ______________________

EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **OAA_30** := ______________________

EIP OUTPUT ASSEMBLY ANALOG LABEL NAME (10 characters) **OAA_31** := ______________________

DNP3 Map Settings (SET DNP n Command)

(Hidden if the DNP option is not included)
(Use SET DNP n command with n = 1, 2, or 3 to create as many as three DNP User Maps; refer to Appendix D: DNP3 Communications 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 (10 characters) **BI_00** := ______________________

DNP Binary Input Label Name (10 characters) **BI_01** := ______________________

DNP Binary Input Label Name (10 characters) **BI_02** := ______________________

DNP Binary Input Label Name (10 characters) **BI_03** := ______________________

DNP Binary Input Label Name (10 characters) **BI_04** := ______________________

DNP Binary Input Label Name (10 characters) **BI_05** := ______________________

DNP Binary Input Label Name (10 characters) **BI_06** := ______________________

DNP Binary Input Label Name (10 characters) **BI_07** := ____________

DNP Binary Input Label Name (10 characters) **BI_08** := ____________

DNP Binary Input Label Name (10 characters) **BI_09** := ____________

DNP Binary Input Label Name (10 characters) **BI_10** := ____________

DNP Binary Input Label Name (10 characters) **BI_11** := ____________

DNP Binary Input Label Name (10 characters) **BI_12** := ____________

DNP Binary Input Label Name (10 characters) **BI_13** := ____________

DNP Binary Input Label Name (10 characters) **BI_14** := ____________

DNP Binary Input Label Name (10 characters) **BI_15** := ____________

DNP Binary Input Label Name (10 characters) **BI_16** := ____________

DNP Binary Input Label Name (10 characters) **BI_17** := ____________

DNP Binary Input Label Name (10 characters) **BI_18** := ____________

DNP Binary Input Label Name (10 characters) **BI_19** := ____________

DNP Binary Input Label Name (10 characters) **BI_20** := ____________

DNP Binary Input Label Name (10 characters) **BI_21** := ____________

DNP Binary Input Label Name (10 characters) **BI_22** := ____________

DNP Binary Input Label Name (10 characters) **BI_23** := ____________

DNP Binary Input Label Name (10 characters) **BI_24** := ____________

DNP Binary Input Label Name (10 characters) **BI_25** := ____________

DNP Binary Input Label Name (10 characters) **BI_26** := ____________

DNP Binary Input Label Name (10 characters) **BI_27** := ____________

DNP Binary Input Label Name (10 characters) **BI_28** := ____________

DNP Binary Input Label Name (10 characters) **BI_29** := ____________

DNP Binary Input Label Name (10 characters) **BI_30** := ____________

DNP Binary Input Label Name (10 characters) **BI_31** := ____________

DNP Binary Input Label Name (10 characters) **BI_32** := ____________

DNP Binary Input Label Name (10 characters) **BI_33** := ____________

DNP Binary Input Label Name (10 characters) **BI_34** := ____________

DNP Binary Input Label Name (10 characters) **BI_35** := ____________

DNP Binary Input Label Name (10 characters) **BI_36** := ____________

DNP Binary Input Label Name (10 characters)	**BI_37** := ________________
DNP Binary Input Label Name (10 characters)	**BI_38** := ________________
DNP Binary Input Label Name (10 characters)	**BI_39** := ________________
DNP Binary Input Label Name (10 characters)	**BI_40** := ________________
DNP Binary Input Label Name (10 characters)	**BI_41** := ________________
DNP Binary Input Label Name (10 characters)	**BI_42** := ________________
DNP Binary Input Label Name (10 characters)	**BI_43** := ________________
DNP Binary Input Label Name (10 characters)	**BI_44** := ________________
DNP Binary Input Label Name (10 characters)	**BI_45** := ________________
DNP Binary Input Label Name (10 characters)	**BI_46** := ________________
DNP Binary Input Label Name (10 characters)	**BI_47** := ________________
DNP Binary Input Label Name (10 characters)	**BI_48** := ________________
DNP Binary Input Label Name (10 characters)	**BI_49** := ________________
DNP Binary Input Label Name (10 characters)	**BI_50** := ________________
DNP Binary Input Label Name (10 characters)	**BI_51** := ________________
DNP Binary Input Label Name (10 characters)	**BI_52** := ________________
DNP Binary Input Label Name (10 characters)	**BI_53** := ________________
DNP Binary Input Label Name (10 characters)	**BI_54** := ________________
DNP Binary Input Label Name (10 characters)	**BI_55** := ________________
DNP Binary Input Label Name (10 characters)	**BI_56** := ________________
DNP Binary Input Label Name (10 characters)	**BI_57** := ________________
DNP Binary Input Label Name (10 characters)	**BI_58** := ________________
DNP Binary Input Label Name (10 characters)	**BI_59** := ________________
DNP Binary Input Label Name (10 characters)	**BI_60** := ________________
DNP Binary Input Label Name (10 characters)	**BI_61** := ________________
DNP Binary Input Label Name (10 characters)	**BI_62** := ________________
DNP Binary Input Label Name (10 characters)	**BI_63** := ________________
DNP Binary Input Label Name (10 characters)	**BI_64** := ________________
DNP Binary Input Label Name (10 characters)	**BI_65** := ________________
DNP Binary Input Label Name (10 characters)	**BI_66** := ________________

DNP Binary Input Label Name (10 characters)	**BI_67** := ____________
DNP Binary Input Label Name (10 characters)	**BI_68** := ____________
DNP Binary Input Label Name (10 characters)	**BI_69** := ____________
DNP Binary Input Label Name (10 characters)	**BI_70** := ____________
DNP Binary Input Label Name (10 characters)	**BI_71** := ____________
DNP Binary Input Label Name (10 characters)	**BI_72** := ____________
DNP Binary Input Label Name (10 characters)	**BI_73** := ____________
DNP Binary Input Label Name (10 characters)	**BI_74** := ____________
DNP Binary Input Label Name (10 characters)	**BI_75** := ____________
DNP Binary Input Label Name (10 characters)	**BI_76** := ____________
DNP Binary Input Label Name (10 characters)	**BI_77** := ____________
DNP Binary Input Label Name (10 characters)	**BI_78** := ____________
DNP Binary Input Label Name (10 characters)	**BI_79** := ____________
DNP Binary Input Label Name (10 characters)	**BI_80** := ____________
DNP Binary Input Label Name (10 characters)	**BI_81** := ____________
DNP Binary Input Label Name (10 characters)	**BI_82** := ____________
DNP Binary Input Label Name (10 characters)	**BI_83** := ____________
DNP Binary Input Label Name (10 characters)	**BI_84** := ____________
DNP Binary Input Label Name (10 characters)	**BI_85** := ____________
DNP Binary Input Label Name (10 characters)	**BI_86** := ____________
DNP Binary Input Label Name (10 characters)	**BI_87** := ____________
DNP Binary Input Label Name (10 characters)	**BI_88** := ____________
DNP Binary Input Label Name (10 characters)	**BI_89** := ____________
DNP Binary Input Label Name (10 characters)	**BI_90** := ____________
DNP Binary Input Label Name (10 characters)	**BI_91** := ____________
DNP Binary Input Label Name (10 characters)	**BI_92** := ____________
DNP Binary Input Label Name (10 characters)	**BI_93** := ____________
DNP Binary Input Label Name (10 characters)	**BI_94** := ____________
DNP Binary Input Label Name (10 characters)	**BI_95** := ____________
DNP Binary Input Label Name (10 characters)	**BI_96** := ____________

DNP Binary Input Label Name (10 characters) **BI_97** := ____________________

DNP Binary Input Label Name (10 characters) **BI_98** := ____________________

DNP Binary Input Label Name (10 characters) **BI_99** := ____________________

Binary Output Map

DNP Binary Output Label Name (10 characters) **BO_00** := ____________________

DNP Binary Output Label Name (10 characters) **BO_01** := ____________________

DNP Binary Output Label Name (10 characters) **BO_02** := ____________________

DNP Binary Output Label Name (10 characters) **BO_03** := ____________________

DNP Binary Output Label Name (10 characters) **BO_04** := ____________________

DNP Binary Output Label Name (10 characters) **BO_05** := ____________________

DNP Binary Output Label Name (10 characters) **BO_06** := ____________________

DNP Binary Output Label Name (10 characters) **BO_07** := ____________________

DNP Binary Output Label Name (10 characters) **BO_08** := ____________________

DNP Binary Output Label Name (10 characters) **BO_09** := ____________________

DNP Binary Output Label Name (10 characters) **BO_10** := ____________________

DNP Binary Output Label Name (10 characters) **BO_11** := ____________________

DNP Binary Output Label Name (10 characters) **BO_12** := ____________________

DNP Binary Output Label Name (10 characters) **BO_13** := ____________________

DNP Binary Output Label Name (10 characters) **BO_14** := ____________________

DNP Binary Output Label Name (10 characters) **BO_15** := ____________________

DNP Binary Output Label Name (10 characters) **BO_16** := ____________________

DNP Binary Output Label Name (10 characters) **BO_17** := ____________________

DNP Binary Output Label Name (10 characters) **BO_18** := ____________________

DNP Binary Output Label Name (10 characters) **BO_19** := ____________________

DNP Binary Output Label Name (10 characters) **BO_20** := ____________________

DNP Binary Output Label Name (10 characters) **BO_21** := ____________________

DNP Binary Output Label Name (10 characters) **BO_22** := ____________________

DNP Binary Output Label Name (10 characters) **BO_23** := ____________________

DNP Binary Output Label Name (10 characters) **BO_24** := ____________________

DNP Binary Output Label Name (10 characters) **BO_25** := ____________________

DNP Binary Output Label Name (10 characters) **BO_26** := ____________________

DNP Binary Output Label Name (10 characters) **BO_27** := ____________________

DNP Binary Output Label Name (10 characters) **BO_28** := ____________________

DNP Binary Output Label Name (10 characters) **BO_29** := ____________________

DNP Binary Output Label Name (10 characters) **BO_30** := ____________________

DNP Binary Output Label Name (10 characters) **BO_31** := ____________________

Analog Input Map

DNP Analog Input Label Name (24 characters)

AI_00 := ____________________

AI_01 := ____________________

AI_02 := ____________________

AI_03 := ____________________

AI_04 := ____________________

AI_05 := ____________________

AI_06 := ____________________

AI_07 := ____________________

AI_08 := ____________________

AI_09 := ____________________

AI_10 := ____________________

AI_11 := ____________________

AI_12 := ____________________

AI_13 := ____________________

AI_14 := ____________________

AI_15 := ____________________

AI_16 := ____________________

AI_17 := ____________________

AI_18 := ____________________

AI_19 := ____________________

AI_20 := ____________________

AI_21 := ______

AI_22 := ______

AI_23 := ______

AI_24 := ______

AI_25 := ______

AI_26 := ______

AI_27 := ______

AI_28 := ______

AI_29 := ______

AI_30 := ______

AI_31 := ______

AI_32 := ______

AI_33 := ______

AI_34 := ______

AI_35 := ______

AI_36 := ______

AI_37 := ______

AI_38 := ______

AI_39 := ______

AI_40 := ______

AI_41 := ______

AI_42 := ______

AI_43 := ______

AI_44 := ______

AI_45 := ______

AI_46 := ______

AI_47 := ______

AI_48 := ______

AI_49 := ______

AI_50 := ______

AI_51 := ______
AI_52 := ______
AI_53 := ______
AI_54 := ______
AI_55 := ______
AI_56 := ______
AI_57 := ______
AI_58 := ______
AI_59 := ______
AI_60 := ______
AI_61 := ______
AI_62 := ______
AI_63 := ______
AI_64 := ______
AI_65 := ______
AI_66 := ______
AI_67 := ______
AI_68 := ______
AI_69 := ______
AI_70 := ______
AI_71 := ______
AI_72 := ______
AI_73 := ______
AI_74 := ______
AI_75 := ______
AI_76 := ______
AI_77 := ______
AI_78 := ______
AI_79 := ______
AI_80 := ______

AI_81 := ______________________________

AI_82 := ______________________________

AI_83 := ______________________________

AI_84 := ______________________________

AI_85 := ______________________________

AI_86 := ______________________________

AI_87 := ______________________________

AI_88 := ______________________________

AI_89 := ______________________________

AI_90 := ______________________________

AI_91 := ______________________________

AI_92 := ______________________________

AI_93 := ______________________________

AI_94 := ______________________________

AI_95 := ______________________________

AI_96 := ______________________________

AI_97 := ______________________________

AI_98 := ______________________________

AI_99 := ______________________________

Analog Output Map

DNP Analog Output Label Name (6 characters) **AO_00** := ____________

DNP Analog Output Label Name (6 characters) **AO_01** := ____________

DNP Analog Output Label Name (6 characters) **AO_02** := ____________

DNP Analog Output Label Name (6 characters) **AO_03** := ____________

DNP Analog Output Label Name (6 characters) **AO_04** := ____________

DNP Analog Output Label Name (6 characters) **AO_05** := ____________

DNP Analog Output Label Name (6 characters) **AO_06** := ____________

DNP Analog Output Label Name (6 characters) **AO_07** := ____________

DNP Analog Output Label Name (6 characters) **AO_08** := ____________

DNP Analog Output Label Name (6 characters)	**AO_09** := ________________
DNP Analog Output Label Name (6 characters)	**AO_10** := ________________
DNP Analog Output Label Name (6 characters)	**AO_11** := ________________
DNP Analog Output Label Name (6 characters)	**AO_12** := ________________
DNP Analog Output Label Name (6 characters)	**AO_13** := ________________
DNP Analog Output Label Name (6 characters)	**AO_14** := ________________
DNP Analog Output Label Name (6 characters)	**AO_15** := ________________
DNP Analog Output Label Name (6 characters)	**AO_16** := ________________
DNP Analog Output Label Name (6 characters)	**AO_17** := ________________
DNP Analog Output Label Name (6 characters)	**AO_18** := ________________
DNP Analog Output Label Name (6 characters)	**AO_19** := ________________
DNP Analog Output Label Name (6 characters)	**AO_20** := ________________
DNP Analog Output Label Name (6 characters)	**AO_21** := ________________
DNP Analog Output Label Name (6 characters)	**AO_22** := ________________
DNP Analog Output Label Name (6 characters)	**AO_23** := ________________
DNP Analog Output Label Name (6 characters)	**AO_24** := ________________
DNP Analog Output Label Name (6 characters)	**AO_25** := ________________
DNP Analog Output Label Name (6 characters)	**AO_26** := ________________
DNP Analog Output Label Name (6 characters)	**AO_27** := ________________
DNP Analog Output Label Name (6 characters)	**AO_28** := ________________
DNP Analog Output Label Name (6 characters)	**AO_29** := ________________
DNP Analog Output Label Name (6 characters)	**AO_30** := ________________
DNP Analog Output Label Name (6 characters)	**AO_31** := ________________

Counter Map

DNP Counter Label Name (11 characters)	**CO_00** := ________________
DNP Counter Label Name (11 characters)	**CO_01** := ________________
DNP Counter Label Name (11 characters)	**CO_02** := ________________
DNP Counter Label Name (11 characters)	**CO_03** := ________________
DNP Counter Label Name (11 characters)	**CO_04** := ________________
DNP Counter Label Name (11 characters)	**CO_05** := ________________

DNP Counter Label Name (11 characters)	**CO_06** := ________________
DNP Counter Label Name (11 characters)	**CO_07** := ________________
DNP Counter Label Name (11 characters)	**CO_08** := ________________
DNP Counter Label Name (11 characters)	**CO_09** := ________________
DNP Counter Label Name (11 characters)	**CO_10** := ________________
DNP Counter Label Name (11 characters)	**CO_11** := ________________
DNP Counter Label Name (11 characters)	**CO_12** := ________________
DNP Counter Label Name (11 characters)	**CO_13** := ________________
DNP Counter Label Name (11 characters)	**CO_14** := ________________
DNP Counter Label Name (11 characters)	**CO_15** := ________________
DNP Counter Label Name (11 characters)	**CO_16** := ________________
DNP Counter Label Name (11 characters)	**CO_17** := ________________
DNP Counter Label Name (11 characters)	**CO_18** := ________________
DNP Counter Label Name (11 characters)	**CO_19** := ________________
DNP Counter Label Name (11 characters)	**CO_20** := ________________
DNP Counter Label Name (11 characters)	**CO_21** := ________________
DNP Counter Label Name (11 characters)	**CO_22** := ________________
DNP Counter Label Name (11 characters)	**CO_23** := ________________
DNP Counter Label Name (11 characters)	**CO_24** := ________________
DNP Counter Label Name (11 characters)	**CO_25** := ________________
DNP Counter Label Name (11 characters)	**CO_26** := ________________
DNP Counter Label Name (11 characters)	**CO_27** := ________________
DNP Counter Label Name (11 characters)	**CO_28** := ________________
DNP Counter Label Name (11 characters)	**CO_29** := ________________
DNP Counter Label Name (11 characters)	**CO_30** := ________________
DNP Counter Label Name (11 characters)	**CO_31** := ________________

IEC 60870-5-103 Map Settings (SET I Command)

(Hidden if the IEC 60870-5-103 option is not included)
(Use the SET I command to input the map required for the IEC 60870-5-103 protocol)

Binary Input Map

Binary Input Label Name (10 characters)	**103BI00** := ______________
Binary Input Label Name (10 characters)	**103BI01** := ______________
Binary Input Label Name (10 characters)	**103BI02** := ______________
Binary Input Label Name (10 characters)	**103BI03** := ______________
Binary Input Label Name (10 characters)	**103BI04** := ______________
Binary Input Label Name (10 characters)	**103BI05** := ______________
Binary Input Label Name (10 characters)	**103BI06** := ______________
Binary Input Label Name (10 characters)	**103BI07** := ______________
Binary Input Label Name (10 characters)	**103BI08** := ______________
Binary Input Label Name (10 characters)	**103BI09** := ______________
Binary Input Label Name (10 characters)	**103BI10** := ______________
Binary Input Label Name (10 characters)	**103BI11** := ______________
Binary Input Label Name (10 characters)	**103BI12** := ______________
Binary Input Label Name (10 characters)	**103BI13** := ______________
Binary Input Label Name (10 characters)	**103BI14** := ______________
Binary Input Label Name (10 characters)	**103BI15** := ______________
Binary Input Label Name (10 characters)	**103BI16** := ______________
Binary Input Label Name (10 characters)	**103BI17** := ______________
Binary Input Label Name (10 characters)	**103BI18** := ______________
Binary Input Label Name (10 characters)	**103BI19** := ______________
Binary Input Label Name (10 characters)	**103BI20** := ______________
Binary Input Label Name (10 characters)	**103BI21** := ______________
Binary Input Label Name (10 characters)	**103BI22** := ______________
Binary Input Label Name (10 characters)	**103BI23** := ______________
Binary Input Label Name (10 characters)	**103BI24** := ______________
Binary Input Label Name (10 characters)	**103BI25** := ______________

Binary Input Label Name (10 characters)	**103BI26** := ________________
Binary Input Label Name (10 characters)	**103BI27** := ________________
Binary Input Label Name (10 characters)	**103BI28** := ________________
Binary Input Label Name (10 characters)	**103BI29** := ________________
Binary Input Label Name (10 characters)	**103BI30** := ________________
Binary Input Label Name (10 characters)	**103BI31** := ________________
Binary Input Label Name (10 characters)	**103BI32** := ________________
Binary Input Label Name (10 characters)	**103BI33** := ________________
Binary Input Label Name (10 characters)	**103BI34** := ________________
Binary Input Label Name (10 characters)	**103BI35** := ________________
Binary Input Label Name (10 characters)	**103BI36** := ________________
Binary Input Label Name (10 characters)	**103BI37** := ________________
Binary Input Label Name (10 characters)	**103BI38** := ________________
Binary Input Label Name (10 characters)	**103BI39** := ________________
Binary Input Label Name (10 characters)	**103BI40** := ________________
Binary Input Label Name (10 characters)	**103BI41** := ________________
Binary Input Label Name (10 characters)	**103BI42** := ________________
Binary Input Label Name (10 characters)	**103BI43** := ________________
Binary Input Label Name (10 characters)	**103BI44** := ________________
Binary Input Label Name (10 characters)	**103BI45** := ________________
Binary Input Label Name (10 characters)	**103BI46** := ________________
Binary Input Label Name (10 characters)	**103BI47** := ________________
Binary Input Label Name (10 characters)	**103BI48** := ________________
Binary Input Label Name (10 characters)	**103BI49** := ________________
Binary Input Label Name (10 characters)	**103BI50** := ________________
Binary Input Label Name (10 characters)	**103BI51** := ________________
Binary Input Label Name (10 characters)	**103BI52** := ________________
Binary Input Label Name (10 characters)	**103BI53** := ________________
Binary Input Label Name (10 characters)	**103BI54** := ________________
Binary Input Label Name (10 characters)	**103BI55** := ________________

Binary Input Label Name (10 characters) **103BI56** := ________________

Binary Input Label Name (10 characters) **103BI57** := ________________

Binary Input Label Name (10 characters) **103BI58** := ________________

Binary Input Label Name (10 characters) **103BI59** := ________________

Binary Input Label Name (10 characters) **103BI60** := ________________

Binary Input Label Name (10 characters) **103BI61** := ________________

Binary Input Label Name (10 characters) **103BI62** := ________________

Binary Input Label Name (10 characters) **103BI63** := ________________

Binary Input Label Name (10 characters) **103BI64** := ________________

Binary Input Label Name (10 characters) **103BI65** := ________________

Binary Input Label Name (10 characters) **103BI66** := ________________

Binary Input Label Name (10 characters) **103BI67** := ________________

Binary Input Label Name (10 characters) **103BI68** := ________________

Binary Input Label Name (10 characters) **103BI69** := ________________

Binary Input Label Name (10 characters) **103BI70** := ________________

Binary Input Label Name (10 characters) **103BI71** := ________________

Binary Input Label Name (10 characters) **103BI72** := ________________

Binary Input Label Name (10 characters) **103BI73** := ________________

Binary Input Label Name (10 characters) **103BI74** := ________________

Binary Input Label Name (10 characters) **103BI75** := ________________

Binary Input Label Name (10 characters) **103BI76** := ________________

Binary Input Label Name (10 characters) **103BI77** := ________________

Binary Input Label Name (10 characters) **103BI78** := ________________

Binary Input Label Name (10 characters) **103BI79** := ________________

Binary Input Label Name (10 characters) **103BI80** := ________________

Binary Input Label Name (10 characters) **103BI81** := ________________

Binary Input Label Name (10 characters) **103BI82** := ________________

Binary Input Label Name (10 characters) **103BI83** := ________________

Binary Input Label Name (10 characters) **103BI84** := ________________

Binary Input Label Name (10 characters) **103BI85** := ________________

Date ____________
Group___________

Binary Input Label Name (10 characters)	**103BI86** := ____________
Binary Input Label Name (10 characters)	**103BI87** := ____________
Binary Input Label Name (10 characters)	**103BI88** := ____________
Binary Input Label Name (10 characters)	**103BI89** := ____________
Binary Input Label Name (10 characters)	**103BI90** := ____________
Binary Input Label Name (10 characters)	**103BI91** := ____________
Binary Input Label Name (10 characters)	**103BI92** := ____________
Binary Input Label Name (10 characters)	**103BI93** := ____________
Binary Input Label Name (10 characters)	**103BI94** := ____________
Binary Input Label Name (10 characters)	**103BI95** := ____________
Binary Input Label Name (10 characters)	**103BI96** := ____________
Binary Input Label Name (10 characters)	**103BI97** := ____________
Binary Input Label Name (10 characters)	**103BI98** := ____________
Binary Input Label Name (10 characters)	**103BI99** := ____________

Binary Target Map

Binary Target Label Name (10 characters)	**103BT00** := ____________
Binary Target Label Name (10 characters)	**103BT01** := ____________
Binary Target Label Name (10 characters)	**103BT02** := ____________
Binary Target Label Name (10 characters)	**103BT03** := ____________
Binary Target Label Name (10 characters)	**103BT04** := ____________
Binary Target Label Name (10 characters)	**103BT05** := ____________
Binary Target Label Name (10 characters)	**103BT06** := ____________
Binary Target Label Name (10 characters)	**103BT07** := ____________

Fault Analog Map

Fault Analog Label Name (10 characters)	**103FA00** := ____________
Fault Analog Label Name (10 characters)	**103FA01** := ____________
Fault Analog Label Name (10 characters)	**103FA02** := ____________
Fault Analog Label Name (10 characters)	**103FA03** := ____________
Fault Analog Label Name (10 characters)	**103FA04** := ____________

Fault Analog Label Name (10 characters) **103FA05** := ______________
Fault Analog Label Name (10 characters) **103FA06** := ______________
Fault Analog Label Name (10 characters) **103FA07** := ______________
Fault Analog Label Name (10 characters) **103FA08** := ______________
Fault Analog Label Name (10 characters) **103FA09** := ______________
Fault Analog Label Name (10 characters) **103FA10** := ______________
Fault Analog Label Name (10 characters) **103FA11** := ______________
Fault Analog Label Name (10 characters) **103FA12** := ______________
Fault Analog Label Name (10 characters) **103FA13** := ______________
Fault Analog Label Name (10 characters) **103FA14** := ______________
Fault Analog Label Name (10 characters) **103FA15** := ______________
Fault Analog Label Name (10 characters) **103FA16** := ______________
Fault Analog Label Name (10 characters) **103FA17** := ______________
Fault Analog Label Name (10 characters) **103FA18** := ______________
Fault Analog Label Name (10 characters) **103FA19** := ______________
Fault Analog Label Name (10 characters) **103FA20** := ______________
Fault Analog Label Name (10 characters) **103FA21** := ______________
Fault Analog Label Name (10 characters) **103FA22** := ______________
Fault Analog Label Name (10 characters) **103FA23** := ______________
Fault Analog Label Name (10 characters) **103FA24** := ______________
Fault Analog Label Name (10 characters) **103FA25** := ______________
Fault Analog Label Name (10 characters) **103FA26** := ______________
Fault Analog Label Name (10 characters) **103FA27** := ______________
Fault Analog Label Name (10 characters) **103FA28** := ______________
Fault Analog Label Name (10 characters) **103FA29** := ______________
Fault Analog Label Name (10 characters) **103FA30** := ______________
Fault Analog Label Name (10 characters) **103FA31** := ______________

Binary Control Map

Binary Control Label Name (10 characters) **103BO00** := ______________
Binary Control Label Name (10 characters) **103BO01** := ______________

Binary Control Label Name (10 characters)	**103BO02** := ________
Binary Control Label Name (10 characters)	**103BO03** := ________
Binary Control Label Name (10 characters)	**103BO04** := ________
Binary Control Label Name (10 characters)	**103BO05** := ________
Binary Control Label Name (10 characters)	**103BO06** := ________
Binary Control Label Name (10 characters)	**103BO07** := ________
Binary Control Label Name (10 characters)	**103BO08** := ________
Binary Control Label Name (10 characters)	**103BO09** := ________
Binary Control Label Name (10 characters)	**103BO10** := ________
Binary Control Label Name (10 characters)	**103BO11** := ________
Binary Control Label Name (10 characters)	**103BO12** := ________
Binary Control Label Name (10 characters)	**103BO13** := ________
Binary Control Label Name (10 characters)	**103BO14** := ________
Binary Control Label Name (10 characters)	**103BO15** := ________
Binary Control Label Name (10 characters)	**103BO16** := ________
Binary Control Label Name (10 characters)	**103BO17** := ________
Binary Control Label Name (10 characters)	**103BO18** := ________
Binary Control Label Name (10 characters)	**103BO19** := ________
Binary Control Label Name (10 characters)	**103BO20** := ________
Binary Control Label Name (10 characters)	**103BO21** := ________
Binary Control Label Name (10 characters)	**103BO22** := ________
Binary Control Label Name (10 characters)	**103BO23** := ________
Binary Control Label Name (10 characters)	**103BO24** := ________
Binary Control Label Name (10 characters)	**103BO25** := ________
Binary Control Label Name (10 characters)	**103BO26** := ________
Binary Control Label Name (10 characters)	**103BO27** := ________
Binary Control Label Name (10 characters)	**103BO28** := ________
Binary Control Label Name (10 characters)	**103BO29** := ________
Binary Control Label Name (10 characters)	**103BO30** := ________
Binary Control Label Name (10 characters)	**103BO31** := ________

Measurand Map

Measurand Label Name (10 characters)	**3MLB000** := ________________
Measurand Label Name (10 characters)	**3MLB001** := ________________
Measurand Label Name (10 characters)	**3MLB002** := ________________
Measurand Label Name (10 characters)	**3MLB003** := ________________
Measurand Label Name (10 characters)	**3MLB004** := ________________
Measurand Label Name (10 characters)	**3MLB005** := ________________
Measurand Label Name (10 characters)	**3MLB006** := ________________
Measurand Label Name (10 characters)	**3MLB007** := ________________
Measurand Label Name (10 characters)	**3MLB008** := ________________
Measurand Label Name (10 characters)	**3MLB009** := ________________
Measurand Label Name (10 characters)	**3MLB010** := ________________
Measurand Label Name (10 characters)	**3MLB011** := ________________
Measurand Label Name (10 characters)	**3MLB012** := ________________
Measurand Label Name (10 characters)	**3MLB013** := ________________
Measurand Label Name (10 characters)	**3MLB014** := ________________
Measurand Label Name (10 characters)	**3MLB015** := ________________
Measurand Label Name (10 characters)	**3MLB016** := ________________
Measurand Label Name (10 characters)	**3MLB017** := ________________
Measurand Label Name (10 characters)	**3MLB018** := ________________
Measurand Label Name (10 characters)	**3MLB019** := ________________
Measurand Label Name (10 characters)	**3MLB020** := ________________
Measurand Label Name (10 characters)	**3MLB021** := ________________
Measurand Label Name (10 characters)	**3MLB022** := ________________
Measurand Label Name (10 characters)	**3MLB023** := ________________
Measurand Label Name (10 characters)	**3MLB024** := ________________
Measurand Label Name (10 characters)	**3MLB025** := ________________
Measurand Label Name (10 characters)	**3MLB026** := ________________
Measurand Label Name (10 characters)	**3MLB027** := ________________
Measurand Label Name (10 characters)	**3MLB028** := ________________

Measurand Label Name (10 characters) **3MLB029** := ________________

Measurand Label Name (10 characters) **3MLB030** := ________________

Measurand Label Name (10 characters) **3MLB031** := ________________

Measurand Label Name (10 characters) **3MLB032** := ________________

Measurand Label Name (10 characters) **3MLB033** := ________________

Measurand Label Name (10 characters) **3MLB034** := ________________

Measurand Label Name (10 characters) **3MLB035** := ________________

Measurand Label Name (10 characters) **3MLB036** := ________________

Measurand Label Name (10 characters) **3MLB037** := ________________

Measurand Label Name (10 characters) **3MLB038** := ________________

Measurand Label Name (10 characters) **3MLB039** := ________________

Measurand Label Name (10 characters) **3MLB040** := ________________

Measurand Label Name (10 characters) **3MLB041** := ________________

Measurand Label Name (10 characters) **3MLB042** := ________________

Measurand Label Name (10 characters) **3MLB043** := ________________

Measurand Label Name (10 characters) **3MLB044** := ________________

Measurand Label Name (10 characters) **3MLB045** := ________________

Measurand Label Name (10 characters) **3MLB046** := ________________

Measurand Label Name (10 characters) **3MLB047** := ________________

Measurand Label Name (10 characters) **3MLB048** := ________________

Measurand Label Name (10 characters) **3MLB049** := ________________

Measurand Label Name (10 characters) **3MLB050** := ________________

Section 7
Communications

Overview

A communications interface and protocol are required for communicating with the SEL-787 Transformer Protection Relay. A communications interface is the physical connection on a device. Once you have established a physical connection, you must use a communications protocol to interact with the relay.

The first part of this section describes communications interfaces and protocols available with the relay, including communications interface connections. The remainder of the section describes the ASCII commands you can use to communicate with the relay to obtain information, reports, data, or perform control functions.

Communications Interfaces

The SEL-787 physical interfaces are shown in *Table 7.1*. Several optional SEL devices are available to provide alternative physical interfaces, including EIA-485, EIA-232 fiber-optic serial port, copper or fiber-optic Ethernet port, single- or dual-redundant.

Table 7.1 SEL-787 Communications Port Interfaces

Port	Communication Port Interface	Location	Feature
PORT F	EIA-232	Front	Standard
PORT 1	Option 1: 10/100BASE-T Ethernet (RJ45 connector) Option 2: Dual, redundant 10/100BASE-T Ethernet (Port 1A, Port 1B) Option 3: 100BASE-FX Ethernet (LC connector) Option 4: Dual, redundant 100BASE-FX Ethernet (Port 1A, Port 1B)	Rear	Ordering Option
PORT 2[a]	Multimode Fiber-Optic Serial (ST connector)	Rear	Standard
PORT 3	Option 1: EIA-232 Option 2: EIA-485	Rear	Ordering Option
PORT 4	Option 1: EIA-232 or EIA-485 Serial Communications Card Option 2: DeviceNet Communications Card[b]	Rear	Ordering Option

[a] This port can receive the RTD measurement information from the optional external SEL-2600 RTD Module. Refer to the SEL-2600 RTD Module Instruction Manual for information on the fiber-optic interface.
[b] Refer to Appendix I: DeviceNet Communications for information on the DeviceNet communications card.

Be sure to evaluate the installation and communications necessary to integrate with existing devices before ordering your SEL-787. For example, consider the fiber-optic interface in noisy installations or for large communications distances. Following is general information on possible applications of the different interfaces.

Serial (EIA-232 and EIA-485) Port

Use the EIA-232 port for communications distances as long as 15 m (49 ft) in low noise environments. Use the optional EIA-485 port for communications distances as long as 1200 m (3937 ft) maximum distance (to achieve this performance, ensure proper line termination at the receiver).

To connect a PC serial port to the relay front-panel serial port and enter relay commands, you need the following:

- ➤ A personal computer equipped with one available EIA-232 serial port
- ➤ A communications cable to connect the computer serial port to the relay serial ports
- ➤ Terminal emulation software to control the computer serial port
- ➤ An SEL-787 Relay

Some of the SEL devices available for integration or communications system robustness are included in the following list:

- ➤ SEL communications processors (SEL-2032, SEL-2030, SEL-2020), SEL-3530 Real-Time Automation Controller (RTAC)
- ➤ SEL-2800 Series Fiber-Optic Transceivers
- ➤ SEL-2890 Ethernet Transceiver
- ➤ SEL-3010 Event Messenger
- ➤ SEL-2505 Remote I/O Module (with SEL-2812 compatible ST fiber-optic port) for connection to relay fiber-optic serial Port 2, or use SEL-2505 with EIA-232 (DB-9) serial port to connect to EIA-232 Port 3 on the relay

A variety of terminal emulation programs on personal computers can communicate with the relay. For the best display, use VT-100 terminal emulation or the closest variation.

The default settings for all EIA-232 serial ports are as follows:

Data Rate = 9600
Data Bits = 8
Parity = N
Stop Bits = 1

To change the port settings, use the **SET P** command (see *Section 6: Settings*) or the front panel. *Section 8: Front-Panel Operations* provides details on making settings with the front panel.

Hardware Flow Control

All EIA-232 serial ports support RTS/CTS hardware handshaking (hardware flow control). To enable hardware handshaking, use the **SET P** command or front-panel `PORT` submenu 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.

Fiber-Optic Serial Port

Use the fiber-optic port (Port 2) for safety and communications distances as far as 1 km. Communications distances as far as 4 km can be achieved by using an SEL-2812 transceiver on Port 3. While Port 2 and the SEL-2812 are compatible, Port 2 is less sensitive than the SEL-2812, which limits the distance to 1 km. This port can receive the RTD measurement information from the optional external SEL-2600 RTD Module.

Telnet or Web Server

NOTE: Telnet and the web server work with other NETMODE settings also, but NETMODE = SWITCHED is easiest to begin communication. The relay hides setting NETMODE when equipped with a single Ethernet port.

Factory-default settings for the Ethernet ports disable all Ethernet protocols except Telnet, HTTP, and PING. Command **SET P 1** accesses settings for both Ethernet ports on the SEL-787: Port 1A and Port 1B. Use the **SET P 1** command to make the following settings:

- IPADDR := IP address assigned by network administrator
- DEFRTR := Default router IP address assigned by network administrator
- NETMODE := SWITCHED (available with dual Ethernet ports)
- ETELNET := Y
- EHTTP := Y

Leave all other settings at their factory-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 autocrossover, so nearly any Cat 5 Ethernet cable with RJ45 connectors, such as an SEL-C627 cable, will work. When the computer does not support autocrossover, use a crossover cable, such as an SEL-C628 cable. If your relay is equipped with dual Ethernet ports, connect to either port. Use a Telnet application or ACSELERATOR QuickSet SEL-5030 Software on the host PC to communicate with the relay. To terminate a Telnet session, use the **EXIT** command from any access level.

In addition, you can communicate with the relay through your web browser. Launch a web browser and enter address http://IPADDR for nonsecure HTTP communication, where IPADDR is the Port 1 IPADDR setting. To terminate the session, close the web browser (see *Section 3: PC Interface* for more details).

Ethernet Port

Use the Ethernet port for interfacing with an Ethernet network environment. SEL-787 Ethernet port choices include single or dual copper or fiber-optic configurations. With dual Ethernet ports the unit has an unmanaged Ethernet switch. Redundant configurations support automatic failover switching from the primary to the backup network if the relay detects a failure in the primary network. The basic concept in the Parallel Redundancy Protocol (PRP) mode of operation is that the Ethernet network and all traffic are fully duplicated with the two copies operating in parallel. The purpose of the protocol is to provide seamless recovery from any single Ethernet network failure. In addition to failover and PRP modes, the unit can operate in a “fixed connection (to netport) mode” or in a “switched mode” (as an unmanaged switch).

Consider working with a networking professional to design your Ethernet network to maximize reliability, minimize system administrator efforts, and provide adequate security.

Several settings control how the relay with the optional Ethernet card operates on an Ethernet network. These settings include IP addressing information, network port failover options, and network speed.

Use the network configuration settings shown in *Table 4.65* to configure the relay for operation on an IP network and to set other parameters affecting the physical Ethernet network interface operation.

Figure 7.1 shows an example of a simple Ethernet network configuration, *Figure 7.2* shows an example of an Ethernet network configuration with dual redundant connections, and *Figure 7.3* shows an example of an Ethernet network configuration with ring structure.

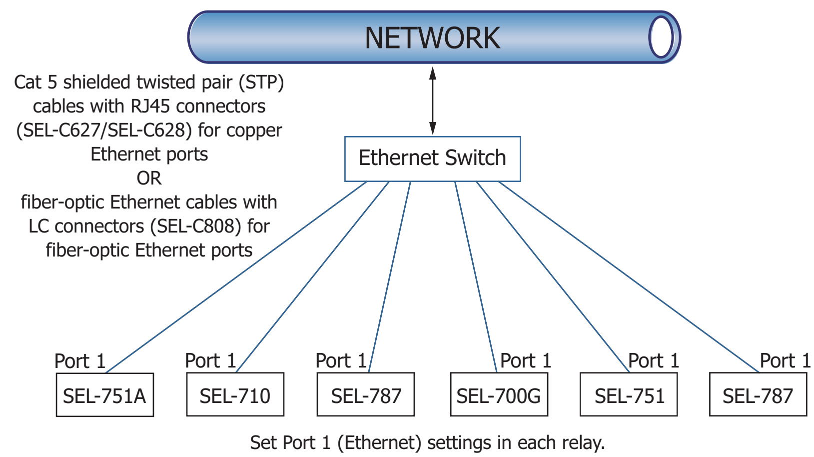


Figure 7.1 Simple Ethernet Network Configuration

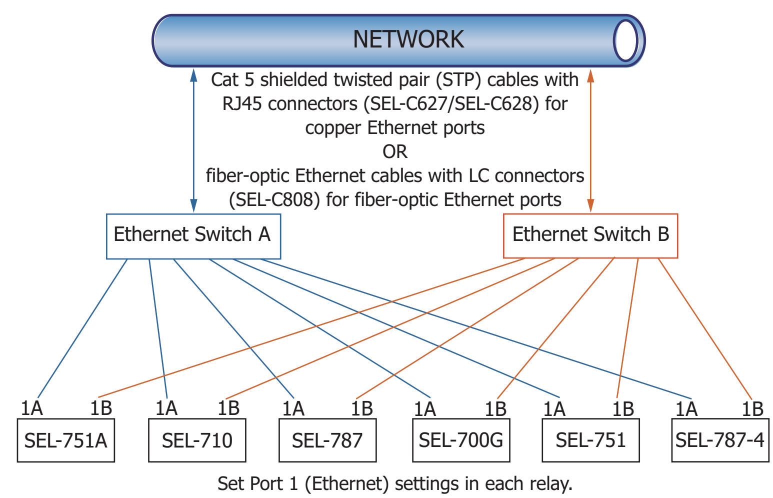


Figure 7.2 Ethernet Network Configuration With Dual Redundant Connections (Failover Mode)

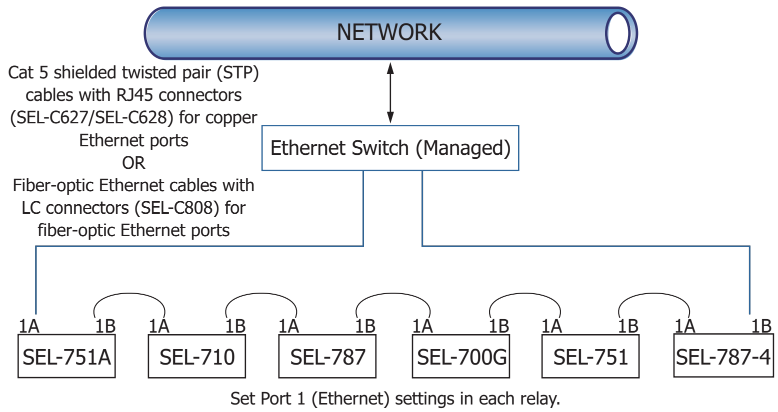


Figure 7.3 Ethernet Network Configuration With Ring Structure (Switched Mode)

Dual Network Port Operation

The SEL-787 dual Ethernet port option has two network ports. Network port failover mode enables the dual Ethernet port to operate as a single network adapter with a primary and standby physical interface. You can connect the two network ports to the same network or to different networks depending on your specific Ethernet network architecture.

Failover Mode

In the failover mode operation, the relay determines the active port. To use failover mode, proceed with the following steps.

NOTE: If you change settings for the host port in the relay and the standby network port is active, the relay resets and returns to operation on the primary port.

Step 1. Set NETMODE to FAILOVER.

Step 2. Set FTIME to the desired network port failover time (OFF, 0.10–65.00 seconds).

Step 3. Set NETPORT to the preferred network interface.

On startup the relay communicates via NETPORT (primary port) selected. If the SEL-787 detects a link failure on the primary port, it activates the standby port after the failover time, FTIME, elapses. If the link status on the primary link returns to normal before the failover time expires, the failover timer resets and uninterrupted operation continues on the primary network port.

Setting FTIME = OFF allows fast port switching (with no intentional delay). Fast port switching can occur within one processing interval (typically 4 to 5 ms) and can help with IEC 61850 GOOSE performance.

After failover, while communicating via standby port, the SEL-787 checks the primary link periodically and continues checking until it detects a normal link status. The relay continues to communicate via the standby port even after the primary port returns to normal. The port of choice for communications is reevaluated on change of settings or failure of the standby port or on reboot. The relay returns to operation on the primary link under those conditions if it detects a normal link status. When the active and backup links both fail, the relay alternates checking for the link status of the primary and standby ports.

Switched Mode

If you have a network configuration where you want to use the relay as an unmanaged or managed switch, set NETMODE to SWITCHED. Set ERSTP := Y to use it as a managed switch. In SWITCHED mode, both links are enabled. The relay responds to the messages it receives on either port. All the messages received on one network port that are not addressed to the relay are transmitted out of the other port without any modifications. In this mode, the relay ignores the NETPORT setting.

SWITCHED mode is often used to connect several relays to each other, creating a network of relays, then connecting at least two relays to a managed switch for redundancy. This configuration is popular because it reduces cost and reduces the number of devices in a network without sacrificing redundancy. Basically, each relay has a redundant path to the network. Refer to *Figure 7.3*.

There are compromises to be made in this configuration, however. When connecting cables between multiple switches in an Ethernet network, physical loops (rings) may occur that cause traffic storms, total bandwidth consumption, and other improper functioning. As a result, a subset of the relays in this configuration can seem unresponsive for extended periods of time.

For example, in *Figure 7.3*, imagine that a DNP master is receiving DNP UDP unsolicited messages from the relays. When a link is broken, it can sometimes take as long as 5 minutes for communications to be restored. For a similar network involving IEC 61850 GOOSE and a broken link, the restoration time can be greater than 5 seconds. The relay offers Rapid Spanning Tree Protocol (RSTP) mode to improve restoration times in such configurations. With RSTP enabled, the expected restoration time of the before-mentioned GOOSE network is around 100 ms.

RSTP protocol controls active paths in an Ethernet network to avoid loops and enable a level of redundancy. All Port 1 protocols are supported when RSTP is enabled. Refer to *Rapid Spanning Tree Protocol (RSTP) on page 7.22* for additional details.

Fixed Connection Mode

If you have a single network and want to use only one network port, or if you have both ports connected but want to force usage of only one port for various reasons, set NETMODE to FIXED and set NETPORT to the port you want to use. Only the selected network port operates and the other port is disabled.

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 for Port 1 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 settings shown in *Table 7.2* are hidden.

Table 7.2 PRP Settings

Setting Prompt	Setting Description	Setting Range	Setting Name := Default Value
PRP ENTRY TIMEOUT	PRP Entry Timeout	400–10000 ms	PRPTOUT := 500
PRP DESTINATION ADDR LSB	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	0–255	PRPADDR := 0
PRP SUPERVISION TX INTERVAL	PRP Supervision TX Interval	1–10 sec	PRPINTV := 2

Autonegotiation, Speed, and Duplex Mode

Single or dual copper Ethernet ports are capable of autonegotiating to determine the link speed and duplex mode. This is accomplished by setting the NETASPD and NETBSPD (network speed) to AUTO. Single or dual copper ports can also be set to a specific speed to be able to apply them in networks with older switch devices. However, the speed setting is ignored for fiber Ethernet ports. The single and dual fiber Ethernet ports are fixed by the hardware to work at 100 Mbps and full duplex mode.

Network Storm Detection

In an Ethernet network, a storm of messages can occur when an incorrect network configuration causes network loops. These network storms can disrupt relay communication. To mitigate such storms, the relay periodically checks the number of messages received over the Ethernet ports. When the relay receives an excessive amount of Ethernet traffic, the relay asserts the STORMDET (storm detect) Relay Word bit and stops processing Ethernet messages. However, the Bridge Protocol Data Units (BPDUs) are processed irrespective of the state of the STORMDET Relay Word bit.

NETPORT Selection

The NETPORT setting gives the you the option to select the primary port of communication in failover or fixed communication modes.

TCP Keep Alive

NOTE: The ETCPKA setting applies to all TCP traffic on Ethernet ports, including Telnet, FTP, IEC 61850, MMS, and C37.118 (PMU). TCP Keep Alive is enabled with default KAIDLE, KAINTV, and KACNT settings for C37.118 (PMU) sessions even when ETCPKA = N.

The ETCPKA setting, along with the KAIDLE, KAINTV, and KACNT settings, can be used to verify that the computer at the remote end of a TCP connection is still available. If ETCPKA is enabled and the relay does not transmit any TCP data within the interval specified by the KAIDLE setting, the relay sends a keep-alive packet to the remote computer. If the relay does not receive a response from the remote computer within the time specified by KAINTV, the keep-alive packet is re-transmitted as many as KACNT times. After this count is reached, the relay considers the remote device no longer available, so the relay terminates the connection without waiting for the idle timer (TIDLE or FTPIDLE) to expire.

The relay monitors MMS inactivity to identify and disconnect MMS clients that have stopped communicating. You can set it from 0 to 4,200,000 seconds via the IED Properties MMS Settings in ACSELERATOR Architect SEL-5032 Software. The MMS inactivity default value is either 120 seconds or 900 seconds, depending on the relay firmware version. Setting this value to 0 disables the MMS inactivity timer. If enabled, the relay starts a timer for an MMS session after it receives an MMS request from the client on that session. It resets the timer whenever it receives a new MMS request from that client. When the timer runs out, the relay disconnects the MMS session, making it available for other MMS clients.

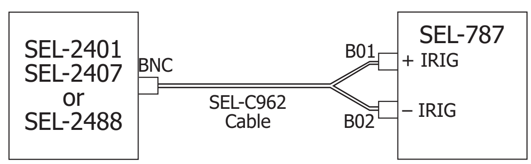
This feature was implemented in addition to the TCP keep-alive timer to specifically handle MMS clients that do not disconnect properly. As there are a limited number of MMS sessions available, this ensures that misbehaving MMS clients do not take up multiple MMS sessions. Note that the MMS inactivity time-out can still disconnect an MMS session even if the relay receives TCP keep-alive messages from that MMS client.

IRIG-B

The SEL-787 has three different physical interfaces, depending on the model options, to provide demodulated IRIG-B time-code input for time synchronization. If the relay has multiple options for IRIG-B input, only one input can be used at a time. Connection diagrams for IRIG-B and settings selection are in *Figure 7.4* through *Figure 7.8* in this section.

Option 1: Terminals B01 and B02

This input is available on all models except models with a dual Ethernet port or a fiber-optic Ethernet port. Refer to *Figure 7.4* for a connection diagram.



B01–B02 IRIG-B input is available on all models except those with fiber-optic Ethernet or dual-copper Ethernet.

If you use a **B01–B02** input, you cannot bring IRIG-B via Port 2 or 3.

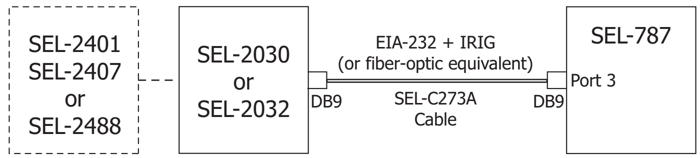
Set Global setting IRIG TIME SOURCE to TIME_SRC := IRIG1.

Figure 7.4 IRIG-B Input (Relay Terminals B01–B02)

Option 2: Port 3 (EIA-232 Option Only)

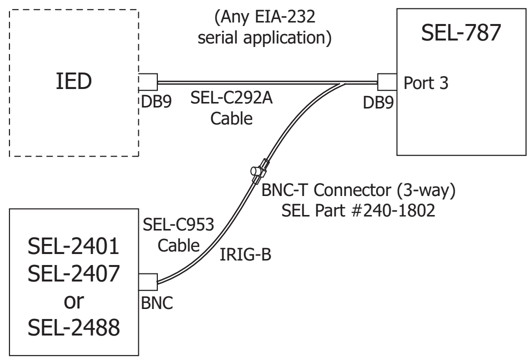
Connect to an SEL communications processor with SEL-C273A Cable to bring IRIG-B input with the EIA-232 Port. Refer to *Figure 7.5* for a connection diagram.

Refer to *Figure 7.6* on how to connect a SEL Time Source (SEL-2401, SEL-2407, or SEL-2488) for IRIG-B input to Port 3.



If you use Port 3, you cannot use **B01**–**B02** input or Port 2.
Set Global setting IRIG TIME SOURCE to TIME_SRC := IRIG1.

Figure 7.5 IRIG-B Input Via EIA-232 Port 3 (SEL Communications Processor as Source)

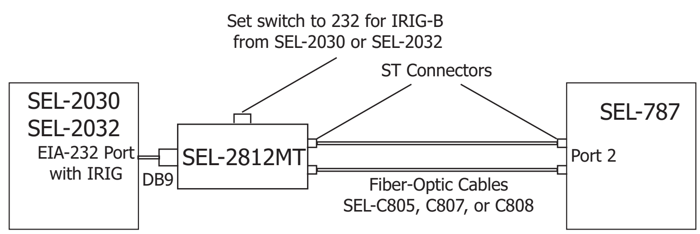


If you use Port 3, you cannot use **B01**–**B02** input or Port 2.
Set Global setting IRIG TIME SOURCE to TIME_SRC := IRIG1.

Figure 7.6 IRIG-B Input Via EIA-232 Port 3 (SEL-2401/2407/2488 Time Source)

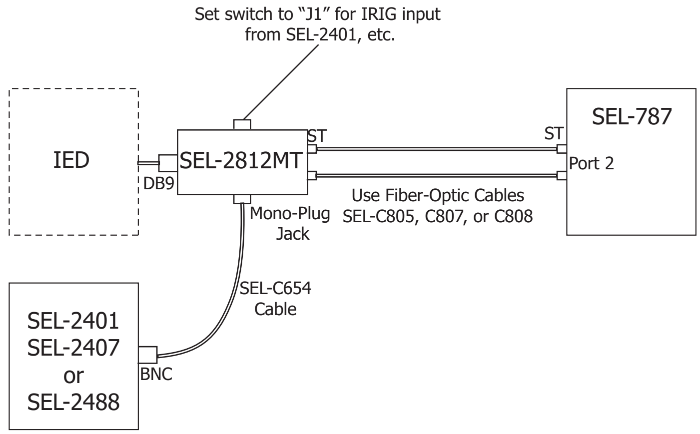
Option 3: Port 2 (Fiber-Optic Serial Port)

Fiber-Optic Serial Port 2 can be used to bring IRIG-B Input to the relay as shown in *Figure 7.7* and *Figure 7.8*.



If you use Port 2 for IRIG-B input, you cannot use **B01**–**B02** input or Port 3 input.
Set Global setting IRIG TIME SOURCE to TIME_SRC := IRIG2.

Figure 7.7 IRIG-B Input Via Fiber-Optic EIA-232 Port 2 (SEL-2030/2032 Time Source)



If you use Port 2 for the IRIG-B input, you cannot use B01–B02 input or Port 3 input.
Set Global setting IRIG TIME SOURCE to TIME_SRC := IRIG2.

Figure 7.8 IRIG-B Input Via Fiber-Optic EIA-232 Port 2 (SEL-2401/2407/2488 Time Source)

+5 Vdc Power Supply

Serial port power can provide as much as 0.25 A total from all of the +5 Vdc pins. Some SEL communications devices require the +5 Vdc power supply. This +5 Vdc is available on Pin 1 only on EIA-232 Port 3 and Port 4.

Connect Your PC to the Relay

The front port of the SEL-787 is a standard female 9-pin connector with pin numbering shown in *Figure 7.9*. The pinout assignments for this port are shown in *Table 7.3*. You can connect to a standard 9-pin computer port with an SEL-C234A Cable; wiring for this cable is shown in *Figure 7.10*. The SEL-C234A Cable and other cables are available from SEL. Use the SEL-5801 Cable Selector Software to select an appropriate cable for another application. This software is available for free download from the SEL website at selinc.com.

For best performance, SEL-C234A Cable should not be more than 15 m (49 ft) long. For long-distance communications and for electrical isolation of communications ports, use the SEL family of fiber-optic transceivers. Contact SEL for more details on these devices.

Port Connector and Communications Cables

Figure 7.9 shows the front-panel EIA-232 serial port (PORT F) DB-9 connector pinout for the SEL-787.

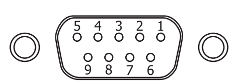


Figure 7.9 EIA-232 DB-9 Connector Pin Numbers

Table 7.3 shows the pin functions for the EIA-232 and EIA-485 serial ports.

Table 7.3 EIA-232/EIA-485 Serial Port Pin Functions

Pin[a]	PORT 3 EIA-232	PORT 3 EIA-485[a]	PORT 4C EIA-232	PORT 4A EIA-485[a]	PORT F EIA-232
1	+5 Vdc	+TX	+5 Vdc	+TX	N/C
2	RXD	–TX	RXD	–TX	RXD
3	TXD	+RX	TXD	+RX	TXD
4	IRIG+	–RX	N/C	–RX	N/C
5	GND	Shield	GND	Shield	GND
6	IRIG–		N/C		N/C
7	RTS		RTS		RTS
8	CTS		CTS		CTS
9	GND		GND		GND

[a] For EIA-485, the pin numbers represent relay terminals _01 through _05.

NOTE: Serial communications cables that are used in the SEL-787 Relays for the MIRRORED BITS protocol should have the **R** designation at the end of the SEL cable number instead of an **A**, e.g., use C234**R** instead of C234**A**. The SEL-C234**R** cable is double shielded and provides better data integrity compared to SEL-C234**A**.

The following cable diagrams show several types of EIA-232 serial communications cables that connect the SEL-787 to other devices. These and other cables are available from SEL. Contact the factory for more information.

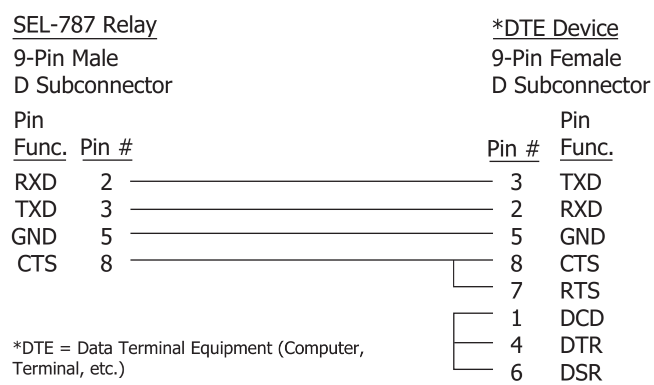


Figure 7.10 SEL-C234A Cable—SEL-787 to DTE Device

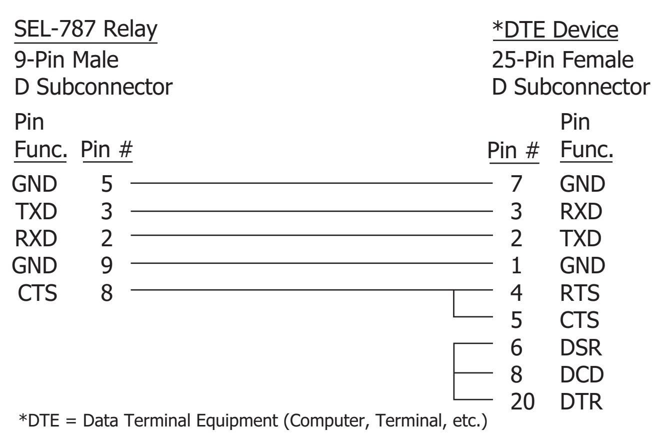


Figure 7.11 SEL-C227A Cable—SEL-787 to DTE Device

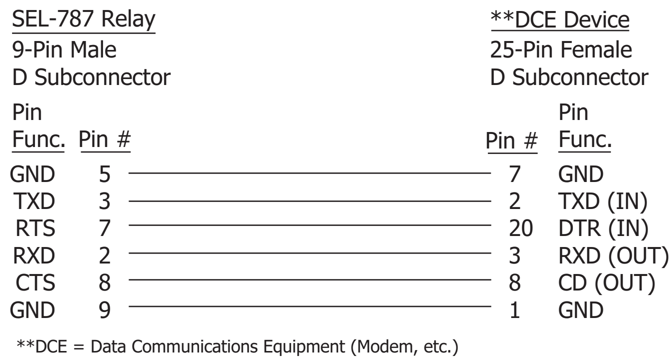


Figure 7.12 SEL-C222 Cable—SEL-787 to Modem

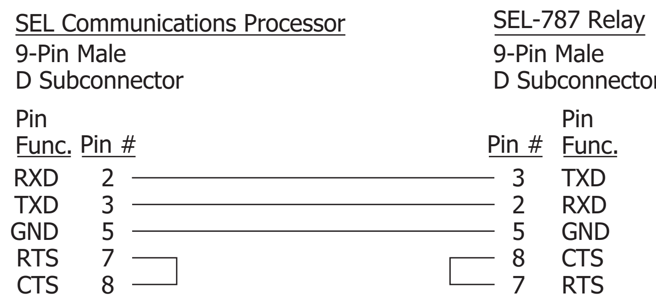


Figure 7.13 SEL-C272A Cable—SEL-787 to SEL Communications Processor (Without IRIG-B Signal)

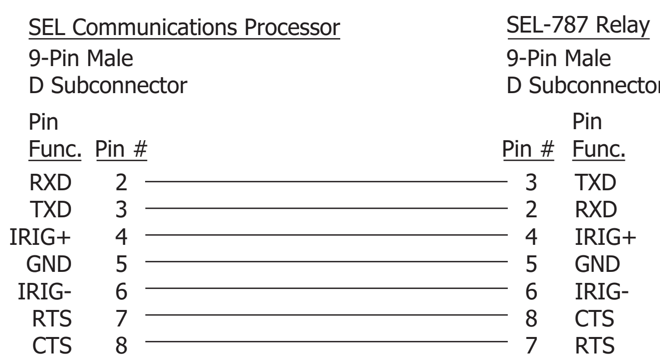


Figure 7.14 SEL-C273A Cable—SEL-787 to SEL Communications Processor (With IRIG-B Signal)

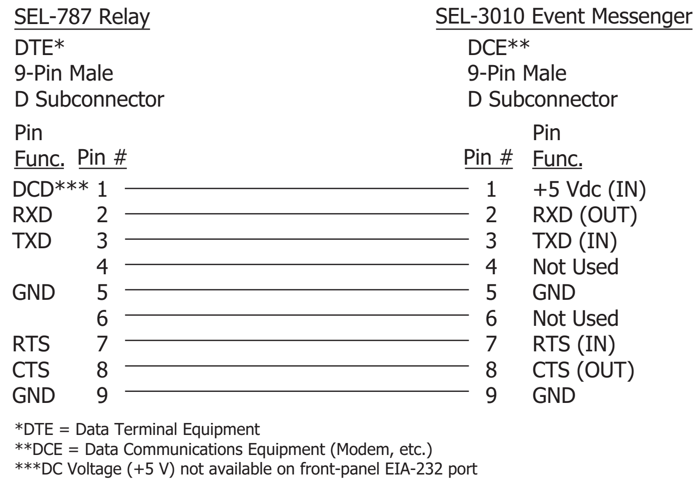


Figure 7.15 SEL-C387 Cable—SEL-787 to SEL-3010

Communications Protocols

Protocols

Although the SEL-787 supports a wide range of protocols, not all protocols are available on all ports. In addition, not all hardware options support all protocols.

Be sure to select the correct hardware to support a particular protocol. For example, if Modbus TCP is necessary for your application, be sure to order the Ethernet option for Port 1. *Table 7.4* shows the ports and the protocols available on each port.

NOTE: FTP, Modbus, and DeviceNet protocols ignore the hide rules of the settings.

Table 7.4 Protocols Supported on the Various Ports

PORT	Supported Protocol
PORT F	SEL ASCII and Compressed ASCII Protocols, SELBOOT, Modbus RTU Slave, IEEE C37.118 Protocol (synchrophasor data), and Event Messenger
PORT 1[a]	Modbus TCP/IP, FTP, EtherNet/IP, IEC 61850, DNP3 LAN/WAN, SNTP, IEEE 1588-2008 firmware-based PTP, Telnet (SEL ASCII, Compressed ASCII, SEL Fast Meter, SEL Fast Operate, SEL Fast SER, SEL Fast Message), C37.118 Protocol (synchrophasor data), PRP, and RSTP
PORT 2	SEL ASCII and Compressed ASCII Protocols, SEL Fast Meter, SEL Fast Operate, SEL Fast SER, SEL Fast Message, MIRRORED BITS, DNP3, IEC 60870-5-103, Modbus RTU Slave, IEEE C37.118 Protocol (synchrophasor data), and Event Messenger
PORT 3	All the protocols supported by PORT 2
PORT 4	All the protocols supported by PORT 2 and DeviceNet

[a] PORT 1 concurrently supports two Modbus, two FTP, two Telnet, five DNP3 LAN/WAN, one SNTP, one PTP, two IEEE C37.118 (synchrophasor data), and seven IEC 61850 sessions, as well as two EIP I/O connections and six EIP message connections.

SEL Communications Protocols

SEL ASCII

This protocol is described in *SEL ASCII Protocol and Commands on page 7.26*.

SEL Compressed ASCII

This protocol provides compressed versions of some of the ASCII commands. The compressed commands are described in *SEL ASCII Protocol and Commands*, and the protocol is described in *Appendix C: SEL Communications Processors*.

SEL Fast Meter

This protocol supports binary messages to transfer metering and digital element messages. Compressed ASCII commands that support Fast Meter are described in *SEL ASCII Protocol and Commands*, and the protocol is described in *Appendix C: SEL Communications Processors*.

SEL Fast Operate

This protocol supports binary messages to transfer operation messages. The protocol is described in *Appendix C: SEL Communications Processors*.

SEL Fast Message

This protocol uses binary messages to receive and transmit data from or to an SEL Communications Processor. The protocol is described in *Appendix C: SEL Communications Processors*.

SEL Fast SER

This protocol is used to receive binary Sequential Events Record unsolicited responses. The protocol is described in *Appendix C: SEL Communications Processors*.

SEL Event Messenger

This is an SEL ASCII protocol with 8 data bits, no parity, and 1 stop bit for transmitting data to the SEL-3010 Event Messenger. Only the communications speed is user settable to match the settings in the SEL-3010. See *Event Messenger Points on page 4.118*.

Other Supported Protocols

MIRRORED BITS Protocol

The SEL-787 supports two MIRRORED BITS communications channels, designated A and B. Within each MIRRORED BITS communications message for a given channel (A or B), there are eight logical data channels (1–8). You can, for example, set MBA on **Port 3** of the base unit and MBB on **Port 4A** of the optional communications card. Attempting to set the PROTO setting to MBA, MB8A, or MBTA when Channel A is already assigned to another port (or MBB, MB8B, or MBTB when Channel B is already assigned on another port) results in the following error message: `This Mirrored Bits channel is assigned to another port`. After displaying the error message, the device returns to the PROTO setting for reentry. The MIRRORED BITS protocol is described in *Appendix J: MIRRORED BITS Communications*.

IEEE C37.118 Protocol

The SEL-787 provides IEEE C37.118 protocol (synchrophasor data) support at serial ports F, 2, 3, or 4. Additionally, Port 1 allows two IEEE C37.118 protocol sessions. The IEEE C37.118 protocol is described in *Appendix K: Synchrophasors*.

Modbus RTU Protocol

The SEL-787 provides Modbus RTU support. Modbus is a protocol described in *Appendix E: Modbus Communications*.

Distributed Network Protocol (DNP3)

The SEL-787 provides DNP3 protocol support if the option is selected. The DNP3 protocol is described in *Appendix D: DNP3 Communications*.

DeviceNet Protocol

The SEL-787 provides DeviceNet support. DeviceNet is an optional protocol described in *Appendix I: DeviceNet Communications*.

IEC 60870-5-103 Protocol

The SEL-787 provides IEC 60870-5-103 protocol support if the option is selected. The protocol is available on Ports **2**, **3**, and **4**. All ports operate using the same map settings. The IEC 60870-5-103 protocol is described in *Appendix H: IEC 60870-5-103 Communications*.

Ethernet Protocols

As with other communications interfaces, you must choose a data exchange protocol that operates over the Ethernet network link to exchange data. The relay supports FTP, Telnet, Ping, Modbus TCP, HTTP, DNP3 LAN/WAN, IEEE C37.118, and IEC 61850 protocols.

Consider working with a networking professional to design your Ethernet network. You should carefully design your Ethernet network to maximize reliability, minimize system administration effort, and provide adequate security.

File Transfer Protocol (FTP) and MMS File Transfer

FTP is a standard protocol for exchanging files between computers over a TCP/IP network. The SEL-787 operates as an FTP server, presenting files to FTP clients. To create an FTP session, you need the FTP username and password. The default username and password are FTPUSER and TAIL, respectively. The SEL-787 supports two FTP sessions at a time. Requests to establish additional FTP sessions are denied.

Manufacturing message 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 7.73* for information on available files.

File dates within the last 12 months are displayed with month, day, hour, and minutes. Dates older than twelve 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 1 setting FTPUSER as the user name in your FTP application. Enter the Port 1 setting FTPACC level 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 the Port 1 setting E61850 is set to Y. No authentication is required. 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 G: IEC 61850 Communications* for information about using MMS.

Telnet Server

Use the Telnet session (TPORT default setting is Port 23) to connect to the relay to use the protocols, which are described in more detail below:

- SEL ASCII
- Compressed ASCII
- Fast Meter
- Fast Operate
- Fast SER

NOTE: Use the **QUIT** command prior to closing the Telnet-to-Host session to set the relay to Access Level 0. Otherwise, the relay remains at an elevated access level until TIDLE expires.

Telnet is a terminal connection across a TCP/IP network that operates in a manner very similar to a direct serial port connection to one of the relay ports. As with FTP, Telnet is a part of TCP/IP. A free Telnet application is included with most computer operating systems, or you can obtain low-cost or free Telnet applications on the Internet.

Ping Server

Ping is an application based on ICMP over an IP network. A free Ping application is included with most computer operating systems. Use a Ping client with the relay Ping server to verify that your network configuration is correct.

IEEE C37.118 Protocol

The SEL-787 provides two streams of IEEE C37.118 protocol (synchrophasor data) support at the Ethernet ports. The IEEE C37.118 protocol is described in *Appendix K: Synchrophasors*.

IEC 61850

Use as many as seven sessions of MMS over a TCP network to exchange data with the relay. Use GOOSE to do real-time data exchange with as many as 64 incoming messages and 8 outgoing messages. For more details on the IEC 61850 protocol, see *Appendix G: IEC 61850 Communications*.

Simple Network Time Protocol (SNTP)

When Port 1 (Ethernet port) setting ESNTP is not OFF, the internal clock of the relay 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. 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 bit TSOK or Relay Word bit IRIGOK asserts, 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 IRIGOK deassert) then the relay synchronizes the internal time-of-day clock to the NTP server, if available. In this way, an NTP server acts either as 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 website, describe how to create an NTP server.

- *AN2009-10: Using an SEL-2401, SEL-2404, or SEL-2407 to Serve NTP Via the SEL-3530 RTAC*
- *AN2009-38: Using SEL Satellite-Synchronized Clocks With the SEL-3332 or SEL-3354 to Output NTP*
- *AN2010-03: Using an SEL-2401, SEL-2404, or SEL-2407 to Create a Stratum 1 Linux NTP Server*

Configuring SNTP Client in the Relay

To enable SNTP in the relay, make the Port 1 setting ESNTP := UNICAST, MANYCAST, or BROADCAST. *Table 7.5* shows each setting associated with SNTP.

Table 7.5 Settings Associated With SNTP

Setting Prompt	Setting Range	Setting Name := Factory Default	Description
ENABLE SNTP CLIENT	OFF, UNICAST, MANYCAST, BROADCAST	ESNTP := OFF	Selects the mode of operation of SNTP. See descriptions in *SNTP Operation Modes on page 7.18*.
PRIMARY SERVER IP ADDRESS	Valid IP Address	SNTPPSIP := 192.168.1.1	Selects primary NTP server when ESNTP = UNICAST, or broadcast address when ESNTP = MANYCAST or BROADCAST.
BACKUP SERVER IP ADDRESS	Valid IP Address	SNTPPSIB := 192.168.1.1	Selects backup NTP server when ESNTP = UNICAST.
SNTP IP (LOCAL) PORT NUMBER	1–65534	SNTPPORT := 123	Ethernet port used by SNTP. Leave at default value unless otherwise required.
SNTP UPDATE RATE	15–3600 sec	SNTPRATE := 60	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 ESNTP = BROADCAST.
SNTP TIMEOUT	5–20 sec	SNTPTO := 5	Determines the time the relay will wait for the NTP master to respond when ESNTP = 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 the 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 with 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.

ESNTP = MANYCAST. In the 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 the original or another server responds.

ESNTP = BROADCAST. If setting SNTPPSIP = 0.0.0.0 while setting ESNTP = BROADCAST, the relay listens for and synchronizes to any broadcasting NTP server. If setting SNTPPSIP is set to a specific IP address while setting ESNTP = BROADCAST, then the relay listens for and synchronizes to only NTP server broadcasts from that address. When synchronized, the relay asserts Relay Word bit TSNTPP. Relay Word bit TNSTPP deasserts if the relay does not receive a valid broadcast within 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-787. Network monitoring software can also be used to ensure that average and worst-case network bandwidth use is moderate.

When installed on a network configured with one Ethernet switch between the SEL-787 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.

Embedded Web Server (HTTP)

When the Port 1 setting EHTTP := Y, the relay displays webpages showing settings, metering, status reports, event files, etc. The relay embedded web server has been optimized and tested to work with the most popular web browsers, but it should work with any standard web browser. As many as three users can access the embedded web server simultaneously. To begin using the embedded read-only web server, launch your web browser and browse to http://IPADDR, where IPADDR is the Port 1 setting IPADDR.

Login using your username and password to view or export various reports, view settings, monitor communications or relay status, or upgrade firmware (Access Level 2 only).

To log out of the web server, either close the web browser window or click **Logout** in the banner bar near the top of the webpage. For more information on the web server, see *Section 3: PC Interface*.

Table 7.6 lists the HTTP settings that are available for configuring the web server.

Table 7.6 HTTP Server Configuration

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE HTTP SERVER	Y, N	EHTTP := Y
HTTP MAXIMUM ACCESS LEVEL	1, 2	HTTPACC := 2
TCP/IP PORT	1–65535	HTTPPORT := 80
HTTP CONNECT BANNER	254 ASCII printable characters	HTTPBAN := This system is for the use of authorized personnel only.
HTTP WEB SERVER TIMEOUT	1–60 min	HTTPIDLE := 10

Precision Time Protocol (PTP)

Configuring PTP in the Relay

PTP in the SEL-787 is software-based only. If the EPTP setting is available and set to Y, then the SEL-787 supports Precision Time Protocol Version 2 (PTPv2) as a slave-only clock as defined by IEEE 1588-2008 on Ports 1A and 1B. *Table 7.7* shows the settings associated with PTP.

Table 7.7 Settings Associated With PTP

Setting Prompt	Setting Range	Setting Name := Factory Default	Description
ENABLE PTP	Y, N	EPTP := N	When set to Y, the device becomes a slave PTP clock
PTP PROFILE	DEFAULT, C37.238	PTPPRO := DEFAULT	Sets the PTP profile
PTP TRANSPORT MECHANISM	UDP, LAYER2	PTPTR := UDP	Transport mechanism for PTP messages
PTP DOMAIN NUMBER	0–255	DOMNUM := 0	PTP domain number of the clock
PTP PATH DELAY MECHANISM	P2P, E2E, OFF	PTHDLY := E2E	Path delay measurement to be used on the PTP network
PEER DELAY REQUEST INTERVAL	1, 2, 4, 8, 16, 32, 64 sec	PDINT := 1	Duration of time between transmissions of peer delay request messages
PTP NUMBER OF ACCEPTABLE MASTERS	1–5, OFF	AMNUM := OFF	Number of acceptable PTP masters
PTP ACCEPTABLE MASTER *n*[a] IP	*zzz*:*yyy*:*xxx*:*www*	AMIP*n* := 192.168.1.12*n*	Acceptable master IP address
PTP ACCEPTABLE MASTER *n*[a] MAC		AMMAC*n*[a] := 00-30-A7-00-00-0*m*[b]	Acceptable master MAC addresses
PTP ALTERNATE PRIORITY1 FOR MASTER *n*[a]	0–255	ALTPRI*n*[a] := 0	If the Acceptable Master Table option is enabled and this setting value is not zero, the Priority1 value received in the Announce message from the specified master will be replaced by this value and used in the Best Master Clock Algorithm (BMCA)
PTP VLAN IDENTIFIER	1–4094	PVLAN := 1	VLAN ID for a C37.238 Ethernet frame
PTP VLAN PRIORITY	0–7	PVLANPR := 4	VLAN priority for a C37.238 Ethernet frame

[a] n = 1–5.
[b] m = A–E.

To achieve the best accuracy (<1 ms), it is necessary to have one or more PTP master clocks and that all intervening equipment (e.g., Ethernet switches) be IEEE 1588-aware (i.e., all intervening network devices need to be transparent or boundary clocks).

In PTP, a clock that provides time to other devices, typically based on GPS input, is a master clock. The intervening switches are transparent clocks. You can connect networks together and pass time from one network to another using boundary clocks. Transparent and boundary clocks are important because they provide time correction in the PTP messages that pass through them, whereas devices that are not IEEE 1588-aware do not provide this correction. Because it is possible for a network to have multiple master clocks, PTP clocks implement algorithms to select the best available clock. The one selected for use by an end device is the grandmaster clock. You can learn more about configuring a PTP network in these application guides:

- “Using the SEL-2488 to Provide IEEE 1588 Version 2 Grandmaster Functionality in a Redundant Network Topology” (AN2015-07)
- “Using the SEL-2488 to Provide IEEE 1588 Version 2 Grandmaster Functionality to Isolated Ethernet Networks” (AN2015-06)

To configure PTP, update the Port 1 PTP settings as described in *Table 7.7*. By default, PTP is disabled in the SEL-787. Set EPTP to Y to enable PTP and to make the other PTP settings available.

PTP implementation in the SEL-787 supports both one-step and two-step clocks. A one-step clock provides time information using a single event message. A two-step clock provides time information by using the combination of an event message and a subsequent general message.

Within PTP, there are multiple clock profiles available. A profile defines the set of PTP features available in a specific application domain. SEL-787 relays support two profiles: Default and Power (C37.238-2011).

The Default profile has many optional features and is intended to address common applications. The Default profile supports both UDP or Layer 2 (802.3) Ethernet transport, and can use either the end-to-end (E2E) or peer-to-peer (P2P) delay mechanism. Grandmaster clocks can send Announce, Sync, and Delay request messages over a wide range of intervals. A Default profile network can consist of boundary clocks or transparent clocks anywhere between the grandmaster and the end devices. The only performance requirement for the Default profile is that a master clock must maintain frequency accuracy to within 0.01 percent.

The Power profile has minimal optional features to facilitate interoperability and performance predictability. The Power profile is only supported on Layer 2 networks and exclusively uses the peer-to-peer delay mechanism. All messages must be sent at 1-second intervals, have 802.1Q VLAN tags, and include the grandmaster ID and (maximum) inaccuracy fields in the Announce message. Transparent clocks are mandatory in a Power profile network and boundary clocks are not allowed. Select the profile by using the PTPPRO setting.

PTP defines a logical grouping of clocks in a network as a clock domain. This allows a logical separation between clocks that participate in different application domains to coexist on the same network. Domains are identified by domain numbers. The domain number for the SEL-787 is selected using the DOMNUM setting. Set DOMNUM to match the domain number configured in the master clocks to which the SEL-787 should synchronize.

The SEL-787 supports transport of PTP messages over UDP or Layer 2 (Ethernet). Use the PTPTR setting to select the PTP transport mechanism. This needs to match the transport mechanism used in the master clocks. Only Layer 2 is available with the Power System profile. If operating in a UDP network, PTP operates on Ports 319 or 320. Except for peer delay messages, the SEL-787 sets the time allowed to live (TTL) value in the UDP/IP header of PTP messages to 64. This allows you to use routers across a WAN to synchronize the SEL-787 PTP master. High-accuracy synchronization may not be achievable across the WAN, so it is left to you to determine if the accuracy meets the needs of your application.

When using the Power System profile, use the VLAN identifier and priority settings, PVLAN and PVLANPR, to set the VLAN ID and priority, respectively, of the Ethernet frames. Be sure to set PVLAN unique from other VLANs used within the SEL-787 relay.

PTP defines two methods for calculating and correcting the communications path delay between the SEL-787 and the master clock: end-to-end (Delay Request Response) and peer-to-peer (Peer Delay Request Response). The end-to-end mechanism calculates the total path delay between the SEL-787 and the master clock.

The peer-to-peer mechanism calculates the total path delay in a piecemeal fashion between each device in the path. Peer-to-peer is the more accurate method and is recommended for use with the SEL-787. Only the peer-to-peer mechanism is available for the Power System profile. The SEL-787 periodically initiates path delay calculations. Use the PTHDLY and PDINT settings to configure the path delay method and the path delay request rate. If PTHDLY is set to OFF, then the SEL-787 does not calculate and correct for path delay.

By default, the SEL-787 synchronizes to any clock on the network that it evaluates to be the best clock based on the BMCA. Use the settings to specify a list of master (grandmaster or boundary) clocks to which the SEL-787 may synchronize. The SEL-787 will not synchronize to any master clock that is not in the list. It is recommended to use this feature for additional security. The AMNUM setting selects the number of master clocks you list. The default is OFF, which means the SEL-787 synchronizes to any master clock on the network. If AMNUM is set to a value other than OFF, the number of allowable masters must be identified in accordance with the PTP transport chosen, i.e., MAC address for 802.3 or IP address for UDP transport.

If the PTP transport (PTPTR) is set to UDP, use the AMIP*n* settings to specify the IP addresses of the clocks to which the SEL-787 is permitted to synchronize. If PTP transport is set to Layer 2, use the AMMAC*n* settings to specify the MAC addresses of the clock to which the SEL-787 is permitted to synchronize.

If the ALTPRI*n* (Alternate Priority1 for Master *n*) setting value is positive, the ALTPRI*n* value replaces the Priority1 value in the received Announce message before the SEL-787 applies the BMCA. The ALTPRI*n* values reprioritize the master clocks locally.

EtherNet/Industrial Protocol (IP)

EtherNet/IP is an industrial protocol that uses standard Ethernet and TCP/IP technology to transport Common Industrial Protocol (CIP) packets. You can enable EtherNet/IP on Port 1 for a maximum of eight simultaneous CIP connections. Of these eight simultaneous connections, you can have as many as two Class 1 (I/O) connections and as many as six combined Class 3 messages and Unconnected Message Manager (UCMM) messages.

When configuring EIP on Port 1, you can create as many as six Class 1 (I/O) connection configurations. Of these six, only two can be used simultaneously. Of the remaining six available connection configurations, as many as three can be Exclusive Owner connection configurations. The remaining connection configurations must be Input Only connection configurations. EtherNet/IP is described in detail in *Appendix F: EtherNet/IP Communications*.

Rapid Spanning Tree Protocol (RSTP)

RSTP is a protocol and is a distributed algorithm that is defined in the IEEE 802.1Q-2014 standard. Devices communicate RSTP through packets called Bridge Protocol Data Units (BPDUs) that travel between adjacent RSTP-enabled devices. These frames allow the devices to determine the root bridge in the network, as well as defines the state and role of each port of devices connected in the RSTP network.

Table 7.8 and *Table 7.9* list the various roles and states supported by the SEL-787. Use the **RSTP** command to view the assigned state and role in the relay. The relay keeps a log of the states and roles in the Sequential Events Recorder (SER) report.

Table 7.8 RSTP Roles Supported in the SEL-787

Roles	Definition
Root Port	A port with the shortest path[a] to the root bridge. All STP and RSTP capable bridges must have exactly one except the root bridge, which cannot have any.
Designation Port	The port that connects a LAN to its designated bridge.
Alternate Port	Represents the best alternative path to the root bridge. This path is different than using the root port. The alternative port moves to the forwarding state if there is a failure on the designated port for the segment.
Backup Port	Represents a redundant path to a segment where another port on the bridge already connects.
Disabled	The port is disabled during the role initialization or it is disabled due to a link or hardware failure.

[a] This is not always the shortest path. The settings in the network define the path costs, so the root port is the one with the smallest path costs to the root switch. There may be a physically shorter path, but because of the path costs of the other devices, a longer path to the root may be used.

Table 7.9 RSTP States Supported in the SEL-787

States	Definition
Forwarding	A port receiving and transmitting message frames and BPDUs.
Learning	A port receiving and transmitting BPDUs; this port does not receive or transmit message frames.
Discarding	A port receiving BPDUs; this port does not receive or transmit message frames.

NOTE: Exercise caution when disabling RSTP (ERSTP := N) in a relay connected in a switched network because doing so could introduce network loops.

There are three RSTP settings available to set on Port 1 after RSTP is enabled. They include the bridge priority (BRDGPRI), which is used to help determine the root bridge in the network, and the port priorities (PORTAPRI and PORTBPRI) for Ports 1A and 1B, which are used to help determine the root port of the device. See *Table 7.44* for more information regarding these settings.

Example of a Simple Topology

The simplest example of a loop is a network of devices connected in a ring (*Figure 7.16*). Devices connected in a ring topology allow traffic to go from one port on one device to another port on another device in either direction around the ring, as the two green lines show in *Figure 7.16* between Devices 1 and 6.

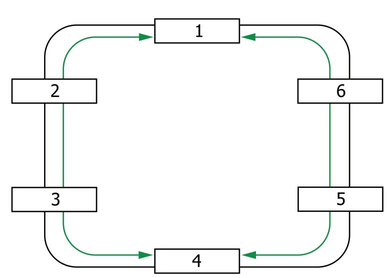


Figure 7.16 Physical Ring Without Loop Mitigation

Disabling the link between Devices 3 and 4 forces traffic to follow a single path across the network (as the green line in *Figure 7.17* shows). The process of disabling links to logically remove loops from the network is called convergence because the devices use RSTP to converge the network into a stable configuration without any loops.

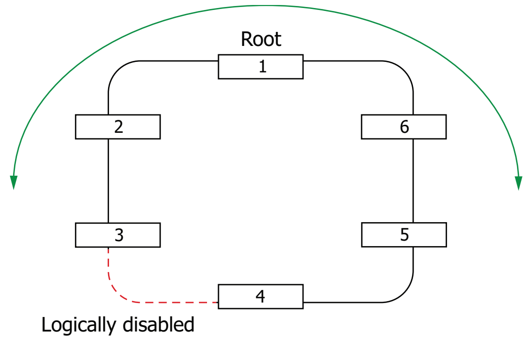


Figure 7.17 Network Convergence With Logically Disabled Link

The logically disabled connections remain physically present and can be quickly enabled by RSTP to provide an alternative path for the network traffic in the event of a physical network failure. For example, if the link between Devices 2 and 3 were to fail, traffic would be disrupted on the network, as indicated by the dashed green line in *Figure 7.18*. Devices 2 and 3 would respond by using RSTP and BPDUs to inform the other devices in the network that an event occurred. The rapid spanning tree algorithm (RSTA) in each network device would then use BPDUs over RSTP to communicate with their respective connected devices, in turn, and eventually the logically disabled link between Devices 3 and 4 would be re-enabled, as shown in *Figure 7.19*.

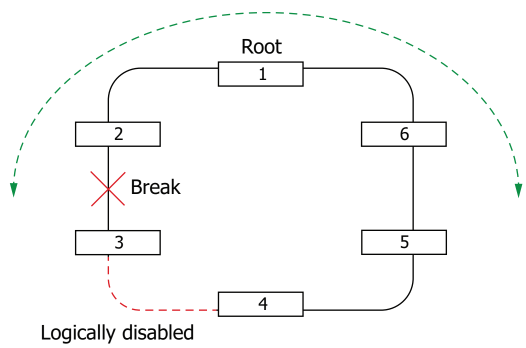


Figure 7.18 Physical Link Failure Between Devices

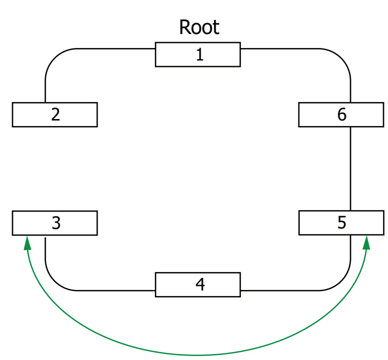


Figure 7.19 Network Convergence

As the green line in *Figure 7.19* shows, traffic can still flow between Devices 3 and 5 but now it is through a different path. The process of re-enabling disabled links to allow traffic to flow and heal the network is called reconvergence. During this change in the network, traffic is temporarily disrupted. *Figure 7.3* is a typical network diagram using SEL-787 in a switched network with ERSTP := Y. Refer to SEL application guide “Understanding RSTP and Choosing the Best Network Topology” (AG2017-21) at selinc.com for additional information on RSTP.

RSTP Performance Measurement

Figure 7.20 shows a convergence example involving a ring network where both SEL-2730M switches and all seven SEL-700 series relays are configured with default RSTP settings. In this example, there is a transmitting device connected to the North SEL-2730M switch and a receiving device connected to the South SEL-2730M switch.

As a result of the devices being configured with default RSTP settings, the network converges to break the loop at Relay 14. This configuration results in the port for Relay 14 to be in discarding state (indicated by “D”). In this state, traffic flows from the North SEL-2730M switch to the South SEL-2730M switch by passing through Link L1.

For this example, consider a link-down event occurring at Link L1. A link-down event is when the cable that connects two devices is physically broken (indicated by the slash). After this link-down event, the network takes approximately 150 ms to reconverge such that the discarding port on Relay 14 transitions into a forwarding state. This allows traffic to flow from the North SEL-2730M switch to the South SEL-2730M switch by passing through all seven relays.

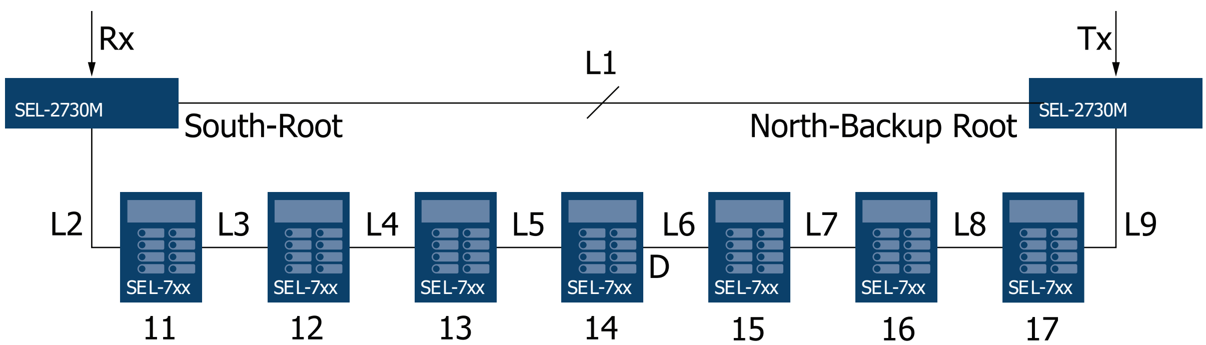


Figure 7.20 Link-Down Event at Link L1

If additional relays are added to this example network, then the reconvergence time will increase by approximately 20 ms per additional relay.

SEL-700 series relays are configured with a Max Age value of 40. This means that a network with SEL-700 series RSTP devices should be created with the understanding that the maximum number of hops from the root in the network should not exceed 40.

To understand the importance of enabling RSTP in an SEL-700 series relay ring network in comparison to leaving it disabled, refer to the SEL application guide “Maintaining Switched-Mode Relay Responsiveness in an RSTP Network” (AG2019-15).

SEL ASCII Protocol and Commands

Message Format

SEL ASCII protocol is designed for manual and automatic communication. All commands the relay receives must be of the following form:

```
<command><CR>  or  <command><CRLF>
```

NOTE: The **<Enter>** key on most keyboards is configured to send the ASCII character 13 (**<Ctrl+M>**) for a carriage return. This manual instructs you to press the **<Enter>** key after commands to send the proper ASCII code to the SEL-787.

A command transmitted to the relay consists of the command followed by either a CR (carriage return) or a CRLF (carriage return and line feed). You can truncate commands to the first three characters. For example, **EVENT 1 <Enter>** becomes **EVE 1 <Enter>**. Use upper- and lowercase characters without distinction, except in passwords.

The relay transmits all messages in the following format:

```
<STX><MESSAGE LINE 1><CRLF>
<MESSAGE LINE 2><CRLF>
.
.
.
<LAST MESSAGE LINE><CRLF><ETX>
```

Each message begins with the start-of-transmission character (ASCII 02) and ends with the end-of-transmission character (ASCII 03). Each line of the message ends with a carriage return and line feed.

Software Flow Control

The relay 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 the relay input buffer. Messages are 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. You can send control characters 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**)

Automatic Messages

When the serial port AUTO setting is Y, the relay sends automatic messages to indicate specific conditions. *Table 7.10* lists these messages.

Table 7.10 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 10: Analyzing Events*.
Self-Test Warning or Failure	The SEL-787 sends a status report each time a self-test warning or failure condition is detected. See *STATUS Command (Relay Self-Test Status) on page 7.66*.

Access Levels

You can issue commands to the SEL-787 via the serial port or Telnet session to view metering values, change relay settings, etc. The available serial port commands are listed in the *SEL-787-2, -3, -4 Relay Command Summary* at the end of this manual. These commands can be accessed only from the corresponding access level, as shown in the *SEL-787-2, -3, -4 Relay Command Summary*. The access levels are:

- Access Level 0 (the lowest access level)
- Access Level 1
- Access Level 2 (the highest access level)
- Access Level C (restricted access level; should be used under direction of SEL only)

The EPORT and MAXACC settings provide you with access controls for the corresponding port. Setting EPORT to N disables the port and hides the remaining port settings. The MAXACC setting selects the highest access level for the port.

Access Level 0

Once serial port communication is established with the SEL-787, the relay sends the following prompt:

```
=
```

This is referred to as Access Level 0. Only a few commands are available at Access Level 0. One is the **ACC** command. See the *SEL-787-2, -3, -4 Relay Command Summary* at the end of this manual. Enter the **ACC** command at the Access Level 0 prompt:

```
=ACC <Enter>
```

The **ACC** command takes the SEL-787 to Access Level 1. See *Access Commands (ACCESS, 2ACCESS, and CAL) on page 7.29* for more detail.

Access Level 1

When the SEL-787 is in Access Level 1, the relay sends the following prompt:

```
=>
```

See the *SEL-787-2, -3, -4 Relay Command Summary* at the end of this manual for the commands available from Access Level 1. The relay can go to Access Level 2 from this level.

The **2AC** command places the relay in Access Level 2. See *Access Commands (ACCESS, 2ACCESS, and CAL)* for more detail. Enter the **2AC** command at the Access Level 1 prompt:

```
=>2AC <Enter>
```

Access Level 2

When the relay is in Access Level 2, the SEL-787 sends the prompt:

```
=>>
```

See the *SEL-787-2, -3, -4 Relay Command Summary* at the end of this manual for the commands available from Access Level 2.

Any of the Access Level 1 commands are also available in Access Level 2.

Access Level C

Access Level C is used exclusively by the SEL factory and SEL field service personnel to diagnose troublesome installations. Do not enter Access Level C except as directed by SEL.

The **CAL** command allows the relay to go to Access Level C. Enter the **CAL** command at the Access Level 2 prompt:

```
=>>CAL <Enter>
```

Command Summary

The *SEL-787-2, -3, -4 Relay Command Summary* at the end of this manual lists the serial port commands alphabetically. Much of the information available from the serial port commands is also available via the front-panel pushbuttons.

Access Level Functions

The serial port commands at the different access levels offer varying levels of control:

- The Access Level 0 commands provide the first layer of security. In addition, Access Level 0 supports several commands required by SEL communications processors.
- The Access Level 1 commands are primarily for reviewing information only (settings, metering, etc.), not changing it.
- The Access Level 2 commands are primarily for changing relay settings.
- Access Level C (restricted access level; should be used under direction of SEL only)

The SEL-787 responds with `Invalid Access Level` when 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 that are not available or are entered incorrectly.

Header

Many of the command responses display the following header at the beginning:

```
[RID Setting]                                Date: mm/dd/yyyy  Time: hh:mm:ss.sss
[TID Setting]                                Time Source: external
```

Table 7.11 lists the header items and their definitions.

Table 7.11 Command Response Header Definitions

Item	Definition
[RID Setting]:	This is the RID (Relay Identifier) setting. The relay ships with the default setting RID = SEL-787-3S; see *ID Settings on page 4.4*.
[TID Setting]:	This is the TID (Terminal Identifier) setting. The relay ships with the default setting TID = TRNSFRMR RELAY; see *ID Settings on page 4.4*.
Date:	This is the date when the command response was given, except for relay response to the **EVE** command (Event), when it is the date the event occurred. You can modify the date display format (Month/Day/Year, Year/Month/Day, or Day/Month/Year) by changing the DATE_F relay setting.
Time:	This is the time when the command response was given, except for relay response to the **EVE** command, when it is the time the event occurred.
Time Source:	This is internal if no time-code input is attached and external if an input is attached.

Command Explanations

This section lists ASCII commands alphabetically. Commands, command options, and command variables to enter are shown in bold. Lowercase italic letters and words in a command represent command variables that are determined based on the application. For example, time ***t*** = 1 to 30 seconds, remote bit number ***n*** = 01 to 32, and ***level***.

Command options appear with brief explanations about the command function. Refer to the references listed with the commands for more information on the control function corresponding to the command or examples of the control response to the command.

You can simplify the task of entering commands by shortening any ASCII command to the first three characters; for example, **ACCESS** becomes **ACC**. Always send a carriage return **<CR>** character or a carriage return character followed by a line feed character **<CR><LF>** to command the control to process the ASCII command. Usually, most terminals and terminal programs interpret the Enter key as a **<CR>**. For example, to send the **ACCESS** command, type **ACC <Enter>**.

Tables in this section show the access level(s) where the command or command option is active. Access levels in this device are Access Level 0, Access Level 1, and Access Level 2.

Access Commands (ACCESS, 2ACCESS, and CAL)

The **ACC**, **2AC**, and **CAL** commands (see *Table 7.12*) provide entry to the multiple access levels. Different commands are available at the different access levels, as shown in the *SEL-787-2, -3, -4 Relay Command Summary* at the end of this manual. Commands **ACC** and **2AC** are explained together because they operate similarly. See *Access Levels on page 7.27* for a discussion of placing the relay in an access level.

Table 7.12 Access Commands

Command	Description	Access Level
ACC	Moves from Access Level 0 to Access Level 1.	0
2AC	Moves from Access Level 1 to Access Level 2.	1
CAL	Moves from Access Level 2 to Access Level C.	2

Password Requirements

Passwords are required unless they are disabled. See *PASSWORD Command (Change Passwords) on page 7.58* for the list of default passwords and for more information on changing and disabling passwords.

Access Level Attempt (Password Required). Assume the following conditions:

- Access Level 1 password is not disabled.
- Access Level is 0.

At the Access Level 0 prompt, enter the **ACC** command:

```
=ACC <Enter>
```

Because the password is not disabled, the relay prompts you for the Access Level 1 password:

```
Password: ?
```

The relay is shipped with the default Access Level 1 password shown in *PASSWORD Command (Change Passwords) on page 7.58*. At the prompt, enter the default password and press the **<Enter>** key. The relay responds with the following:

```
[RID Setting]                              Date: mm/dd/yyyy  Time: hh:mm:ss
[TID Setting]                              Time Source: external

Level 1
=>
```

The => prompt indicates the relay is now in Access Level 1.

If the entered password is incorrect, the relay prompts you for the password again (`Password: ?`). The relay prompts for the password as many as three times. If the requested password is incorrectly entered three times, the relay pulses the SALARM Relay Word bit for one second and remains at Access Level 0 (= prompt).

Access Level Attempt (Password Not Required). Assume the following conditions:

- Access Level 1 password is disabled.
- Access Level is 0.

At the Access Level 0 prompt, enter the **ACC** command:

```
=ACC <Enter>
```

Because the password is disabled, the relay does not prompt you for a password and goes directly to Access Level 1. The relay responds with the following:

```
[RID Setting]                          Date: mm/dd/yyyy  Time: hh:mm:ss.sss
[TID Setting]                          Time Source: external
Level 1
=>
```

The => prompt indicates the relay is now in Access Level 1.

The two previous examples demonstrate going from Access Level 0 to Access Level 1. The procedure to go from Access Level 1 to Access Level 2 with the **2AC** command entered at the access level screen prompt is similar. Access Level C can be accessed from Access Level 2 with the **CAL** command. The relay pulses the SALARM Relay Word bit for one second after a successful Level 2 or Level C access, or if access is denied.

89CLOSE Command (Close Disconnect)

The **89C** command (see *Table 7.13*) is used to close a 2-position disconnect, or the respective in-line or earthing disconnect of a 3-position disconnect. The **89C *m*** command asserts Relay Word bit 89CC2P*m* for 1/4 cycle when executed, while the **89C *n m*** command asserts Relay Word bit 89CC3P*nm* for 1/4 cycle when executed. See *Figure 9.2* for how these Relay Word bits are used in the disconnect close control logic.

Table 7.13 89CLOSE Command

Command	Description	Access Level
89CLOSE *m*	Closes Two-Position Disconnect *m*, where *m* = 1 to 16.	2
89CLOSE *n m*	Closes Three-Position Disconnect *m*, where *m* = 1 or 2 and *n* = L or E for in-line or earthing disconnect.	2

To issue the **89C 1** command, enter the following.

```
=>>89C 1 <Enter>
Close 2P1 Y/N ? Y <Enter>
Are you sure (Y/N)? Y <Enter>
Operation In Progress.......
Disconnect Closed

=>>
```

Typing **N <Enter>** after either of the prompts aborts the command.

Following a successful issuance of the command, the relay displays `Operation In Progress`…. While 89IP2P*m*/89IP3P*nm* is asserted and the respective Relay Word bits 89OP2P*m*/89OP3P*nm*, 89CL2P*m*/89CL3P*nm*, and 89AL2P*m*/89AL3P*nm* are deasserted, a dot (.) is appended to the message every half second to show progress. While the operation is in progress, communications are unavailable on the port where the **89C** command was executed. If none of the Relay Word bits assert within 60 seconds, the relay exits the **89C** command. Following the in-progress state, the Relay Word bit that asserts determines the subsequent status message displayed in the terminal (`Disconnect Open` if 89OP2P*m*/89OP3P*nm* is asserted, `Disconnect Closed` if 89CL2P*m*/89CL3P*nm* is asserted, or `Status Undetermined - Check Wiring` if 89AL2P*m*/89AL3P*nm* is asserted). See *Disconnect Control Settings on page 9.2*.

The **89C** command is supervised by the main board breaker control jumper (see *Table 2.24*). If the breaker control jumper is not in place (breaker control jumper = OFF), the relay does not execute the **89C** command and responds with the following:

```
=>>89CLOSE L 1 <Enter>

Command Aborted: No Breaker Jumper

=>>
```

When setting EN_LRC := Y (see *Table 9.6*), the Relay Word bit LOCAL supervises the **89C** command. If the LOCAL bit is asserted (LOCAL = 1), the relay does not execute the **89C** command from the ASCII terminal and responds with the following:

```
=>>89C L 1 <Enter>

Command Aborted: Device in Local Control

=>>
```

The Relay Word bit LOCAL is determined by the LOCAL SELOGIC control equation (see *Table 9.6*).

89OPEN Command (Open Disconnect)

The **89O** command (see *Table 7.14*) is used to open a 2-position disconnect, or the respective in-line or earthing disconnect of a 3-position disconnect. The **89O *m*** command asserts Relay Word bit 89OC2P*m* for 1/4 cycle when executed, while the **89O *n m*** command asserts Relay Word bit 89OC3P*nm* for 1/4 cycle when executed. See *Figure 9.3* for how these Relay Word bits are used in the disconnect open control logic.

Table 7.14 89OPEN Command

Command	Description	Access Level
89OPEN *m*	Opens 2-position disconnect *m*, where *m* = 1 to 16.	2
89OPEN *n m*	Opens 3-position disconnect *m*, where *m* = 1 or 2 and *n* = L or E for in-line or earthing disconnect.	2

To issue the **89O 1** command, enter the following.

```
=>>89O 1 <Enter>
Open 2P1 Y/N ? Y <Enter>
Are you sure (Y/N)? Y <Enter>
Operation In Progress.......
Disconnect Open

=>>
```

Typing **N <Enter>** after either of the prompts aborts the command.

Following a successful issuance of the command, the relay displays `Operation In Progress...`. While 89IP2P*m*/89IP3P*nm* is asserted and the respective Relay Word bits 89OP2P*m*/89OP3P*nm*, 89CL2P*m*/89CL3P*nm*, and 89AL2P*m*/89AL3P*nm* are deasserted, a dot (.) is appended to the message every half second to show progress. While the operation is in progress, communications are unavailable on the port where the **89O** command was executed. If none of the Relay Word bits assert within 60 seconds, the relay exits the **89O** command. Following the in-progress state, the Relay Word bit that asserts determines the subsequent status message displayed in the terminal (`Disconnect Open` if 89OP2P*m*/89OP3P*nm* is asserted, `Disconnect Closed` if 89CL2P*m*/89CL3P*nm* is asserted, or `Status Undetermined - Check Wiring` if 89AL2P*m*/89AL3P*nm* is asserted). See *Disconnect Control Settings on page 9.2*.

The **89O** command is supervised by the main board breaker control jumper (see *Table 2.24*). If the breaker control jumper is not in place (breaker control jumper = OFF), the relay does not execute the **89O** command and responds with the following:

```
=>>89OPEN L 1 <Enter>

Command Aborted: No Breaker Jumper

=>>
```

When setting EN_LRC := Y (see *Table 9.6*), the Relay Word bit LOCAL supervises the **89O** command. If the LOCAL bit is asserted (LOCAL = 1), the relay does not execute the **89O** command and responds with the following:

```
=>>89O L 1 <Enter>

Command Aborted: Device in Local Control

=>>
```

The Relay Word bit LOCAL is determined by the LOCAL SELOGIC control equation (see *Table 9.6*).

ANALOG Command

Use the **ANA** command to test an analog output by temporarily assigning a value to an analog output channel (see *Table 7.15* for the command description and for the format). After entering the **ANA** command, the device suspends normal operation of the analog output channel and scales the output to a percentage of full scale. After assigning the specified value for the specified time, the device returns to normal operation. Entering any character (including pressing the space key) ends the command before reaching the specified interval completion. You can test the analog output in one of the following two modes:

- Fixed percentage: Outputs a fixed percentage of the signal for a specified duration
- Ramp: Ramps the output from minimum to maximum of full scale over the time specified

Table 7.15 ANALOG Command

Command	Description	Access Level
ANA ***c p t***	Temporarily assigns a value to an analog output channel.	2
Parameters		
c	The analog channel (either the channel name, e.g., A0301, or the channel number, e.g., 301).	
p	A percentage of full scale, or either the letter "R" or "r" to indicate ramp mode.	
t	The duration (in decimal minutes) of the test.	

NOTE: 0% = low span, 100% = high span. For a scaled output from 4–20 mA, 0 percent is 4 mA and 100 percent is 20 mA.

When parameter *p* is a percentage, the relay displays the following message during the test:

```
Outputting xx.xx [units] to Analog Output Port for y.y minutes. Press any key to end
    test
```

where:

`xx.xx` is the calculation of percent of full scale
`[units]` is either mA or V, depending on the channel type setting
`y.y` is the time in minutes

When parameter *p* is a ramp function, the device displays the following message during the test:

```
Ramping Analog Output at xx.xx [units]/min; full scale in y.y minutes. Press any key
    to end test
```

where:

`xx.xx` is the calculation based upon range/time *t*
`[units]` is either mA or V, depending on the channel type setting
`y.y` is the time in minutes

For either mode of operation (percentage or ramp), when the time expires, or upon pressing a key, the analog output port returns to normal operation and the device displays the following message:

```
Analog Output Port Test Complete
```

Example 1

The following is an example of the device response to the **ANA** command in the percentage mode. For this example, we assume the analog output signal type is 4–20 mA, and we want to test the analog output at 75 percent of rating for 5.5 minutes. To check the device output, calculate the expected mA output as follows:

$$\text{Output} = \left[(20.00\text{ mA} - 4.00\text{ mA}) \bullet \frac{75}{100}\right] + 4.00\text{ mA} = 16.00\text{ mA}$$

To start the test, enter **ANA AO301 75 5.5** at the Access Level 2 prompt:

```
=>>ANA AO301 75 5.5 <Enter>
Outputting 16.00 mA to Analog Output Port for 5.5 minutes.
Press any key to end test
```

Example 2

The following is an example of the ramp mode when the analog output signal type is 4–20 mA for a 9.0 minute test.

To check the device output, calculate the current/time (mA/min) output as follows:

$$\text{Output} = \left[\frac{20.00\ \text{mA} - 4.00\ \text{mA}}{9.0\ \text{min}}\right] = 1.78\ \text{mA/min}$$

To start the test, enter **ANA AO301 R 9.0** at the Access Level 2 prompt:

```
=>>ANA AO301 R 9.0 <Enter>
Ramping Analog Output at 1.78 mA/min; full scale in 9.0 minutes.
Press any key to end test
```

BRE n Command (Monitor Breaker n Data, where n = 1, 2, 3, or 4)

Use the **BRE *n*** command to view the breaker monitor report.

```
=>BRE 1 <Enter>

SEL-787-3S                                  Date: 08/22/2013   Time: 13:39:46.813
TRNSFRMR RELAY                              Time Source: External


Breaker 1 Monitor Data

Trip Counters

Rly Trips (counts)          6
Ext Trips (counts)          0

Cumulative Interrupted Currents

                                 IA          IB          IC
Rly Trip Current (kA)              7.5         5.3         6.6
Ext Trip Current (kA)              0.0         0.0         0.0

Breaker Contact Wear

                                 A    B    C
Wear (%)                          0    0    0


LAST RESET = 08/19/2013 14:26:23

=>
```

Figure 7.21 BRE 1 Command Response

See *Breaker Monitor on page 5.25* for further details on the breaker monitor.

BRE n W or R Command (Preload/Reset Breaker Wear, where n = 1, 2, 3, or 4)

The **BRE *n* W** command only saves new settings after the `Save Changes (Y/N)?` message. If a data entry error is made using the **BRE *n* W** command, the values echoed after the `Invalid format, changes not saved` message are the previous breaker wear values, unchanged by the aborted **BRE *n* W** attempt.

```
=>>BRE 1 W <Enter>

Breaker 1 Wear Preload

Relay (or Internal) Trip Counter (0-65000)    =     0     ? 14  <Enter>

Internal Current (0.0-999999 kA)      IA      = 0.0      ? 32.4  <Enter>

                                      IB      = 0.0      ? 18.6  <Enter>

                                      IC      = 0.0      ? 22.6  <Enter>

External Trip Counter (0-65000)               =     0     ? 2  <Enter>

External Current (0.0-999999 kA)      IA      = 0.0      ? 0.8  <Enter>

                                      IB      = 0.0      ? 0.6  <Enter>

                                      IC      = 0.0      ? 0.7  <Enter>

Percent Wear (0-100%)                 A-phase =   0       ? 22  <Enter>

                                      B-phase =   0       ? 28  <Enter>

                                      C-phase =   0       ? 25  <Enter>


Last Reset                            Date    = 10/12/2014 ? 10/12/2014 <Enter>

                                      Time    = 14:27:10  ? 17:50:12  <Enter>

Save changes (Y,N)? Y <Enter>

=>>
```

Figure 7.22 BRE 1 W Command Response

Use the **BRE *n* R** command to reset the breaker monitor:

```
=>>BRE 1 R <Enter>

Reset Breaker Wear (Y,N)? Y <Enter>
Clearing Complete

=>>
```

Figure 7.23 BRE 1 R Command Response

See *Breaker Monitor on page 5.25* for further details on the breaker monitor.

CEV Command

The SEL-787 provides Compressed ASCII event reports to facilitate event report storage and display. SEL communications processors and the SEL-5601-2 SYNCHROWAVE Event Software take advantage of the Compressed ASCII format. Use the **CHIS** command to display Compressed ASCII event history information. Use the **CSUM** command to display Compressed ASCII event summary information. Use the **CEVENT *n*** (**CEV *n***) command to display Compressed ASCII event reports. Parameter *n* indicates the event number. The events can be accessed by the event record number or by their unique reference number. The most recent event report is record number one (1), the next most recent report is record number two (2), and so on. Reference numbers start at 10000 and increment by 1 with each event. When the event report list is cleared, the reference number resets to 10000. See *Table C.2* for further information. Compressed ASCII Event Reports contain all of the Relay Word bits. The **CEV *n* R** command shows the raw Compressed ASCII event report.

CLOSE n Command (Close Breaker n, where n = 1, 2, 3, or 4)

The **CLO *n*** (**CLOSE *n***) command asserts Relay Word bit CC*n* for 1/4 cycle when it is executed. Relay Word bit CC*n* can then be programmed into the CL*n* SELOGIC control equation to assert the CLOSE *n* Relay Word bit, which in turn asserts an output contact (e.g., OUT*xxx* = CLOSE *n*) to close Circuit Breaker *n* (see *Table 4.39* and *Figure 4.67* for factory-default settings CL1, CL2, CL 3, and CL4 and the close logic).

To issue the **CLO 1** command, enter the following.

```
=>>CLO 1 <Enter>

Close Breaker1 (Y,N)? Y <Enter>

=>>
```

Typing **N <Enter>** after the above prompt aborts the command.

The **CLO *n*** commands are supervised by the main board breaker control jumper (see *Table 2.24*). If the breaker control jumper is not in place (breaker control jumper = OFF), the relay does not execute the **CLO *n*** command and responds with the following.

```
=>>CLO 1 <Enter>

Command Aborted: No Breaker Jumper

=>>
```

When setting EN_LRC := Y (see *Table 9.6*), the Relay Word bit LOCAL supervises the **CLO *n*** command. If the LOCAL bit is asserted (LOCAL = 1), the relay does not execute the **CLO *n*** command and responds with the following:

```
=>>CLO 1 <Enter>

Command Aborted: Device in Local Control

=>>
```

The Relay Word bit LOCAL is determined by the LOCAL SELOGIC control equation (see *Table 9.6*).

COM PTP Command

The **COM PTP** command provides a report of the Precision Time Protocol (PTP) data sets maintained by the device as well as statistics for the measured time offsets with the parent (master) clock. The PTP data sets contain information about the state, identity, and configuration of the local, parent, and grandmaster clocks in addition to properties of the time being distributed by the grandmaster clock.

Table 7.16 COM PTP Command

Command	Description	Access Level
COM PTP	Displays the PTP data sets and offset statistics for the active PTP slave port or for the last active PTP slave port.	1
COM PTP C or **R**	Clears or resets the PTP offset statistics for all ports.	1

If the EPTP setting is set to No and the **COM PTP** command (with or without any parameters) is sent to the relay, the relay responds with:

```
=>COM PTP <Enter>

PTP Not Enabled
```

If a temporary resource shortage exists, a settings change is in progress, or the PTP component is not yet initialized, and the **COM PTP** command is sent to the relay, the relay responds with:

```
=>COM PTP <Enter>

Command is not available
```

If EPTP is enabled and the **COM PTP C** or **R** command is sent to the SEL-787, the SEL-787 responds with:

```
=>COM PTP C <Enter>

Clear PTP offset statistics?
Are you sure? Y N
```

If you select Y, the relay responds with: `Clearing Complete`. If N is selected, the relay responds with: `Command Canceled`. If anything else is selected, the relay responds with: `Command Canceled`.

If a **COM PTP C** or **R** is sent to the SEL-787 and the PTP component is enabled, but not yet initialized, the SEL-787 responds with:

```
=>COM PTP R <Enter>

Command is not available
```

The SEL-787 Relay saves the date and time when the PTP offset statistics are cleared. The format of the offset clearing date matches the DATE_F Global setting. The statistic clearing date and time is the time of the last user reset via an ASCII command, the last Port 1 settings change, or the last power up. The time stamp of the most recent event is displayed.

An example response to the **COM PTP** command when PTP is available is shown in *Figure 7.24*.

```
=>>COM PTP <Enter>

SEL-787-4X                                  Date: 05/13/2019   Time: 10:01:41.976
TRNSFRMR RELAY                              Time Source: External


PTP offset statistics previously cleared on 05/09/2019 09:32:18 (UTC)


Settings Data Set
  PTP Profile : Default
  Transport Mechanism : UDP
  Path Delay : P2P
```

Figure 7.24 COM PTP Command Response When PTP is Available

```
Default Data Set
  Two Step : true
  Clock Identity : 00 30 A7 FF FE 12 32 22
  Number of Ports : 1
  Clock Quality
    Clock Class : 255
    Clock Accuracy : 254
    Offset Log Variance : 0
  Priority1 : 255
  Priority2 : 255
  Domain Number : 0
  Slave Only : true


Current Data Set
  Steps Removed : 1

Parent Data Set
  Parent Port Identity
  Clock Identity : 00 30 A7 FF FE 0B 29 91
    Port Number : 1
  Grandmaster Clock Identity : 00 30 A7 FF FE 0B 29 91
  Grandmaster Clock Quality
    Clock Class : Synchronized with PTP timescale 6
    Clock Accuracy : Within 100 ns
    Offset Log Variance : 18887
  Grandmaster Priority1 : 128
  Grandmaster Priority2 : 128


Time Properties Data Set
  Current UTC Offset : 37
  Current UTC Offset Valid : true
  Leap59 : false
  Leap61 : false
  Time Traceable : true
  Frequency Traceable : true
  PTP Timescale : true
  Time Source : GPS
  Local Time Offset
    Offset Valid : true
    Name : UTC-07:00
    Current Offset : -25237 s
    Jump Seconds : -3600 s
    Time of Next Jump : 1572771637 s


Port Data Set
  Port Identity
    Clock Identity : 00 30 A7 FF FE 12 32 22
    Port Number : 1
  Port State : SLAVE
  Log Pdelay Request Interval : 0
  Peer Mean Path Delay : 0 ns
  Announce Receipt Timeout : 4 intervals
  Path Delay Mechanism : P2P
  Failed to Receive Response : true
  Received Multiple Pdelay Responses : false
  Reason for Non-synchronization :
  Port status : A, ACTIVE

=>>
```

Figure 7.24 COM PTP Command Response When PTP is Available (Continued)

A description of each PTP data set displayed in *Figure 7.24* is provided in *Table 7.17*.

Table 7.17 PTP Data Set Descriptions (Sheet 1 of 5)

Type of Data Set	Information Field	Description
Settings	PTP Profile	This value is the same as PTPPRO.
	Transport Mechanism	This value is the same as PTPTR.
	Path Delay	This value is the same as PTHDLY.

Table 7.17 PTP Data Set Descriptions (Sheet 2 of 5)

<table>
<tr><th>Type of Data Set</th><th>Information Field</th><th>Description</th></tr>
<tr><td>Default</td><td>Two Step</td><td>For the default data, this is set to TRUE. A two-step clock provides time information using the combination of an event message and a subsequent general message. A one-step clock provides times information by using a single event message.</td></tr>
<tr><td></td><td>Clock Identity</td><td>This is an 8-octet number that uniquely identifies the clock on the network. It is derived from the Ethernet MAC address.</td></tr>
<tr><td></td><td>Number of Ports</td><td>This is the number of Ethernet ports used to communicate PTP messages. It is always 1 for SEL-787 Relays.</td></tr>
<tr><td></td><td>Clock Quality</td><td>This contains information about clock class, accuracy, and variance for the SEL-787 Relay.</td></tr>
<tr><td></td><td>Priority1</td><td>This is the first priority for the SEL-787 Relay used in the default BMCA. It is always set to 255.</td></tr>
<tr><td></td><td>Priority2</td><td>This is the second priority for the SEL-787 Relay used in the default BMCA. It is always set to 255.</td></tr>
<tr><td></td><td>Domain Number</td><td>This value is the same as DOMNUM. It is the PTP domain number that the clock is part of.</td></tr>
<tr><td></td><td>Slave Only</td><td>This is always TRUE for SEL-787 Relays.</td></tr>
<tr><td>Current</td><td>Steps Removed</td><td>This is the number of communications paths between the SEL-787 Relay and the grandmaster clock. A communications path is the link between a master and a slave port. Hence, links to transparent clocks do not count as separate paths. The values range from 1–65535.</td></tr>
<tr><td>Parent</td><td>Parent Port Identity</td><td>This contains the clock identity and port number of the adjacent clock to which the SEL-787 clock is synchronized. The port number identifies the specific port on the adjacent clock from which the SEL-787 clock is receiving PTP messages.</td></tr>
<tr><td></td><td>Grandmaster Clock Identity</td><td>This is the clock identity of the grandmaster clock that the SEL-787 is synchronized to.</td></tr>
<tr><td></td><td>Grandmaster Clock Quality</td><td>This contains the class, accuracy, and variance of the grandmaster clock.</td></tr>
<tr><td></td><td>Grandmaster Clock Class</td><td>This field displays an ASCII message based on the received clock class code described as follows:
<table>
<tr><th>Code (decimal)</th><th>Message</th></tr>
<tr><td>68–122, 133–170, 216–232</td><td>Profile specific value</td></tr>
<tr><td>6</td><td>Synchronized with PTP timescale</td></tr>
<tr><td>7</td><td>Holdover with PTP timescale</td></tr>
<tr><td>13</td><td>Synchronized with ARB timescale</td></tr>
<tr><td>14</td><td>Holdover with ARB timescale</td></tr>
<tr><td>52</td><td>Holdover degrade A with PTP timescale</td></tr>
<tr><td>58</td><td>Holdover degrade A with ARB timescale</td></tr>
<tr><td>187</td><td>Holdover degrade B with PTP timescale</td></tr>
<tr><td>193</td><td>Holdover degrade B with ARB timescale</td></tr>
<tr><td>248</td><td>Default</td></tr>
<tr><td>255</td><td>Slave only</td></tr>
<tr><td>All other codes</td><td>Reserved with decimal code value (xxx)</td></tr>
</table></td></tr>
</table>

Table 7.17 PTP Data Set Descriptions (Sheet 3 of 5)

<table>
<tr><th>Type of Data Set</th><th>Information Field</th><th>Description</th></tr>
<tr><td></td><td>Grandmaster Clock Accuracy</td><td>This field displays a ASCII message based on the received clock accuracy enumeration value described as follows:
<table>
<tr><th>Value (Hex)</th><th>Message</th></tr>
<tr><td>20</td><td>Within 25 ns</td></tr>
<tr><td>21</td><td>Within 100 ns</td></tr>
<tr><td>22</td><td>Within 250 ns</td></tr>
<tr><td>23</td><td>Within 1 µs</td></tr>
<tr><td>24</td><td>Within 2.5 µs</td></tr>
<tr><td>25</td><td>Within 10 µs</td></tr>
<tr><td>26</td><td>Within 25 µs</td></tr>
<tr><td>27</td><td>Within 100 µs</td></tr>
<tr><td>28</td><td>Within 250 µs</td></tr>
<tr><td>29</td><td>Within 1 ms</td></tr>
<tr><td>2A</td><td>Within 2.5 ms</td></tr>
<tr><td>2B</td><td>Within 10 ms</td></tr>
<tr><td>2C</td><td>Within 25 ms</td></tr>
<tr><td>2D</td><td>Within 100 ms</td></tr>
<tr><td>2E</td><td>Within 250 ms</td></tr>
<tr><td>2F</td><td>Within 1 s</td></tr>
<tr><td>30</td><td>Within 10 s</td></tr>
<tr><td>31</td><td>Greater than 10 s</td></tr>
<tr><td>80–FD</td><td>Profile specific value (0xyy)</td></tr>
<tr><td>FE</td><td>Unknown</td></tr>
<tr><td>All other codes</td><td>Reserved (0xyy)</td></tr>
</table></td></tr>
<tr><td></td><td>Grandmaster Priority1</td><td>This is the priority1 value set in the grandmaster clock. If the setting ALTPRIn > 0, its value is used as the reported priority1 value for Grandmaster n. The expected value is between 0 to 255.</td></tr>
<tr><td></td><td>Grandmaster Priority2</td><td>This is the priority2 value set in the grandmaster clock. The expected value is between 0–255.</td></tr>
<tr><td></td><td>C37.238 TLV Information</td><td>This is the C37.238 TLV information received. It is valid only in the Power System profile. In the case of the Default profile, this section is hidden.</td></tr>
<tr><td>Time Properties</td><td>Current UTC Offset</td><td>This is the current number of leap seconds between TAI and UTC.</td></tr>
<tr><td></td><td>Current UTC Offset Valid</td><td>This attribute is TRUE if the current UTC Offset is valid and should be used. Otherwise, it is FALSE.</td></tr>
<tr><td></td><td>Leap59</td><td>This is set to TRUE if there is an impending leap second removal, i.e., the last minute of the current day contains 59 seconds.</td></tr>
<tr><td></td><td>Leap61</td><td>This is set to TRUE if there is an impending leap second insertion, i.e., the last minute of the current day contains 61 seconds.</td></tr>
<tr><td></td><td>Time Traceable</td><td>This indicates if the time being served is traceable to UTC reference time.</td></tr>
<tr><td></td><td>Frequency Traceable</td><td>This indicates if the frequency being distributed is traceable to a primary source.</td></tr>
</table>

Table 7.17 PTP Data Set Descriptions (Sheet 4 of 5)

Type of Data Set	Information Field	Description
	PTP Timescale	This is TRUE if the time being served uses the PTP/UTC timescale. Otherwise, it is FALSE.
	Time Source	This shows the source of the time being distributed based on the value of the timeSource enumeration as shown in the following table.

Code (decimal)	Message
10	ATOMIC_CLOCK
20	GPS
30	TERRESTRIAL_RADIO
40	PTP
50	NTP
60	HAND_SET
90	OTHER
A0	INTERNAL_OSCILLATOR
F0–FE	PROFILE SPECIFIC VALUE (0xyy)
All other codes	RESERVED (0xyy)

Type of Data Set	Information Field	Description
	Local Time Offset	This is the offset of local time from UTC and information about impending change in the offset.
Port	Port Identity	This contains the clock ID and port number of the SEL-787 Relay on the PTP network.
	Port State	This is the synchronization state of the SEL-787 Relay: LISTENING, SLAVE, UNCALIBRATED, or FAULTY. The relay is synchronized if the state is SLAVE.
	Log Delay Request Interval	If the end-to-end delay mechanism is enabled, then this is the logarithm to base 2 of the delay request intervals (in seconds) received from the master clock. If the peer-to-peer (P2P) delay mechanism is enabled, these data are hidden. Also, these data are hidden when the delay mechanism is set to OFF.
	Log Pdelay Request Interval	If the peer-to-peer (P2P) delay mechanism is enabled, this is the logarithm to base 2 of the configured peer delay request intervals (PDINT). If the end-to-end delay mechanism is enabled, these data are hidden. Also, these data are hidden when the delay mechanism is set to OFF.
	Peer Mean Path Delay	If the peer-to-peer (P2P) delay mechanism is enabled, this is the measured mean peer delay on the SEL-787 Relay. If the peer-to-peer (P2P) delay mechanism is not selected (PTHDLY ≠ P2P), these data are hidden.
	Announcement Receipt Timeout	This value is always 4 announce intervals.
	Path Delay Mechanism	This is the same value as PTHDLY.
	Failed to Receive Response	The value is TRUE if no response is received after 5 consecutive Delay or Pdelay Requests from the port. Otherwise, the value is FALSE. These data are hidden if PTHDLY = OFF.
	Received Multiple Pdelay Responses	This is set to TRUE if a response is received from more than one clock to a Pdelay request from the SEL-787. The port state will transition to FAULTY when this happens. The value is reset to FALSE when only one clock responds to Pdelay requests from the SEL-787. These data are hidden if PTHDLY ≠ P2P.

Table 7.17 PTP Data Set Descriptions (Sheet 5 of 5)

<table>
<tr><th>Type of Data Set</th><th>Information Field</th><th>Description</th></tr>
<tr><td></td><td>Reason for Nonsynchronization</td><td>If the SEL-787 Relay is failing to synchronize, this will provide one of the following reasons for the failure: incorrect domain number, clock not in the acceptable master table, or missing TLV in Announce messages. Otherwise, the string is empty.
<table>
<tr><th>#</th><th>Reason for Nonsynchronization Display Strings</th></tr>
<tr><td>1</td><td>Received Announce message for a different domain:
<domain number></td></tr>
<tr><td>2</td><td>Received Announce message from an unacceptable master:
<MAC or IP address></td></tr>
<tr><td>3</td><td>Required TLV is missing or incorrectly formatted by clock
<clock id></td></tr>
</table></td></tr>
<tr><td></td><td>Port Status</td><td>This displays the Port 1A and 1B time-synchronization status. If the port is not synchronized to a PTP master, NA is displayed. If a port is in the SLAVE state and it is chosen as a master, ACTIVE is displayed.
Additional port status indications are available via Relay Word bits PTPA, PTPB, PASEL, and PBSEL. When Ethernet Port 1A is active, PASEL asserts. Similarly, when Ethernet Port 1B is active, PBSEL asserts. If the operating mode of Port 1 of the relay is PRP, then PTPA asserts if PTP is enabled and the relay is receiving PTP messages on Port 1A. Similarly, in PRP mode, PTPB asserts if PTP is enabled and the relay is receiving PTP messages on Port 1B.</td></tr>
</table>

COMMUNICATIONS Command

The **COM *x*** command (see *Table 7.18*) displays communications statistics for the MIRRORED BITS communications channels. For more information on MIRRORED BITS communications, see *Appendix J: MIRRORED BITS Communications*.

The summary report includes information on the failure of ROKA or ROKB. The Last Error field displays the reason for the most recent channel error, even if the channel was already failed. We define failure reasons as one of the following error types:

- Device disabled
- Framing error
- Parity error
- Overrun
- Re-sync
- Data error
- Loopback
- Underrun

Table 7.18 COM Command (Sheet 1 of 2)

Command	Description	Access Level
COM S A or **COM S B**	Returns a summary report of the last 255 records in the communications buffer for either MIRRORED BITS communications Channel A or Channel B when only one channel is enabled.	1
COM A	Returns a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.	1
COM B	Returns a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel B.	1

Table 7.18 COM Command (Sheet 2 of 2)

Command	Description	Access Level
COM L A	Appends a long report to the summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.	1
COM L B	Appends a long report to the summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel B.	1
COM C	Clears all communications records. If both MIRRORED BITS channels are enabled, omitting the channel specifier (A or B) clears both channels.	1
COM C A	Clears all communications records for Channel A.	1
COM C B	Clears all communications records for Channel B.	1

CONTROL Command (Control Remote Bit)

Use the **CON** command (see *Table 7.19*) to control remote bits (Relay Word bits RB01–RB32). You can also use the **CON** function from the front panel HMI to pulse the output contacts. Remote bits are device variables that you set via serial port communication only; you cannot navigate remote bits via the front-panel HMI. You can select the control operation from three states: set, clear, or pulse, as described in *Table 7.19*.

Table 7.19 CONTROL Command

Command	Description	Access Level
CON RB*nn k*	Sets a remote bit to set, clear, or pulse.	2
Subcommand		
S	Set remote bit (ON position)	2
C	Clear remote bit (OFF position)	2
P	Pulse remote bit for 1/4 cycle (MOMENTARY position)	2
Parameters		
nn	A number from 01 to 32, representing RB01 through RB32	
k	S, C, or P	

For example, use the following command to set Remote Bit RB05:

```
=>>CON RB05 S <Enter>
```

COPY Command

Use the **COPY *j k*** command (see *Table 7.20*) to copy the settings of Group *j* to the settings of Group *k*. The settings of Group *j* effectively overwrite the settings of Group *k*. Parameters *j* and *k* can be any available settings group number 1 through 4.

Table 7.20 COPY Command

Command	Description	Access Level
COPY *j k*	Copies settings values from Group *j* to Group *k*.	2
Parameters		
j	1, 2, 3, or 4.	
k	1, 2, 3, or 4.	

For example when you enter the **COPY 1 3** command, the relay responds, `Are you sure (Y/N)?` Answer **Y <Enter>** (for yes) to complete copying. The resultant settings in Group 3 are overwritten by the settings in Group 1.

COUNTER Command (Counter Values)

The device generates the values of the 32 counters in response to the **COU** command (see *Table 7.21*).

Table 7.21 COUNTER Command

Command	Description	Access Level
COU *n*	Displays current state of device counters *n* times, with a 1/2-second delay between each display.	1

DATE Command (View/Change Date)

Use the **DATE** command (see *Table 7.22*) to view and set the relay date.

Table 7.22 DATE Command

Command	Description	Access Level
DATE	Displays the internal clock date.	1
DATE *mm/dd/yyyy*, ***yyyy/mm/dd***, or ***dd/mm/yyyy***	Sets the internal clock date (DATE_F set to MDY, YMD, or DMY).	1

The relay can overwrite the date entered by using other time sources such as IRIG. Enter the **DATE** command with a date to set the internal clock date.

Separate the month, day, and year parameters with spaces, commas, slashes, colons, and semicolons. Set the year in 4-digit form (for dates 2000–2099). Global setting DATE_F sets the date format.

ETH Command

The **ETH** command (Access Level 1) can be used to display the Ethernet port (**PORT 1**) status, as shown in *Figure 7.25*, for the redundant fiber-optic (FX) Ethernet **Port 1A** and **Port 1B** configuration. The copper Ethernet port is labeled as TX. The response is similar for relays with the single Ethernet port option.

Different Ethernet configurations and different NETMODE settings result in slightly different information being displayed, as shown in the following figures.

```
=>ETH <Enter>

SEL-787-4X                                  Date: 07/10/2015   Time: 20:16:05.914
FEEDER RELAY                                Time Source: External

NETMODE: PRP

             LINK   SPEED  DUPLEX MEDIA
PORT 1A      Up     100M   Full   TX
PORT 1B      Up     100M   Full   TX

IP Port:

MAC: 00-30-A7-01-02-04
IP ADDRESS: 10.10.52.221
SUBNET MASK: 255.255.255.0
DEFAULT GATEWAY: 10.10.52.1

         PACKETS                BYTES              ERRORS
      SENT      RCVD          SENT        RCVD       SENT    RCVD
      5098      1000        645526       88876          0       0

=>
```

Figure 7.25 Ethernet Port (PORT 1) Status Report When NETMODE := PRP

```
=>ETH <Enter>

SEL-787-4X                                  Date: 07/10/2015   Time: 20:18:11.791
FEEDER RELAY                                Time Source: External

NETMODE: FIXED

 PRIMARY PORT:  PORT 1A
 ACTIVE PORT:   PORT 1A

             LINK   SPEED  DUPLEX MEDIA
PORT 1A      Up     100M   Full   TX

IP Port:

MAC: 00-30-A7-01-02-04
IP ADDRESS: 10.10.52.221
SUBNET MASK: 255.255.255.0
DEFAULT GATEWAY: 10.10.52.1

         PACKETS                BYTES              ERRORS
      SENT      RCVD          SENT        RCVD       SENT    RCVD
       143       107         14652        7861          0       0

=>
```

NOTE: Relays with older CPU cards can be upgraded to firmware versions R112 or higher, but the relay will not have the GOOSE performance improvements (i.e., a GOOSE port with a dedicated MAC address).

Figure 7.26 Ethernet Port (PORT 1) Status Report When NETMODE := FIXED

```
=>ETH <Enter>

SEL-787-4X                                  Date: 10/25/2016   Time: 10:59:25.558
FEEDER RELAY                                Time Source: Internal

NETMODE: FAILOVER

PRIMARY PORT:  1A
ACTIVE PORT:   1A

             LINK   SPEED  DUPLEX MEDIA
PORT 1A      Up     100M   Full   TX
PORT 1B      Down   --     --     TX

=>
```

Figure 7.27 Ethernet Port (PORT 1) Status Report When NETMODE := FAILOVER, E61850 := Y, and EGSE := Y

NOTE: Relays with older CPU cards can be upgraded to firmware versions R112 or higher, but the relay will not have the GOOSE performance improvements (i.e., a GOOSE port with a dedicated MAC address).

```
IP Port:

MAC: 00-30-A7-67-32-10
IP ADDRESS: 10.10.52.244
SUBNET MASK: 255.255.255.0
DEFAULT GATEWAY: 10.10.52.1

         PACKETS                BYTES              ERRORS
      SENT      RCVD        SENT       RCVD      SENT    RCVD
        36        72        2660       5081         0       0

GOOSE Port:

MAC: 00-30-A7-78-10-20

         PACKETS                BYTES              ERRORS
      SENT      RCVD        SENT       RCVD      SENT    RCVD
         0         0           0          0         0       0

=>
```

Figure 7.27 Ethernet Port (PORT 1) Status Report When NETMODE := FAILOVER, E61850 := Y, and EGSE := Y(Continued)

```
=>ETH <Enter>

SEL-787-4X                                  Date: 07/10/2015   Time: 20:21:34.698
FEEDER RELAY                                Time Source: External

NETMODE: SWITCHED

             LINK   SPEED  DUPLEX MEDIA
PORT 1A      Up     100M   Full   TX
PORT 1B      Up     100M   Full   TX

IP Port:

MAC: 00-30-A7-01-02-04
IP ADDRESS: 10.10.52.221
SUBNET MASK: 255.255.255.0
DEFAULT GATEWAY: 10.10.52.1

         PACKETS                BYTES              ERRORS
      SENT      RCVD        SENT       RCVD      SENT    RCVD
        93        74        8537       5096         0       0

=>
```

Figure 7.28 Ethernet Port (PORT 1) Status Report When NETMODE := SWITCHED

The command response for the single Ethernet port option is as shown in *Figure 7.29*.

```
=>ETH <Enter>

SEL-787-4X                                 Date: 06/05/2010  Time: 10:41:44
FEEDER RELAY                                Time Source: Internal

 MAC: 00-30-A7-00-75-6A
 IP ADDRESS: 192.168.1.2
 SUBNET MASK: 255.255.255.0
 DEFAULT GATEWAY: 192.168.1.1

             LINK   SPEED  DUPLEX   MEDIA
PORT 1A      Up     100M    Full      TX

=>
```

Figure 7.29 Ethernet Port (PORT 1) Status Report for the Single Ethernet Port Option

EVENT Command (Event Reports)

Use the **EVE** command (see *Table 7.23*) to view event reports. See *Section 10: Analyzing Events* for further details on retrieving and analyzing event reports. See the *HISTORY Command on page 7.52* for details on clearing event reports.

Table 7.23 EVENT Command (Event Reports)

Command	Description	Access Level
EVE *n m*	Return the *n* event report with 4-samples/cycle data from Slot *m*.	1
EVE *n m* R or **EVE R *n***	Return the *n* event report with raw (unfiltered) 32 samples/cycle analog data and 4 samples/cycle digital data from Slot *m*.	1
EVE D *n m*	Return the *n* digital data event report with 4-samples/cycle data from Slot *m*.	1
EVE D *n m* R	Return the *n* digital data event report with 32-samples/cycle data from Slot *m*.	1
EVE DIF1 *n*	Return the *n* differential element 1 event report, with 4-samples/cycle data.	1
EVE DIF2 *n*	Return the *n* differential element 2 event report, with 4-samples/cycle data.	1
EVE DIF3 *n*	Return the *n* differential element 3 event report, with 4-samples/cycle data.	1
Parameters		
n	Indicates a record or event reference number. The most recent event has a record number of 1 and increments by 1 with each event, whereas the event reference number is a unique number that starts at 10000 and increments by 1 with each event (see *Event Reference Number on page 10.4* for details). If *n* is not specified, the relay displays the latest event report by default.	
m	Specifies the slot (*m* = Z or E). If *m* is not specified, the relay defaults to Slot Z. Slot Z contains Winding 1 and Winding 2 and Slot E contains Winding 3 and Winding 4 or the voltage channels.	

FILE Command

The **FIL** command (see *Table 7.24*) is a safe and efficient means of transferring files between intelligent electronic devices (IEDs) and external support software (ESS). The **FIL** command ignores the hide rules and transfers visible as well as hidden settings, except for the settings hidden by a part number. The **FIL** command is supported if you connect over the serial or Ethernet ports.

Table 7.24 FILE Command

Command	Description	Access Level
FIL DIR	Returns a list of files.	1
FIL READ *filename*	Transfers settings file *filename* from the relay to the PC.	1
FIL WRITE *filename*	Transfers settings file *filename* from the PC to the relay.	2
FIL SHOW *filename*	Displays contents of the file *filename*.	1

GOOSE Command

Use the **GOOSE** command to display transmit and receive GOOSE messaging information, which can be used for troubleshooting. The **GOOSE** command variants and options are shown in *Table 7.25*.

Table 7.25 GOOSE Command Variants

Command Variant	Description	Access Level
GOOSE	Displays GOOSE information.	1
GOOSE *k*	Displays GOOSE information *k* times.	1
GOOSE S	Displays a list of GOOSE subscriptions with their ID.	1
GOOSE S *n*	Displays GOOSE statistics for subscription ID *n*.	1
GOOSE S ALL	Displays GOOSE statistics for all subscriptions.	1
GOOSE S *n* L	Displays GOOSE statistics for subscription ID *n* including error history.	1
GOOSE S ALL L	Displays GOOSE statistics for all subscriptions including error history.	1
GOOSE S *n* C	Clears GOOSE statistics for subscription ID *n*.	1
GOOSE S ALL C	Clears GOOSE statistics for all subscriptions.	1

The information displayed for each GOOSE IED is described in *Table 7.26*.

Table 7.26 GOOSE IED Description (Sheet 1 of 2)

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_351S_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_351S_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 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.

Table 7.26 GOOSE IED Description (Sheet 2 of 2)

Information Field	Description
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
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_351S_1CFG/LLN0$DSet13).
Receive Data Set Reference	This field represents the datSetRef (Data Set Reference) that includes the iedName (IED name), ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class), and datSet (Data Set Name) (e.g., SEL_351S_1CFG/LLN0$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_351S_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*.
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 dataset.
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.

Table 7.27 Warning and Error Codes for GOOSE Subscriptions

Code	Enumeration[a]	Definition	Error/Warning
–	0	No errors present.	–
HOST DISABLED	1	Optional code for when the subscribing device is disabled or becomes unresponsive after the **GOOSE** command has been issued.	Error
CONF REV MISMA	2	Configuration revision mismatch. Displayed when the value of the configuration revision number in the received GOOSE message does not match with the value of the configuration revision number present in the CID file.	Error
NEED COMMISSIO	3	Needs commissioning. Displayed when the received GOOSE message has NdsCom = true.	Error
MSG CORRUPTED	4	Message corrupted. Displayed when a received GOOSE message does not meet the proper format or is corrupted.	Error
TTL EXPIRED	5	Time-to-live expired.	Error
OUT OF SEQUENC	6	Out-of-sequence (OOS) error. This error is present when the StNum or SqNum value between received GOOSE messages is not sequential.	Warning
INVALID QUAL	7	Invalid date quality received.	Warning

[a] Enumerations are used to communicate GOOSE error codes in the LGOS logical node.

Figure 7.30 shows an example response to the **GOOSE** command.

```
=>GOOSE

GOOSE Transmit Status

 MultiCastAddr   Ptag:Vlan AppID  StNum      SqNum      TTL    Code
-----------------------------------------------------------------------------
SEL_787d4_1CFG/LLN0$GO$GPub01
 01-0C-CD-01-00-19 4:1     4121   1          5612       358
 Data Set: SEL_787d4_1CFG/LLN0$GPDSet01

SEL_787d4_1CFG/LLN0$GO$NewGOOSEMessage
 01-0C-CD-01-00-03 4:3     3      1          5612       358
 Data Set: SEL_787d4_1CFG/LLN0$NewDataset


GOOSE Receive Status

 MultiCastAddr   Ptag:Vlan AppID  StNum      SqNum      TTL    Code
-----------------------------------------------------------------------------
SEL_700G_1CFG/LLN0$GO$NewGOOSEMessage
 01-0C-CD-01-00-05 4:3     5      1          5653       2000
 Data Set: SEL_700G_1CFG/LLN0$NewDataset

SEL_710d5_1CFG/LLN0$GO$NewGOOSEMessage
 01-0C-CD-01-00-04 4:3     4      11299      3          2000
 Data Set: SEL_710d5_1CFG/LLN0$NewDataset


=>GOO S 1 L

 SubsID 1
-----------------------------------------------------------------------------
 Ctrl Ref: SEL_700G_1CFG/LLN0$GO$NewGOOSEMessage
 AppID   : 5
 From    : 04/20/2018 12:34:22.502  To: 04/20/2018 14:09:47.992
```

Figure 7.30 GOOSE Command Response

```
Accumulated downtime duration                       : 0000:00:00.391
Maximum downtime duration                           : 0000:00:00.391
Date & time maximum downtime began                  : 04/20/2018 12:35:28.785
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    04/20/2018  12:35:28.785  0000:00:00.391  TTL EXPIRED

=>
```

Figure 7.30 GOOSE Command Response (Continued)

GROUP Command

Use the **GROUP** command (see *Table 7.28*) to display the active settings group or try to force an active settings group change (SS*n* SELOGIC control equations have priority over the **GROUP** command).

Table 7.28 GROUP Command

Command	Description	Access Level
GROUP	Displays the active settings group.	1
GROUP *n*	Changes the active Group *n*.	2
Parameter		
n	Indicates group numbers 1–4.	

When you change the active group, the relay responds with a confirmation prompt: `Are you sure (Y/N)?` Answer **Y <Enter>** to change the active group. The relay asserts the Relay Word bit SALARM for one second when you change the active group.

If any of the SELOGIC control equations SS1–SS4 are set when you issue the **GROUP *n*** command, the group change will fail. The relay responds: `Command Unavailable: Active setting group SELOGIC equations have priority over the GROUP command`.

HELP Command

The **HELP** command (see *Table 7.29*) gives a list of commands available at the present access level. You can also get a description of any particular command; type **HELP** followed by the name of the command for help on each command.

Table 7.29 HELP Command

Command	Description	Access Level
HELP	Displays a list of each command available at the present access level with a one-line description.	1
HELP *command*	Displays information on the command *command*.	1

HISTORY Command

Use the **HIS** command (see *Table 7.30*) to view a list of one-line descriptions of relay events or clear the list (and corresponding event reports) from nonvolatile memory. For more information on event reports, see *Section 10: Analyzing Events*.

Table 7.30 HISTORY Command

Command	Description	Access Level
HIS	Returns event histories with the oldest at the bottom of the list and the most recent at the top of the list.	1
HIS ***n***	Returns 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 C or **R**	Clears/resets the event history and all corresponding event reports from nonvolatile memory.	1
HIS CA or **RA**	Clears/resets the event history and all corresponding event reports from nonvolatile memory and resets the unique reference number to 10000.	1

ID Command

Use the **ID** command (see *Table 7.31*) to extract device identification codes, as shown in *Figure 7.31*. You can use the information in the SPECIAL field in the **ID** command response to determine the hardware and firmware compatibility of the relay. Contact SEL technical support before you downgrade the relay firmware.

Table 7.31 ID Command

Command	Description	Access Level
ID	Returns a list of device identification codes.	0

```
=ID <Enter>

"FID=SEL-787-4-X441-V0-Z005003-D20220627","091E"
"BFID=SLBT7XX-R600-V0-Z000000-D20200331","0949"
"CID=30A8","0259"
"DEVID=SEL-787-3S","0483"
"DEVCODE=79","0317"
"PARTNO=07874XE1A4X0XA585A670","076F"
"CONFIG=111002010","0419"
"SPECIAL=0","02DE"
"SEL DISPLAY PACKAGE=3.0.40787.4390","089A"
"CUSTOMER DISPLAY PACKAGE=1.575719065","099D"
"iedName=SEL_787d4_1","0671"
"type=SEL_787d4","04F0"
"configVersion=ICD-787-4-X205-V0-Z302006-D20220401","0D8A"
"LIB61850ID=DF8157E4","04ED"
```

Figure 7.31 ID Command Response

IRIG Command

Use the **IRIG** command to direct the relay to read the demodulated IRIG-B time code at the serial port or IRIG-B input (see *Table 7.32*).

Table 7.32 IRIG Command

Command	Description	Access Level
IRIG	Forces synchronization of internal control clock to IRIG-B time-code input.	1

To force the relay to synchronize to IRIG-B, enter the following command:

```
=>IRIG <Enter>
```

If the relay successfully synchronizes to IRIG-B, it sends the following header and access level prompt:

```
SEL-787-3S                  Date: 08/22/2013 Time: 08:56:03.190
TRNSFRMR RELAY                Time Source: External
=>
```

If no IRIG-B code is present at the serial port input or if the code cannot be read successfully, the relay responds with `IRIG-B DATA ERROR`.

If an IRIG-B signal is present, the relay synchronizes its internal clock with IRIG-B. It is not necessary to issue the **IRIG** command to synchronize the relay clock with IRIG-B. Use the **IRI**G command to determine if the relay is properly reading the IRIG-B signal.

L_D Command (Load Firmware)

Use the **L_D** command (see *Table 7.33*) to load firmware. See *Appendix A: Firmware, ICD, and Manual Versions* for information on changes to the firmware and instruction manual. See *Appendix B: Firmware Upgrade Instructions* for further details on downloading firmware. Only download firmware to the front port.

Table 7.33 L_D Command (Load Firmware)

Command	Description	Access Level
L_D	Loads new firmware.	2

LDP Command (Load Profile Report)

Use the **LDP** commands (see *Table 7.34*) to view and manage the load profile report (see *Figure 5.22*). If there is no stored data and an **LDP** command is issued, the relay responds with `No data available`.

Table 7.34 LDP Commands

Command	Description	Access Level
LDP ***row1 row2*** **LDP** ***date1 date2***	Displays a numeric progression of all load profile report rows. Use the **LDP** command with parameters to display a numeric or reverse numeric subset of the load profile rows.	1
LDP C	Clears the load profile report from nonvolatile memory.	1
Parameters		
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.	

LOOPBACK Command

The **LOO** command (see *Table 7.35*) is used for testing the MIRRORED BITS communications channel for proper communication. For more information on MIRRORED BITS, see *Appendix J: MIRRORED BITS Communications*. With the transmitter of the communications channel physically looped back to the receiver, the MIRRORED BITS addressing will be wrong and ROK will be deasserted. 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 asserts 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.

Table 7.35 LOO Command

Command	Description	Access Level
LOO	Enables loopback testing of MIRRORED BITS channels.	2
LOO A	Enables loopback on MIRRORED BITS Channel A for the next 5 minutes.	2
LOO B	Enables loopback on MIRRORED BITS Channel B for the next 5 minutes.	2
LOO R	Cancels the loopback test.	2

```
=>>LOO A <Enter>
Loopback will be enabled on Mirrored Bits channel A for the next 5 minutes.
The RMB values will be forced to default values while loopback is enabled.
Are you sure (Y/N)?
=>>
```

If only one MIRRORED BITS port is enabled, the channel specifier (A or B) can be omitted. To enable loopback mode for other than the 5-minute default, enter the number of minutes (1–5000) that you want as a command parameter. To allow the loopback data to modify the RMB values, include the DATA parameter.

```
=>>LOO 10 DATA <Enter>
Loopback will be enabled on Mirrored Bits channel A for the next 10 minutes.
The RMB values will be allowed to change while loopback is enabled.
Are you sure (Y/N)? N <Enter>
Canceled.
=>>
```

To disable loopback mode before the selected number of minutes, re-issue the **LOO** command with the R parameter. The R parameter returns the device to normal operation. If both MIRRORED BITS channels are enabled, omitting the channel specifier in the disable command causes both channels to be disabled.

```
=>>LOO R <Enter>
Loopback is disabled on both channels.
=>>
```

MAC Command

Use the **MAC** command to display the MAC addresses of **PORT 1**, as in the following:

NOTE: Relays with older CPU cards can be upgraded to firmware versions R200 or higher, but the relay will not have the GOOSE performance improvements (i.e., a GOOSE port with a dedicated MAC address).

```
=>MAC <Enter>

Port 1 (IP) MAC Address: 00-30-A7-67-32-10
Port 1 (GOOSE) MAC Address: 00-30-A7-78-10-20

=>
```

MET Command (Metering Data)

The **MET** command (see *Table 7.36* and *Table 7.37*) provides access to the relay metering data.

Table 7.36 METER Command

Command	Description	Access Level
MET *c n*	Displays the metering data.	1
MET *c* R	Resets the metering data.	2
Parameters		
c	Identifies the meter class. If *c* is not specified, the relay displays the fundamental meter report.	
n	Specifies the number of times (1–32767) to repeat the meter response.	

Table 7.37 Meter Class (Sheet 1 of 2)

c	Meter Class
F	Fundamental Metering
E[a]	Energy Metering
M[a]	Maximum/Minimum Metering
RMS	RMS Metering
T	Thermal and RTD Metering
AI	Analog Input (Transducer) Metering
MV	SELOGIC Math Variable Metering
DE[a]	Demand Metering

Table 7.37 Meter Class (Sheet 2 of 2)

c	Meter Class
PE[a]	Peak Demand Metering
PM	Synchrophasor Metering
H	Harmonic Metering
DIF	Differential Metering
RA	Remote Analog Metering

[a] Reset metering available.

For more information on metering and example responses for each meter class, see *Section 5: Metering and Monitoring*.

On issuing the **MET *c* R** command for resetting metering quantities in class *c*, the relay responds: `Reset Metering Quantities (Y,N)?` Upon confirming (pressing **Y**), the metering quantities are reset and the relay responds with `Reset Complete`.

OPEN n Command (Open Breaker n, Where n = 1, 2, 3, or 4)

The **OPE *n*** (OPEN) command asserts Relay Word bit OC*n* for 1/4 cycle when it is executed. Relay Word bit OC*n* can then be programmed into the TR*n* SELOGIC control equation to assert the TRIP*n* Relay Word bit, which in turn asserts an output contact (e.g., OUT301 = TRIP*n*) to open Circuit Breaker *n* (see *Table 4.40* and *Figure 4.66* for factory-default setting TR*n* and the trip logic).

To issue the **OPE 1** command, enter the following.

```
=>>OPE 1 <Enter>

Open Breaker1 (Y,N)? Y <Enter>

=>>
```

Typing **N <Enter>** after the previous prompt aborts the command.

The **OPE *n*** command is supervised by the main board breaker control jumper (see *Table 2.24*). If the breaker control jumper is not in place (breaker control jumper = OFF), the relay does not execute the **OPE *n*** command and responds with the following.

```
=>>OPE 1 <Enter>

Command Aborted: No Breaker Jumper

=>>
```

When setting EN_LRC := Y (see *Table 9.6*), the Relay Word bit LOCAL supervises the **OPE *n*** command. If the LOCAL bit is asserted (LOCAL = 1), the relay does not execute the **OPE *n*** command and responds with the following:

```
=>>OPE 1 <Enter>

Command Aborted: Device in Local Control

=>>
```

The Relay Word bit LOCAL is determined by the LOCAL SELOGIC control equation (see *Table 9.6*).

PASSWORD Command (Change Passwords)

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

Use the **PAS** command (see *Table 7.38*) to change existing passwords.

Table 7.38 PASSWORD Command

Command	Description	Access Level
PAS *level*	Changes the password for Access Level *level*.	2, C
Parameter		
level	Represents the relay Access Level 1, 2, or C.	

The factory-default passwords are as shown in *Table 7.39*.

Table 7.39 Factory-Default Passwords for Access Levels 1, 2, and C

Access Level	Factory-Default Passwords
1	OTTER
2	TAIL
C	CLARKE

To change the password for Access Level 1 to #Ot3579!ijd7, enter the following command sequence:

```
=>>PAS 1  <Enter>
New PW: ?#0t3579!ijd7 <Enter>
Confirm PW: ?#0t3579!ijd7 <Enter>
Password Changed
=>>
```

Similarly, use **PAS 2** to change the Access Level 2 password and **PAS C** to change the Access Level C password.

Table 7.40 Valid Password Characters

<table>
<tr><td>Alpha</td><td>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</td></tr>
<tr><td>Numeric</td><td>0 1 2 3 4 5 6 7 8 9</td></tr>
<tr><td>Special</td><td>! " # $ % & ' ( ) * + , - . / : ; < = > ? @ [\ ] ^ _ ` { | } ~</td></tr>
</table>

Passwords can contain as many as 12 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, and strong passwords are shown below:

- #0t3579!ijd7
- $A24.68&,mvj
- (Ih2dcs)36dn
- *4u-Iwg+?lf-

PING Command

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. The **PING** command (Access Level 1) allows you to determine if a host is reachable across an IP network and/or if the Ethernet port (Port 1) is functioning and configured correctly. A typical **PING** command response is shown in *Figure 7.32*.

The command structure is:

PING *x.x.x.x t*

where:

x.x.x.x is the Host IP address and

t is the PING interval in seconds, with a 2 to 255 second range

The default PING interval is one second when *t* is not specified. The relay sends ping messages to the remote node until you stop the PING test by pressing the **Q** key.

```
=>PING 10.201.7.52 <Enter>

Press the Q key to end the ping test.

Pinging 10.201.7.52 every 1 second(s):

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
Ping test stopped.

Ping Statistics for 10.201.7.52
   Packets: Sent = 7, Received = 6, Lost = 1
   Duplicated = 0

=>
```

Figure 7.32 PING Command Response

PULSE Command

NOTE: The **PULSE** command is available when the breaker control jumper on the main board is in the ENABLED position.

Use the **PULSE** command (see *Table 7.41*) to pulse any of the relay outputs for a specified time. This function aids you in relay testing and commissioning. When a **PUL** command is issued, the selected contact will close or open depending on the output contact type (a or b). The **PUL** command energizes the coil and does not have any effect if the coil is already energized. The outputs are OUT*nnn*, where *nnn* represents 101–103 (standard), 301–308 (optional), 401–408 (optional), or 501–508 (optional). For example, OUTPUT 301 refers to Output 01 in Slot C.

Table 7.41 PUL OUTnnn Command

Command	Description	Access Level
PUL OUT*nnn*	Pulses output OUT*nnn* for 1 second.	2
PUL OUT*nnn s*	Pulses output OUT*nnn* for *s* seconds.	2
Parameters		
nnn	Output number.	
s	Time in seconds, with a range of 1–30.	

QUIT Command

Use the **QUIT** command (see *Table 7.42*) to revert to Access Level 0.

Table 7.42 QUIT Command

Command	Description	Access Level
QUIT	Goes to Access Level 0.	0

Access Level 0 is the lowest access level; the SEL-787 performs no password check to descend to this level (or to remain at this level).

RSTP Command

Use the **RSTP** command (see *Table 7.43*) to display the RSTP statistics and the present RSTP configuration when RSTP is enabled.

Table 7.43 RSTP Command

Command	Description	Access Level
RSTP	Displays the RSTP statistics and the present RSTP configuration.	1

Table 7.44 describes the information displayed in the output of the **RSTP** command.

Table 7.44 RSTP Command Definitions (Sheet 1 of 2)

Information Field	Description
ROOT BRIDGE	Reveals the role of the relay in the RSTP configuration. It will either display YES or NO.
BRIDGE ID	Displays the Bridge ID of the relay, which consists of the bridge priority (in decimal format) and the MAC address of the relay.
ROOT BRIDGE ID	Displays the Bridge ID of the root bridge, which consists of the bridge priority (in decimal format) and the MAC address of the root bridge.
ROOT PORT	Displays the port number (i.e., Port 1A or Port 1B) that is forwarding towards the root bridge when the relay is a designated bridge. If the relay is the root bridge, this displays NA.
TIME SINCE TOPOLOGY CHANGE	Displays the number of seconds since the last topology change occurred.
BRIDGE PRIORITY	Determines the root bridge. The bridge with the lowest value becomes the root bridge. It can be set under the Port 1 settings.
HELLO TIME	Interval in which the relay sends BPDUs. It is fixed at 2 seconds.
MAX AGE	Maximum number of hops before a BPDU is discarded. It is fixed at 40.
FORWARD DELAY	The time that the relay must spend in the listening and learning states before transitioning to forwarding. It is fixed at 21 seconds. This is only used when the relay is in STP compatibility mode.
PORT 1A PROTOCOL	Displays either STP or RSTP.
PORT 1B PROTOCOL	Displays either STP or RSTP.
PORT 1A STATE	The state of Port 1A.
PORT 1B STATE	The state of Port 1B.
PORT 1A ROLE	The role of Port 1A.
PORT 1B ROLE	The role of Port 1B.

Table 7.44 RSTP Command Definitions (Sheet 2 of 2)

Information Field	Description
PORT 1A PRIORITY	Determines which port the device selects as a root port when there is a tie between two ports. The port with the lower value will become the root port. It can be set under the Port 1 settings.
PORT 1B PRIORITY	Determines which port the device selects as a root port when there is a tie between two ports. The port with the lower value will become the root port. It can be set under the Port 1 settings.
PORT 1A PATH COST	Helps determine which path the device selects to a root bridge. The device selects paths with the lowest overall cost first. It is fixed at 200000.
PORT 1B PATH COST	Helps determine which path the device selects to a root bridge. The device selects paths with the lowest overall cost first. It is fixed at 200000.
PORT 1A EDGE PORT	If YES, Port 1A is an edge port. If NO, it is not.
PORT 1B EDGE PORT	If YES, Port 1B is an edge port. If NO, it is not.
PORT 1A BPDU COUNT	Displays the number of BPDUs received on Port 1A.
PORT 1B BPDU COUNT	Displays the number of BPDUs received on Port 1B.

Figure 7.33 shows an example response to the **RSTP** command.

```
=>RSTP <Enter>

SEL-787-4                                  Date: 08/26/2022   Time: 10:55:23.711
XMER RELAY                                 Time Source: External


RSTP Communication Statistics:

Root Bridge: NO
Bridge Id: 28672-0030A71BF353
Root Bridge Id: 20480-0030A71C931C
Root Port: 1B
Time Since Topology Change: 154111 sec
Bridge Priority: 28672;   Hello Time:  2 sec
Max Age: 40;   Forward Delay:  21 sec

PORT PROTOCOL  STATE       ROLE    PRIORITY  PATHCOST EDGE #BPDU-RCVD
 1A   RSTP   Discarding   Disabled    128    200000   False    553073
 1B   RSTP   Forwarding   Rootport    128    200000   False     77077

=>
```

Figure 7.33 RSTP Command Response

R_S Command (Restore Factory Defaults)

NOTE: In firmware versions R302-V0 and higher, the relay firmware retains the IP address, subnet mask, and default router settings after an R_S command is issued.

Use the **R_S** command (see *Table 7.45*) to restore the factory-default settings.

Table 7.45 R_S Command (Restore Factory Defaults)

Command	Description	Access Level
R_S	Restores the factory-default settings and passwords and reboots the system.[a]	2

[a] Only available after a settings or critical RAM failure.

SER Command (Sequential Events Recorder Report)

Use the **SER** commands (see *Table 7.46*) to view and manage the Sequential Events Recorder report. If there is no SER report row stored, the relay responds with `No data available`. See *Section 10: Analyzing Events* for further details on SER reports.

Table 7.46 SER Command (Sequential Events Recorder Report)

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 C or **R**	Use this command to clear/reset the SER records.	1
Parameters		
row1	Append *row1* to return a chronological progression of the first *row1* rows. For example, use **SER 5** to return the first five rows.	
row1 row2	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. For example, use **SER 1 10** to return the first 10 rows in numeric order or **SER 10 1** to return these same items in reverse numeric order.	
date1	Append *date1* to return all rows with this date. For example, use **SER 1/1/2014** to return all records for January 1, 2014.	
date1 date2	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. For example, use **SER 1/5/2014 1/7/2014** to return all records for January 5, 6, and 7, 2014.	

SER D Command

The **SER D** command shows a list of SER items that the relay has automatically removed. These are "chattering" elements. You can automatically remove chattering SER elements in the SER Chatter Criteria category of the Report settings; the enable setting is ESERDEL. See *Report Settings (SET R Command) on page 4.155* for more information on SER automatic deletion and reinsertion.

Table 7.47 SER D Command

Command	Description	Access Level
SER D	Lists chattering SER elements that the relay is removing from the SER records.	1

If you issue the **SER D** command and you have not enabled automatic removal of chattering SER elements (Report setting ESERDEL), the relay responds, `Automatic removal of chattering SER elements not enabled`.

SET Command (Change Settings)

The **SET** command is for viewing or changing the relay settings (see *Table 7.48*).

Table 7.48 SET Command (Change Settings)

Command	Description	Access Level
SET *n s* TERSE	Sets the relay settings, beginning at the first setting for Group *n*.	2
SET L *n s* TERSE	Sets the general logic settings for Group *n*.	2
SET G *s* TERSE	Sets the global settings.	2
SET P *k s* TERSE	Sets the serial port settings. *k* specifies the port; *k* defaults to the active port if not listed.	2
SET R *s* TERSE	Sets the report settings such as Sequential Events Recorder (SER) and Event Report (ER) settings.	2
SET F *s* TERSE	Sets the front-panel settings.	2
SET I TERSE	Sets the IEC 60870-5-103 settings.	2
SET M *s* TERSE	Sets the Modbus user map settings.	2
SET E *m s* TERSE	Sets the EtherNet/IP Assembly Map *m* settings.	2
SET DNP *m s* TERSE	Sets the DNP Map *m* settings.	2
Parameters		
n	Indicates the group number 1, 2, 3, or 4.	
k	Indicates the port number 1, 2, 3, 4, or F.	
m	Indicates the DNP map number 1, 2, or 3.	
s	Appends *s*, the name of the specific setting you want to view, and jumps to this setting. If *s* is not entered, the relay starts at the first setting.	
TERSE	Append TERSE or TE to skip the settings 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 7.49*.

Table 7.49 SET Command Editing Keystrokes

Press Key(s)	Results
<Enter>	Retains the setting and moves to the next setting.
^ <Enter>	Returns to the previous setting.
< <Enter>	Returns to the previous setting category.
> <Enter>	Moves to the next setting category.
END <Enter>	Exits the editing session, then prompts you to save the settings.
<Ctrl+X>	Aborts the editing session without saving changes.

The relay checks each setting to ensure that it is within the allowed range. If the setting is not within the allowed range, the relay generates an `Out of Range` message and prompts you for the setting again.

When all the settings are entered, the relay displays the new settings and prompts you for approval to enable them. Answer **Y <Enter>** to enable the new settings. The relay is disabled for as long as one second while it saves the new settings. The SALARM Relay Word bit is set momentarily, and the **ENABLED** LED extinguishes while the relay is disabled.

SHOW Command (Show/View Settings)

When showing settings, the relay displays the settings label and the present value from nonvolatile memory for each setting class. See *Table 7.50* for the **SHOW** command settings and format.

Table 7.50 SHOW Command (Show/View Settings)

Command	Description	Access Level
SHO *n s*	Shows the group settings for Group *n*.	1
SHO L *n s*	Shows the general logic settings for Group *n*.	1
SHO G *s*	Shows the Global settings.	1
SHO P *k s*	Shows the serial port settings. *k* specifies the port; *k* defaults to the active port if not listed.	1
SHO R *s*	Shows the report settings such as Sequential Events Recorder (SER) and Event Report (ER) settings.	1
SHO F *s*	Shows the front-panel settings.	1
SHO I	Shows the IEC 60870-5-103 settings.	1
SHO M *s*	Shows the Modbus user map settings.	1
SHO E *m s*	Shows the EtherNet/IP Assembly Map *m* settings (*m* = 1, 2, or 3).	1
SHO DNP *m s*	Shows the DNP Map *m* settings.	1
Parameters		
n	Indicates the group number 1, 2, 3, or 4.	
k	Indicates the port number 1, 2, 3, 4, or F.	
m	Indicates the DNP map number 1, 2, or 3.	
s	Append *s*, the name of the specific setting you want to view, and jump to this setting. If *s* is not entered, the relay starts at the first setting.	

```
=>SHO <Enter>

Group 1
Relay Settings

ID Settings
RID      := SEL-787-3S
TID      := TRNSFRMR RELAY


Config Settings
E87W1    := Y           E87W2    := Y           E87W3    := Y
W1CT     := WYE         W2CT     := WYE         W3CT     := WYE
CTR1     := 100         CTR2     := 1000        CTR3     := 1000
MVA      := 50.0        ICOM     := N           VWDG1    := 138.00
VWDG2    := 13.80       VWDG3    := 13.80       PTR      := 120.00
PTRS     := 120.00      VNOM     := 13.80       DELTA_Y  := DELTA
VIWDG    := 2           COMPANG  := 0           SINGLEV  := N

Xfmr Differential
TAP1     := 2.08        TAP2     := 2.08        TAP3     := 2.08
O87P     := 0.30        87AP     := 0.15        87AD     := 5.0
SLP1     := 25          SLP2     := 70          IRS1     := 6.0
U87P     := 10.0        PCT2     := 15          PCT4     := 15
PCT5     := 35          TH5P     := OFF         HRSTR    := Y
HBLK     := N
```

Figure 7.34 SHOW Command Example

```
WDG1 Max Ph IOC
50P11P   := OFF          50P12P   := OFF          50P13P   := OFF
50P14P   := OFF

WDG1 Res IOC
50G11P   := OFF          50G12P   := OFF

WDG1 Neg Seq IOC
50Q11P   := OFF          50Q12P   := OFF

WDG1 Max Ph TOC
51P1P    := OFF

WDG1 Res TOC
51G1P    := OFF

WDG1 Neg Seq TOC
51Q1P    := OFF


WDG2 Max Ph IOC
50P21P   := OFF          50P22P   := OFF          50P23P   := OFF
50P24P   := OFF

WDG2 Res IOC
50G21P   := OFF          50G22P   := OFF

WDG2 Neg Seq IOC
50Q21P   := OFF          50Q22P   := OFF

WDG2 Max Ph TOC
51P2P    := OFF

WDG2 Res TOC
51G2P    := OFF

WDG2 Neg Seq TOC
51Q2P    := OFF

WDG3 Per Ph IOC
50P31AP  := OFF          50P31BP  := OFF          50P31CP  := OFF
50P32AP  := OFF          50P32BP  := OFF          50P32CP  := OFF

WDG3 Per Ph TOC
51P3AP   := OFF          51P3BP   := OFF          51P3CP   := OFF

WDG3 Max Ph IOC
50P31P   := OFF          50P32P   := OFF          50P33P   := OFF
50P34P   := OFF

WDG3 Res IOC
50G31P   := OFF          50G32P   := OFF

WDG3 Neg Seq IOC
50Q31P   := OFF          50Q32P   := OFF


WDG3 Max Ph TOC
51P3P    := OFF

WDG3 Res TOC
51G3P    := OFF

WDG3 Neg Seq TOC
51Q3P    := OFF

RTD Settings
E49RTD   := NONE

Ph Undervoltage
27PP1P   := OFF          27PP2P   := OFF          27S1P    := OFF
27S2P    := OFF

Ph Overvoltage
59PP1P   := OFF          59PP2P   := OFF          59Q1P    := OFF
59Q2P    := OFF          59S1P    := OFF          59S2P    := OFF

Volts per Hertz
E24      := Y            24WDG    := WYE          24D1P    := 105
24D1D    := 1.00         24CCS    := ID           24IP     := 105
24IC     := 2.0          24ITD    := 0.1          24D2P2   := 176
24D2D2   := 3.00         24CR     := 240.00
24TC     := 1
```

Figure 7.34 SHOW Command Example (Continued)

```
SyncCheck Set
E25      := N

Power Elements
EPWR     := N

Freq Settings
81D1TP   := OFF           81D2TP   := OFF           81D3TP   := OFF
81D4TP   := OFF

Demand Mtr Set
EDEM     := OFF

Trip/Close Logic
TDURD    := 0.50          CFD1     := 0.50          CFD2     := 0.50
CFD3     := 0.50
TR1      := 50P11T OR 51P1T OR 51Q1T OR LT05 AND SV03T OR OC1
TR2      := 51P2T OR 51Q2T OR LT06 AND SV03T OR OC2
TR3      := 51P3T OR 51Q3T OR LT07 AND SV03T OR OC3
TRXFMR   := 87R OR 87U
REMTRIP  := 0
ULTRIP1  := NOT ( 51P1P OR 51Q1P OR 52A1 )
ULTRIP2  := NOT ( 51P2P OR 51Q2P OR 52A2 )
ULTRIP3  := NOT ( 51P3P OR 51Q3P OR 52A3 )
ULTRXFMR := NOT ( 87R OR 87U )
52A1     := IN101
CL1      := SV02T AND LT05 OR CC1
ULCL1    := TRIP1 OR TRIPXFMR
52A2     := IN102
CL2      := SV02T AND LT06 OR CC2
ULCL2    := TRIP2 OR TRIPXFMR
52A3     := 0
CL3      := SV02T AND LT07 OR CC3
ULCL3    := TRIP3 OR TRIPXFMR

=>
```

Figure 7.34 SHOW Command Example (Continued)

STATUS Command (Relay Self-Test Status)

The **STA** command (see *Table 7.51*) displays the status report. See *Figure 7.35* for an example of a status report.

Table 7.51 STATUS Command (Relay Self-Test Status)

Command	Description	Access Level
STA *n*	Displays the relay self-test information *n* times. Defaults to 1 if *n* is not specified.	1
STA S	Displays the memory and execution utilization for the SELOGIC control equations.	1
STA C or **R**	Reboots the relay and clears the self-test warning and failure status results.	2
Parameter		
n	Specifies the number of times (1–32767) to repeat the self-test information.	

Refer to *Section 11: Testing and Troubleshooting* for self-test thresholds and corrective actions, as well as hardware configuration conflict resolution. *Table 7.52* shows the status report definitions and message formats for each test. Refer to *Figure 1.2* and *Figure 1.3* for **STATUS** command response outputs.

Table 7.52 STATUS Command Report and Definitions (Sheet 1 of 2)

STATUS Report Designator	Definition	Message Format
Serial Num	Serial number	Text Data
FID	Firmware identifier string	Text Data

Table 7.52 STATUS Command Report and Definitions (Sheet 2 of 2)

STATUS Report Designator	Definition	Message Format
CID	Firmware checksum identifier	Hex
PART NUM	Part number	Text Data
FPGA	FPGA programming unsuccessful, or FPGA failed	OK/FAIL
GPSB	General Purpose Serial Bus	OK/FAIL
HMI	Front-panel FPGA programming unsuccessful, or front-panel FPGA failed	OK/WARN
RAM	Volatile memory integrity	OK/FAIL
ROM	Firmware integrity	OK/FAIL
CR_RAM	Integrity of settings in RAM and code that runs in RAM	OK/FAIL
NON_VOL	Integrity of data stored in nonvolatile memory	OK/FAIL
CLOCK	Clock functionality	OK/WARN
RTD	Integrity of RTD module/communications	OK/FAIL
CID_FILE	Configured IED description file	OK/FAIL
x.x V	Power supply status	Voltage/FAIL
BATT	Clock battery voltage	Voltage/WARN
CARD_C	Integrity of Card C	OK/FAIL
CARD_D	Integrity of Card D	OK/FAIL
CARD_E	Integrity of Card E	OK/FAIL
CARD_Z	Integrity of Card Z	OK/FAIL
Current Offset (IAW1, IBW1, ICW1, IAW2, IBW2, ICW2, IAW3, IBW3, ICW3, IAW4, IBW4, ICW4)	Measurement of dc offset in hardware circuits of current channels	Measurement of dc offset/WARN
Voltage Offset (VS, VA, VB, VC)	Measurement of dc offset in hardware circuits of voltage channels	Measurement of dc offset/WARN
DN_MAC_ID	Specific DeviceNet card identification	Text Data
ASA	Manufacturers identifier for DeviceNet	Text Data
DN_Rate	DeviceNet card network communications data rate ___kbps	Text Data
DN_Status	DeviceNet connection and fault status 000b bbbb	Text Data

NOTE: The STA S report gives the available SELOGIC capacity of the relay. For example, Execution 90% means that 90% of the execution capacity is still available.

Figure 7.35 shows the typical relay output for the **STATUS S** command, showing available SELOGIC control equation capability.

```
=>STA S <Enter>

SEL-787-3S                                  Date: 08/22/2013   Time: 14:47:40.044
TRNSFRMR RELAY                              Time Source: Internal

Part Number = 07873SE1B0X0X7585063X

SELogic Equation Available Capacity

Global (%)   81
FP (%)       78
Report (%)   98

               GROUP 1  GROUP 2  GROUP 3  GROUP 4
Execution (%)   67       67       67       67
Group (%)       82       82       82       82
Logic (%)       88       88       88       88

=>
```

Figure 7.35 Typical Relay Output for STATUS S Command

SUMMARY Command

The **SUM** command (see *Table 7.53*) displays an event summary in human-readable format.

Table 7.53 SUMMARY Command

Command	Description	Access Level
SUM ***n***	The command without arguments displays the latest event summary. Use *n* to display particular event summary (where *n* is either the event record or the reference number).	1
SUM R or **C**	Use this command to clear the archive.	1

Each event summary report shows the date, time, current and voltage magnitudes (primary values), LED targets, frequency, and hottest RTD values (if RTDs are enabled). The relay reports the voltage and current when the largest current occurs during the event. The event summary report also shows the event type (type of trip).

TARGET Command (Display Relay Word Bit Status)

The **TAR** command (see *Table 7.54*) displays the status of front-panel target LEDs or Relay Word bits, whether these LEDs or Relay Word bits are asserted or deasserted.

Table 7.54 TARGET Command (Display Relay Word Bit Status)

Command	Description	Access Level
TAR *name k* **TAR *n*** **TAR *n k***	Use **TAR** without parameters to display Relay Word Row 0 or the last displayed target row.	1
TAR R	Clears the front-panel tripping targets. Unlatches the trip logic for testing purposes (see *Figure 8.5*). Shows Relay Word Row 0.	1
Parameters		
name	Displays the Relay Word row with the Relay Word bit name.	
n	Shows Relay Word row number *n*.	
k	Repeats *k* times (1–32767).	

NOTE: The **TARGET R** command cannot reset the latched targets if a TRIP condition is present.

The elements are represented as Relay Word bits and are listed in rows of eight, called Relay Word rows. The first four rows, representing the front-panel operation and target LEDs, correspond to *Table 7.55*. All the Relay Word rows are described in *Table L.1* and *Table L.2*.

Relay Word bits are used in SELOGIC control equations. See *Appendix L: Relay Word Bits*.

The **TAR** command does not remap the front-panel target LEDs, as is done in some previous SEL relays.

Table 7.55 Front-Panel LEDs and the TAR 0 Command

LEDs	7	6	5	4	3	2	1	0
TAR 0	ENABLED	TRIP_LED	TLED_01	TLED_02	TLED_03	TLED_04	TLED_05	TLED_06

TEST DB Command

Use the **TEST DB** command to temporarily force the relay to send fixed analog and/or digital values over communications interfaces for protocol testing.

If the relay is enabled to control IEC 61850 Mode/Behavior, then the **TEST DB** command can only be used when the relay is in On mode. The **TEST DB** command cannot be used in any other mode. If the **TEST DB** command is active while the relay is in On mode, a change of mode will deactivate the **TEST DB** command.

Table 7.56 TEST DB Commands (Sheet 1 of 2)

Command	Description	Access Level
TEST DB	Displays the present status of digital and analog overrides.	2
TEST DB A *name value*	Forces the protocol analog element *name* to override *value*.	2
TEST DB D *name value*	Forces the protocol digital element *name* to override *value*.	2
TEST DB *name* OFF	Clears (analog or digital) override for element *name*.	2
TEST DB A OFF	Clears all analog overrides.	2

Table 7.56 TEST DB Commands (Sheet 2 of 2)

Command	Description	Access Level
TEST DB D OFF	Clears all digital overrides.	2
TEST DB OFF	Clears all analog and digital overrides.	2

⚠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.

NOTE: The **TEST DB** command does not support digital points for the SEL Fast Message protocol.

The **TEST DB** command provides a method to override Relay Word bits or analog values to aid in the testing and commissioning of communications interfaces only and should not be used on an energized system. The command overrides values in the communications interfaces (ASCII, SEL Fast Message, DNP3, Modbus, EtherNet/IP, IEC 60870-5-103, 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.

R1*xx* firmware versions use a previous version of the **TEST DB** command that aids in the testing and commissioning of the IEC 61850 protocol only. Note that the **TEST DB** command supported by R1*xx* firmware versions provides a method to override Relay Word Bits only and should not be used on an energized system. If used on an energized system, it can lead to unwanted operations, including a potential trip.

To override analog data in a communications interface, enter the following from Access Level 2 or higher:

NOTE: When using the **TEST DB** command to generate values for Fast Meter testing, you may need to override all current and voltage angles (IAW1_ANG, VA_ANG, etc.) to ensure the expected phase relationship.

```
=>>TEST DB A name value <Enter>
```

NOTE: When using the **TEST DB** command, specifying a negative value may yield an unexpected display in some instances.

where *value* is a numerical value and *name* is an analog label from *Table M.1*, with an "x" in the DNP3, Modbus, EtherNet/IP, Fast Meter, IEC 60870-5-103, or IEC 61850 column. For example, the **TEST DB** command can be used to force the value of the A-phase current magnitude transmitted to a remote device to 100 amperes:

```
=>>TEST DB A IAW1_MAG 100 <Enter>
```

To override digital data in an SEL ASCII, Modbus, EtherNet/IP, DNP3, IEC 60870-5-103, or IEC 61850 communications interface, enter the following from Access Level 2 or higher:

```
=>>TEST DB D name value <Enter>
```

where *name* is a Relay Word bit (see *Table L.1*) and *value* is 1 or 0. For example, if Relay Word bit 51P1T := logical 0, the **TEST DB** command can be used effectively to test the communications interface by forcing the communicated status of this Relay Word bit to logical 1:

```
=>>TEST DB D 51P1T 1 <Enter>
```

Values listed in the SER triggers SER1, SER2, SER3, and SER4 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>

SEL-787                          Date: 02/02/09    Time: 16:24:38.764
FEEDER RELAY                     Time Source: Internal

NAME          OVERRIDE VALUE
IAW1_MAG             100.0000
FREQ                 60.0000

=>>
```

Individual overrides are cleared using the **TEST DB** command with the OFF parameter:

```
=>>TEST DB D name OFF <Enter>
```

Entering **TEST DB A OFF** clears all analog overrides and **TEST DB D OFF** clears all digital overrides. Entering **TEST DB OFF** without any parameters clears all overrides. When there are no overrides, the relay automatically exits the Test Mode and clears all of the overrides if no **TEST DB** commands are entered for 30 minutes.

TFE Command (Through-Fault Event Report)

The **TFE** command displays the following data for each individually recorded through-fault event:

- Date and time
- Duration (seconds)
- Maximum current (primary amperes) for each monitored current input

The following cumulative values (updated for each new through-fault event) are also displayed:

➤ Through-fault count
➤ Total accumulated percentage of through-fault capability used up per phase

There are various choices for the **TFE** command, listed briefly below. Refer to *Section 5: Metering and Monitoring* for a complete description of the through-fault event reports.

Table 7.57 TFE Command (Through-Fault Event Report)

Command	Description	Access Level
TFE	Displays cumulative and individual through-fault event data. The 20 most recent individual events are displayed.	1
TFE A	Displays cumulative and individual through-fault event data. All of the most recent individual events are displayed, as many as 500.	1
TFE C or **R**	Clears/resets cumulative and individual through-fault event data.	2
TFE *n*	Displays cumulative and individual through-fault event data. The *n* most recent individual events are displayed, where *n* = 1 to 500.	1
TFE P	Preloads cumulative through-fault event data.	2

TIME Command (View/Change Time)

The **TIME** command (see *Table 7.58*) returns information about the SEL-787 internal clock. You can also set the clock if you specify hours and minutes (seconds data are optional). Separate the hours, minutes, and seconds with colons, semicolons, spaces, commas, or slashes.

Table 7.58 TIME Command (View/Change Time)

Command	Description	Access Level
TIME	Displays the present internal clock time.	1
TIME *hh*	Sets the internal clock to *hh*.	1
TIME *hh:mm*	Sets the internal clock to *hh:mm*.	1
TIME *hh:mm:ss*	Sets the internal clock to *hh:mm:ss*.	1

Use the **TIME *hh***, **TIME *hh:mm***, and **TIME *hh:mm:ss*** commands to set the internal clock time. The value *hh* is for hours from 0–23; the value *mm* is for minutes from 0–59; the value *ss* is for seconds from 0–59. If you enter a valid time, the relay updates and saves the time in the nonvolatile clock, and displays the time you just entered. If you enter an invalid time, the SEL-787 responds with `Invalid Time`.

TRIGGER Command (Trigger Event Report)

Use the **TRI** command (see *Table 7.59*) to trigger the SEL-787 to record data for high-resolution oscillographs and event reports.

Table 7.59 TRIGGER Command (Trigger Event Report)

Command	Description	Access Level
TRI	Triggers an event report data capture.	1

When you issue the **TRI** command, the SEL-787 responds with `Triggered`. If the event does not trigger within one second, the relay responds with `Did not trigger`. See *Section 10: Analyzing Events* for further details on event reports.

VECTOR Command (Show Diagnostic Information)

Issue the **VEC** command under the direction of SEL. 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.

Table 7.60 VECTOR Command

Command	Description	Access Level
VEC D	Displays the standard vector report.	2
VEC E	Displays the extended vector report.	2

Language Support

All of the ASCII commands can be displayed in multiple languages (English or Spanish). When you set the port setting LANG (see *Table 4.64*) to either ENGLISH or SPANISH, the SEL-787 displays the ASCII commands in the corresponding language. See *SEL-787-2, -3, -4 Relay Command Summary* for a list of the commands.

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 with SEL ASCII protocol or the Ethernet port with Telnet, use the **FILE DIR** command to access the file interface. When using the Ethernet port, the FTP and MMS protocols supported by the Ethernet port present the file structure and send and receive files.

Send and receive files using the following protocols.

Protocol	Port Availability
File Transfer Protocol	Ethernet only
Manufacturing Message Specification	Ethernet only
Ymodem	Serial and Ethernet

FTP and MMS File Structure

FTP and the IEC 61850 MMS have a two-level file structure. Files are available at the root level and in subdirectories. *Table 7.61* shows the directories and their contents.

Table 7.61 FTP and MMS Virtual File Structure

Directory	Contents
/ (Root)	CFG.TXT file, CFG.XML file, ERR.TXT file and SET_61850.CID and the SETTINGS, REPORTS, EVENTS, COMTRADE[a], and HMI[b] directories
/SETTINGS	Relay settings
/REPORTS	SER, LDP, BRE, TFE, and HIS reports
/EVENTS	CEV, COMTRADE, and HIS reports
/COMTRADE[a]	COMTRADE events
/HMI[b]	Touchscreen settings (SET_HMI.zds and CDP.zds) and diagnostics (HMI_ALL.zip)
/UPGRADE[c]	Digitally signed firmware upgrades

[a] The COMTRADE directory is only available in the MMS file structure.
[b] Available only in the SEL-787 touchscreen display model. HMI_ALL.ZIP is not available in the MMS file structure.
[c] Only present in SEL-787 relays with relay firmware R300 and higher. Relay firmware R300 and higher supports firmware upgrade over Ethernet. To write to the directory, the Port 1 setting EETHFWU must be enabled.

Root Directory

The root directory (/) contains files and subdirectories as shown in *Table 7.61*.

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. Calibration settings are included only when the file is read at Access Level C.

```
[INFO]
RELAYTYPE=SEL-751
FID=SEL-787-4-X495-V1-Z008004-D20200206
BFID=SLBT7XX-X106-V0-Z000000-D20191226
PARTNO=7873SE1B4X2X7585087X
[FRONTPANEL]
BDP=3.0.40751.4940
[CLASSES]
PF,"Port F"
P2,"Port 2"
P3,"Port 3"
P1,"Port 1"
G,"Global"
1,"Group 1"
2,"Group 2"
3,"Group 3"
4,"Group 4"
L1,"Logic 1"
L2,"Logic 2"
L3,"Logic 3"
L4,"Logic 4"
M,"Modbus User Map"
R,"Report"
F,"Front Panel"
D1,"DNP Map 1 Settings"
D2,"DNP Map 2 Settings"
D3,"DNP Map 3 Settings"
I,"IEC 60870-5-103 Map"
E1,"EtherNet/IP Assembly Map 1 Settings"
E2,"EtherNet/IP Assembly Map 2 Settings"
E3,"EtherNet/IP Assembly Map 3 Settings"
```

Figure 7.36 CFG.TXT File

CFG.XML File (Read-Only). Present only in units with the Ethernet option, the CFG.XML file is supplementary to the CFG.TXT file. The CFG.XML file describes the IED configuration and 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 G: IEC 61850 Communications* for more information.

Settings Directory (Available for FTP and MMS)

You can access the relay settings through files in the SETTINGS directory. It is recommended 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 it is not empty, the relay detects errors in the SET_*cn*.TXT file.

Step 4. For any detected errors, modify the settings and send the settings until the relay accepts your settings.

Step 5. Repeat *Step 2–Step 4* for each settings class that you want to modify.

Step 6. After all setting changes are complete, 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. Calibration settings are included only when the file is read at Access Level C.

SET_cn.TXT Files (Read and Write). There is a file for each instance of each setting class. *Table 7.62* 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.

Table 7.62 Settings Directory Files (Sheet 1 of 2)

File Name	Settings Description
SET_*n*.TXT	Group; *n* in range 1–4
SET_D*n*.TXT	DNP3 Map; *n* in range 1–3
SET_F.TXT	Front panel
SET_G.TXT	Global

Table 7.62 Settings Directory Files (Sheet 2 of 2)

File Name	Settings Description
SET_I.TXT	IEC 60870 Map
SET_L*n*.TXT	Logic; *n* in range 1–4
SET_M.TXT	Modbus Map
SET_E*n*.TXT	EtherNet/IP Assembly Map; *n* in range 1–3
SET_P*n*.TXT	Port; *n* in range 1, 2, 3, 4, F
SET_R.TXT	Report
SET_ALL.TXT	All instances of all settings classes
ERR.TXT	Error log for most recently written settings file

Reports Directory (Read-Only) (Available for FTP and MMS)

Use the REPORTS directory to retrieve files that contain the reports shown in *Table 7.63*. Note that the relay provides a report file that contains the latest information each time you request the file. Each time you request a report, the relay stores its corresponding command response in the designated text file.

Table 7.63 Reports Directory Files

File Name	Description	Equivalent Command Response
BRE_*n*.TXT	Breaker *n* Report (*n* = 1, 2, 3, or 4)	**BRE *n***
CHISTORY.TXT	Compressed ASCII History Report	**CHI**
HISTORY.TXT	History Report	**HIS**
CLDP.TXT	Compressed Load Profile Data	**CLDP**
LDP.TXT	Load Profile Data	**LDP**
CSER.TXT	Compressed Sequence of Events	**CSER**
SER.TXT	Sequence of Events	**SER**
TFE.TXT	Through Fault Event Reports	**TFE**

Events Directory (Read-Only) (Available for FTP and MMS)

The relay provides history, event reports, and oscillography files in the EVENTS directory as shown in *Table 7.64*.

Event reports are available in the following formats:

- SEL Compressed 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 7.64*.

Oscillography files are generated at the time the event is triggered (see *Event Reporting on page 10.2*). Higher resolution oscillography is available with SEL Compressed ASCII 32-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 7.79*.

Table 7.64 Event Directory Files

File Name	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*	**CEV *nnnnn***
CR_*nnnnn*.CEV	Compressed 32-samples/cycle ASCII raw event report; event ID number = *nnnnn*	**CEV R *nnnnn***
CD_*nnnnn*.CEV	Compressed 4-samples/cycle differential element event report; event ID number = *nnnnn*	**CEV DIF *nnnnn***
HR_*nnnnn*.CFG[b]	COMTRADE configuration file; event ID number = *nnnnn*	N/A
HR_*nnnnn*.DAT[b]	COMTRADE binary data file; event ID number = *nnnnn*	N/A
HR_*nnnnn*.HDR[b]	COMTRADE header file; event ID number = *nnnnn*	N/A

[a] Also available in the Reports directory for convenience.
[b] 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 7.64* are used to create an event report that conforms to the COMTRADE standard. The event is an unfiltered (raw) 32-samples/cycle event. The field, *nnnnn*, corresponds to the unique event identification number displayed by the **HIS** command. For details on event reports see *Section 10: Analyzing Events*.

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 7.64* for all the files available in the COMTRADE directory.

HMI Directory (Read and Write)

Use the HMI directory to retrieve the diagnostic information and the setting files that apply to the touchscreen. Refer to *Table 7.61* for all the files available in the HMI directory.

UPGRADE Directory

Table 7.65 shows the file contents of the UPGRADE directory. The UPGRADE directory is available at Access Level 2 and higher on relays that support Ethernet firmware upgrades. To write to the directory, Port 1 setting EETHFWU must be enabled. The RELAY.zds and SELBOOT.zds files are write-only files. The ERR.txt file is a read-only file.

Table 7.65 Firmware Upgrade Files and Read/Write Access Level

File	Description	Read Access Level	Write Access Level
ERR.txt	Digitally signed firmware upgrade error file	1, 2, C	N/A
RELAY.zds	Digitally signed relay firmware upgrade file	N/A	2, C
SLBT.zds	Digitally signed SELBOOT firmware upgrade file	N/A	2, C

Ymodem File Structure

All the files available (see *Table 7.66*) for Ymodem protocol are in the root directory. See *FILE Command on page 7.48* for a response to the **FIL DIR** command.

Table 7.66 Files Available for Ymodem Protocol (Sheet 1 of 2)

File Name	Description	Read Access Level	Write Access Level
CFG.TXT	See *Root Directory on page 7.74*	1, 2, C	N/A
ERR.TXT	See *Settings Directory (Available for FTP and MMS) on page 7.75*	1, 2, C	N/A
SET_ALL.TXT[a]	See *Settings Directory (Available for FTP and MMS) on page 7.75*	1, 2, C	N/A
SET_*n*.TXT	See *Settings Directory (Available for FTP and MMS) on page 7.75*	1, 2, C	2, C
SET_C.TXT[a]	See *Settings Directory (Available for FTP and MMS) on page 7.75*	C	C
SET_D*n*.TXT	See *Settings Directory (Available for FTP and MMS) on page 7.75*	1, 2, C	2, C
SET_F.TXT	See *Settings Directory (Available for FTP and MMS) on page 7.75*	1, 2, C	2, C
SET_G.TXT	See *Settings Directory (Available for FTP and MMS) on page 7.75*	1, 2, C	2, C
SET_I.TXT	See *Settings Directory (Available for FTP and MMS) on page 7.75*	1, 2, C	2, C
SET_L*n*.TXT	See *Settings Directory (Available for FTP and MMS) on page 7.75*	1, 2, C	2, C
SET_M.TXT	See *Settings Directory (Available for FTP and MMS) on page 7.75*	1, 2, C	2, C
SET_P*n*.TXT	See *Settings Directory (Available for FTP and MMS) on page 7.75*	1, 2, C	2, C
SET_R.TXT	See *Settings Directory (Available for FTP and MMS) on page 7.75*	1, 2, C	2, C
C4_*nnnnn*.CEV	See *Events Directory (Read-Only) (Available for FTP and MMS) on page 7.76*	1, 2, C	N/A
CD_*nnnnn*.CEV	See *Events Directory (Read-Only) (Available for FTP and MMS) on page 7.76*	1, 2, C	N/A
CR_*nnnnn*.CEV	See *Events Directory (Read-Only) (Available for FTP and MMS) on page 7.76*	1, 2, C	N/A
HR_*nnnnn*.CFG	See *Events Directory (Read-Only) (Available for FTP and MMS) on page 7.76*	1, 2, C	N/A
HR_*nnnnn*.DAT	See *Events Directory (Read-Only) (Available for FTP and MMS) on page 7.76*	1, 2, C	N/A
HR_*nnnnn*.HDR	See *Events Directory (Read-Only) (Available for FTP and MMS) on page 7.76*	1, 2, C	N/A
BRE_*n*.TXT	See *Reports Directory (Read-Only) (Available for FTP and MMS) on page 7.76*	1, 2, C	N/A
CHISTORY.TXT	See *Reports Directory (Read-Only) (Available for FTP and MMS) on page 7.76*	1, 2, C	N/A

Table 7.66 Files Available for Ymodem Protocol (Sheet 2 of 2)

File Name	Description	Read Access Level	Write Access Level
HISTORY.TXT	See *Reports Directory (Read-Only) (Available for FTP and MMS) on page 7.76*	1, 2, C	N/A
CLDP.TXT	See *Reports Directory (Read-Only) (Available for FTP and MMS) on page 7.76*	1, 2, C	N/A
LDP.TXT	See *Reports Directory (Read-Only) (Available for FTP and MMS) on page 7.76*	1, 2, C	N/A
CSER.TXT	See *Reports Directory (Read-Only) (Available for FTP and MMS) on page 7.76*	1, 2, C	N/A
SER.TXT	See *Reports Directory (Read-Only) (Available for FTP and MMS) on page 7.76*	1, 2, C	N/A
TFE.TXT	See *Reports Directory (Read-Only) (Available for FTP and MMS) on page 7.76*	1, 2, C	N/A
SET_HMI.zds	See *HMI Directory (Read and Write) on page 7.77*	1, 2, C	2, C
CDP.zds	See *HMI Directory (Read and Write) on page 7.77*	1, 2, C	2, C
HMI_ALL.zip	See *HMI Directory (Read and Write) on page 7.77*	1, 2, C	N/A

[a] Calibration settings are included only when accessed at Access Level C.

Batch File Access

Files can be accessed as a batch by using the supported wild card character, *.

FTP and MMS Wildcard Usage

Table 7.67 shows examples using supported wildcards. Note that these wildcards may be appended to a directory path (e.g., /specified_directory/*.txt).

Table 7.67 FTP and MMS Wildcard Usage Examples

Usage	Description	Example	Note
*xyz	Lists all files and/or subdirectories in a specified directory whose name (including extension) ends with xyz.	/*.TXT	List 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.

Ymodem Wildcard Usage

NOTE: Ymodem protocol does not support wildcards for settings files.

Event, report, and diagnostic files can also be accessed as a batch using wildcards.

Table 7.68 Ymodem Wildcard Usage Examples

Usage	Description	Example	Note
*xyz	Lists all files that end with xyz.	FILE DIR HIS*.TXT	Lists all of the metering files (HISTORY.TXT)
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)

Section 8

Front-Panel Operations

Overview

The SEL-787 Transformer Protection Relay front panel makes data collection and control quick and efficient. You can order all of the SEL-787 model relays with either the two-line LCD (2 x 16 characters) or the 5-inch, color, 800 x 480-pixel touchscreen display, as shown in *Table 1.3* and *Figure 8.1*. Each display option comes with eight front-panel pushbuttons. Use either front panel to analyze operating information, view and change relay settings, and perform control functions. You can use the front panel to accomplish the following activities:

- Read metering
- Inspect targets
- Access settings
- Control relay operations
- View diagnostics

Figure 8.1 SEL-787 Front-Panel Options

The two-line display and the touchscreen display front-panel models are similar in all aspects except the display and navigation scheme. The touchscreen display model offers additional features with respect to monitoring, control, and device status that are discussed in Touchscreen Display Front Panel. The function of operation and target LEDs and the **TARGET RESET** and control pushbuttons are similar in both front-panel variations.

This section includes the following:

- *Two-Line Display Front Panel on page 8.2*. Discusses the navigation scheme in the two-line display models, the operation of target LEDs, and programming of the control pushbuttons.
- *Touchscreen Display Front Panel on page 8.20*. Discusses the navigation scheme and the display screens in the touchscreen display model.

Two-Line Display Front Panel

Front-Panel Layout

NOTE: Refer to Figure 8.31 for the pushbutton and LED numbering conventions.

NOTE: If the relay part number specifies the Spanish language option, all of the front-panel pushbutton and LED labels will be in Spanish.

Figure 8.2 through *Figure 8.5* identify the following features of each front panel:

- Human-Machine Interface (HMI)
- TARGET RESET and navigation pushbuttons
- Operation and target LEDs
- Operator control pushbuttons and pushbutton LEDs
- EIA-232 Serial Port (PORT F). See *Section 7: Communications* for details on the serial port.

You can use the following features of the versatile front panel to customize it to your needs:

- Rotating display on the HMI
- Programmable tricolor target LEDs
- Programmable tricolor pushbutton LEDs
- Slide-in configurable front-panel labels to change the identification of target LEDs, pushbuttons, pushbutton LEDs and their operation.

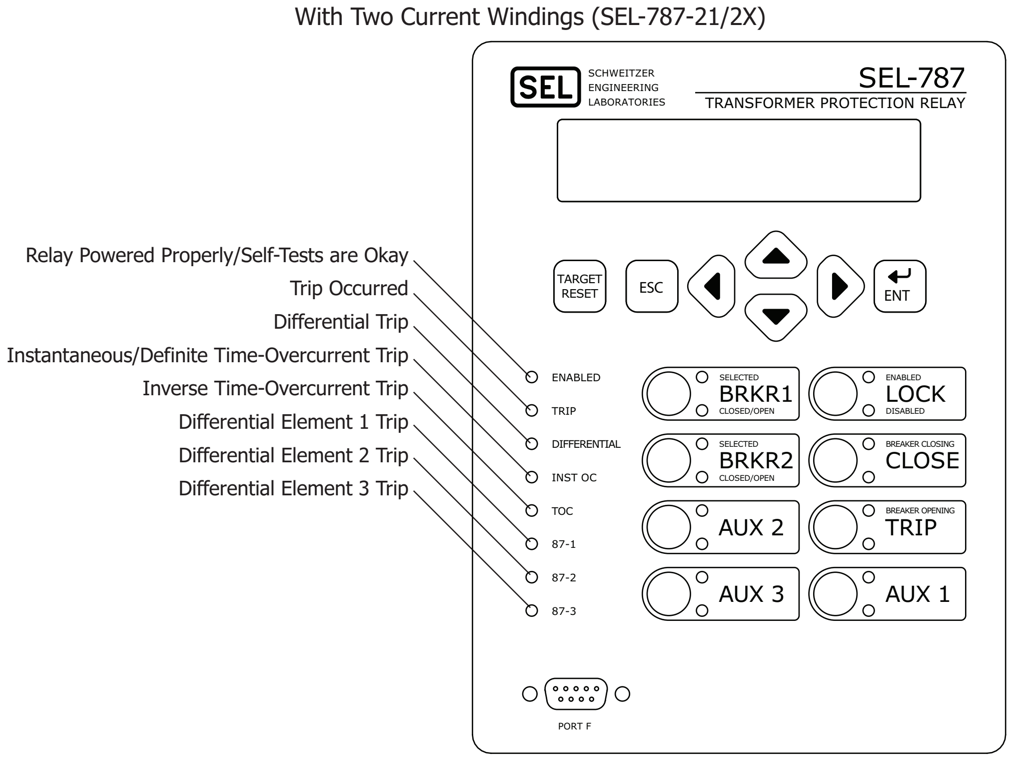


Figure 8.2 SEL-787-21/2X Front-Panel Overview

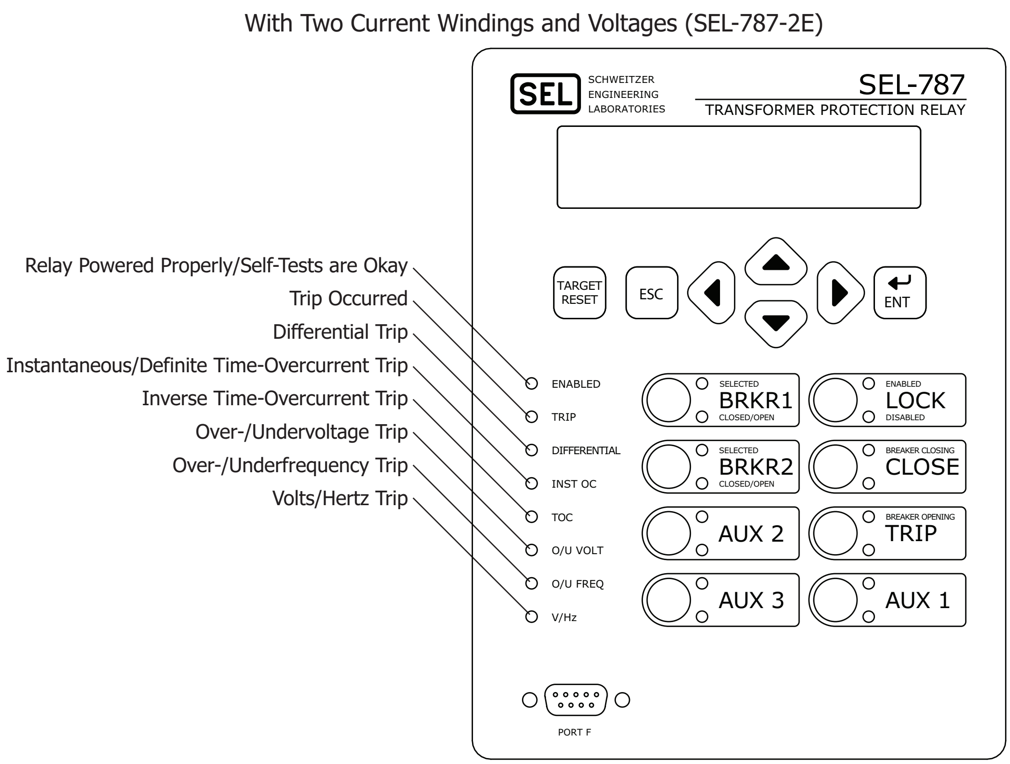


Figure 8.3 SEL-787-2E Front-Panel Overview

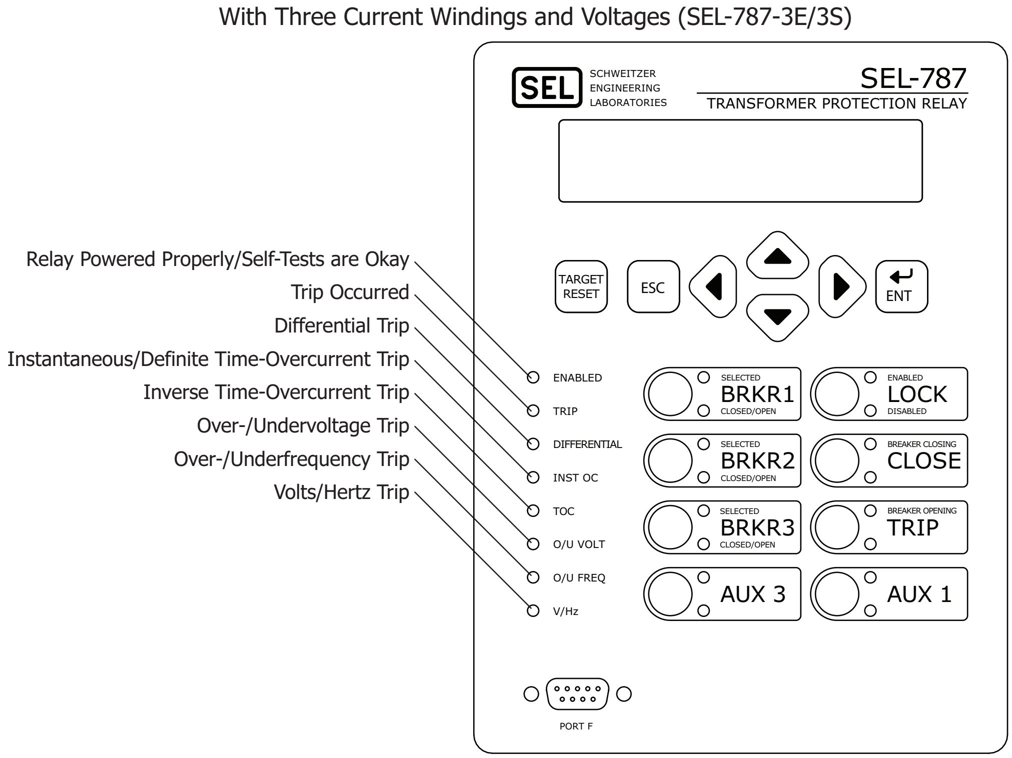


Figure 8.4 SEL-787-3E/3S Front-Panel Overview

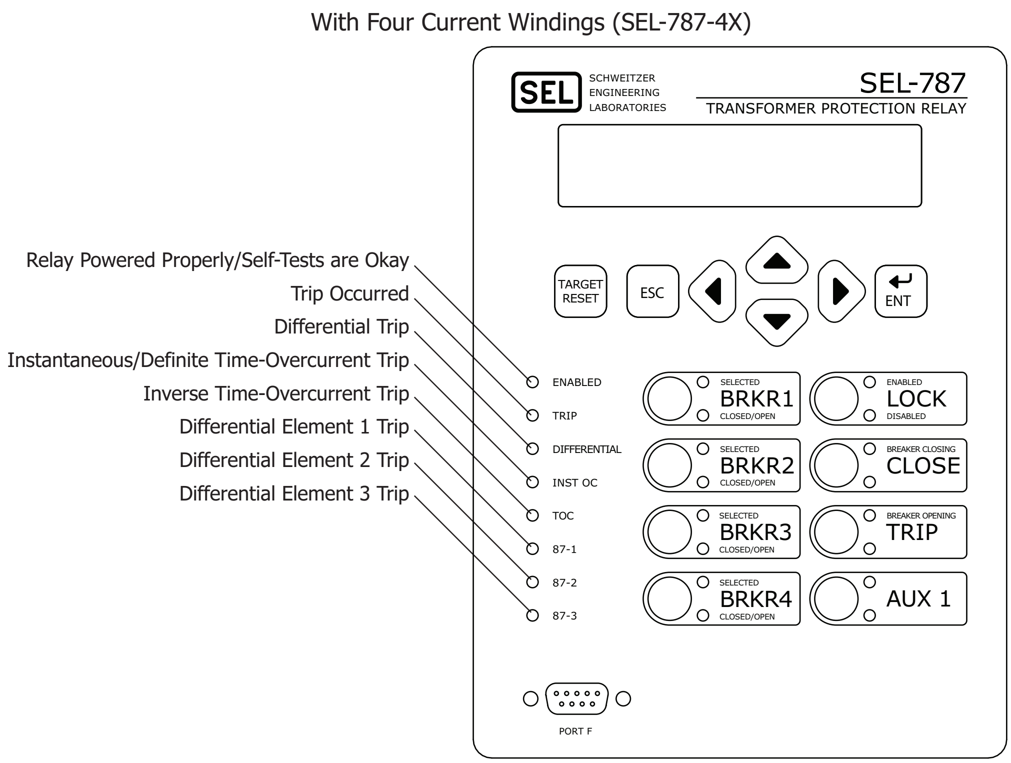


Figure 8.5 SEL-787-4X Front-Panel Overview

Two-Line Display HMI

Contrast

NOTE: See the Preface for an explanation of typographic conventions used to describe menus, the front-panel display, and the front-panel pushbuttons.

NOTE: The two-line display updates every second.

You can adjust the LCD screen contrast to suit your viewing angle and lighting conditions. To change screen contrast, press and hold the **ESC** pushbutton for two seconds. The SEL-787 displays a contrast adjustment box. Pressing the **Right Arrow** pushbutton increases the contrast. Pressing the **Left Arrow** pushbutton decreases the screen contrast. When you are finished adjusting the screen contrast, press the **ENT** pushbutton; this process is a shortcut for changing the LCD contrast setting FP_CONT in the front-panel settings.

Front-Panel Automatic Messages

The relay displays automatic messages, overriding the rotating display, under the conditions described in *Table 8.1*, with the relay failure having the highest priority, followed by trip and alarm when the front-panel setting FP_AUTO := OVERRIDE.

If the front-panel setting FP_AUTO := ROTATING, then the rotating display messages continue and any TRIP or ALARM message is added to the rotation. Relay failure still overrides the rotating display.

Table 8.1 Front-Panel Automatic Messages (FP_AUTO := OVERRIDE)

Condition	Front-Panel Message
Relay detecting any failure	Displays the type of latest failure (see *Section 11: Testing and Troubleshooting*).
Relay trip has occurred	Displays the type or cause of the trip. Refer to *Table 10.2* for a list of trip display messages.
Relay alarm condition has occurred	Displays the type of alarm. The **TRIP** LED is also flashing during an alarm condition. See *Table 8.3* for a list of the alarm conditions.

Front-Panel Security

Front-Panel Access Levels

The SEL-787 front panel typically operates at Access Level 1 and provides viewing of relay measurements and settings. Some activities, such as editing settings and controlling output contacts, are restricted to those operators who know the Access Level 2 passwords.

In the figures that follow, restricted activities are indicated by the padlock symbol.

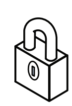


Figure 8.6 Access Level Security Padlock Symbol

Before you can perform a front-panel menu activity that is marked with the padlock symbol, you must enter the correct Access Level 2 password. After you have correctly entered the password, you can perform other Access Level 2 activities without reentering the password.

Access Level 2 Password Entry

When you try to perform an Access Level 2 activity, the relay determines whether you have entered the correct Access Level 2 password since the front-panel inactivity timer expired. If you have not, the relay displays the screen shown in *Figure 8.7* for you to enter the password.

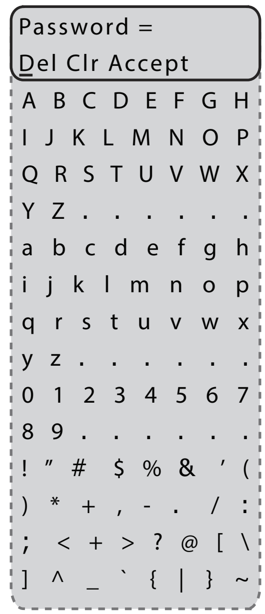


Figure 8.7 Password Entry Screen

See *PASSWORD Command (Change Passwords) on page 7.58* for the list of default passwords and for more information on changing passwords.

Front-Panel Timeout

To help prevent unauthorized access to password-protected functions, the SEL-787 provides a front-panel timeout, setting FP_TO. A timer is reset every time a front-panel pushbutton is pressed. Once the timeout period has expired, the access level is reset to Access Level 1. Manually reset the access level by selecting `Quit` from the `MAIN` menu.

Front-Panel Menus and Screens

Navigating the Menus

The SEL-787 front panel gives you access to most of the information that the relay measures and stores. You can also use front-panel controls to view or modify relay settings.

All of the front-panel functions are accessible through use of the six-button keypad and LCD display. Use the keypad (shown in *Figure 8.8*) to maneuver within the front-panel menu structure, described in detail throughout the remainder of this section. *Table 8.2* describes the function of each front-panel pushbutton.

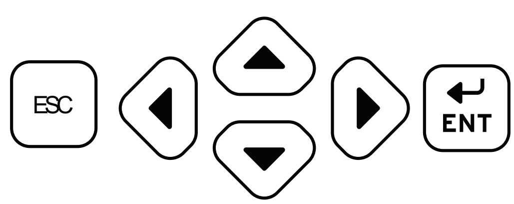


Figure 8.8 Front-Panel Pushbuttons

Table 8.2 Front-Panel Pushbutton Functions

Pushbutton	Function
Up Arrow	Move up within a menu or data list. While editing a setting value, increase the value of the underlined digit.
Down Arrow	Move down within a menu or data list. While editing a setting value, decrease the value of the underlined digit.
Left Arrow	Move the cursor to the left.
Right Arrow	Move the cursor to the right.
ESC	Escape from the current menu or display. Displays additional information if lockout condition exists. Hold for two seconds to display contrast adjustment screen.
ENT	Move from the rotating display to the `MAIN` menu. Select the menu item at the cursor. Select the displayed setting to edit that setting.

The SEL-787 automatically scrolls information that requires more space than provided by a 16-character LCD line. Use the **Left Arrow** and **Right Arrow** pushbuttons to suspend automatic scrolling and enable manual scrolling of this information.

MAIN Menu

Figure 8.9 shows the `MAIN` menu screen. Using the **Up Arrow** or **Down Arrow** and **ENT** pushbuttons, you can navigate to specific menu item in the `MAIN` menu. Each menu item is explained in detail in the following paragraphs.

```
MAIN
Meter
Events
Targets
Control
Set/Show
Status
Breaker
Quit
```

Figure 8.9 Main Menu

Meter Menu. Select the `Meter` menu item from the `MAIN` menu as shown in *Figure 8.10* to view metering data. The `Meter` menu has menu items for viewing different types of metering data like Fundamental, rms, Thermal, etc. Select the type of metering and view the data using the **Up Arrow** or **Down Arrow** pushbuttons. See *Metering on page 5.3* for a description of the available data fields.

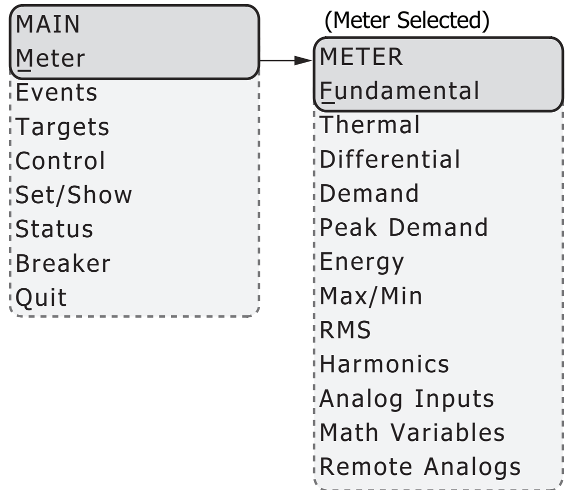


Figure 8.10 MAIN Menu and METER Submenu

For viewing Energy (or Max/Min) metering data, select the `Energy` (or `Max/Min`) menu item from the `METER` menu and select the `Display` menu item as shown in *Figure 8.11*.

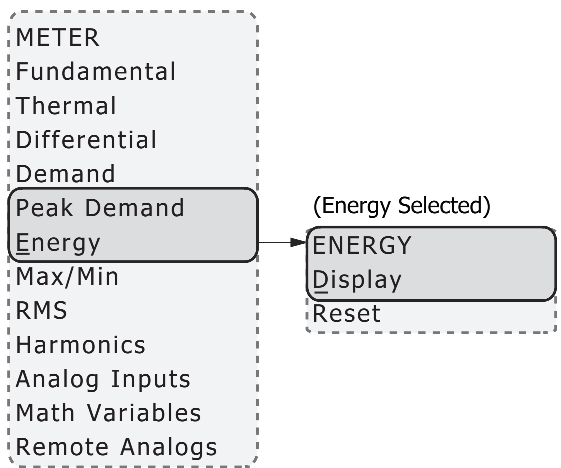


Figure 8.11 METER Menu and ENERGY Submenu

You can reset Energy (or Max/Min, Demand, Peak Demand) metering data from the front-panel HMI by selecting the `Reset` menu item in `Energy` (or `Max/Min`, `Demand`, `Peak Demand`) menu. After selecting `Reset` and confirming the reset, the relay displays as shown in *Figure 8.12*.

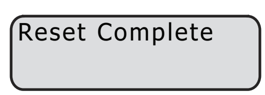


Figure 8.12 Relay Response When Energy (or Max/Min, Demand, Peak Demand) Metering Is Reset

Assume the relay configuration contains no analog input cards. In response to a request for analog data (selecting Analog Inputs), the device displays the message as shown in *Figure 8.13*.

Figure 8.13 Relay Response When No Analog Cards Are Installed

Assume the math variables are not enabled. In response to a request for math variable data (selecting Math Variables), the device displays the message as shown in *Figure 8.14*.

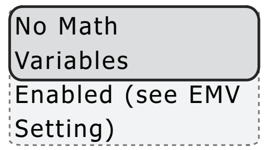


Figure 8.14 Relay Response When No Math Variables Are Enabled

Events Menu. Select the Events menu item from the MAIN menu as shown in *Figure 8.15*. EVENTS menu has Display and Clear as menu items. Select Display to view events and Clear to delete all the events data.

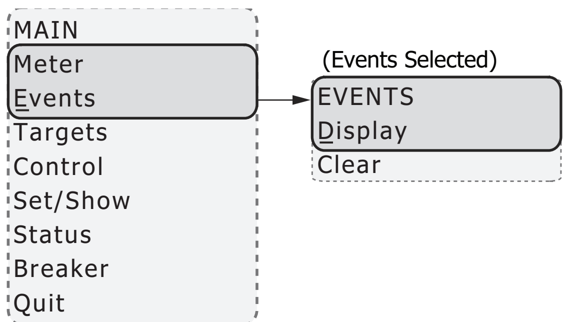


Figure 8.15 MAIN Menu and EVENTS Submenu

Figure 8.16 shows the DISPLAY menu when Display is selected from the EVENTS menu with events in the order of occurrence starting with the most recent. You can select an event from the DISPLAY menu and navigate through the event data.

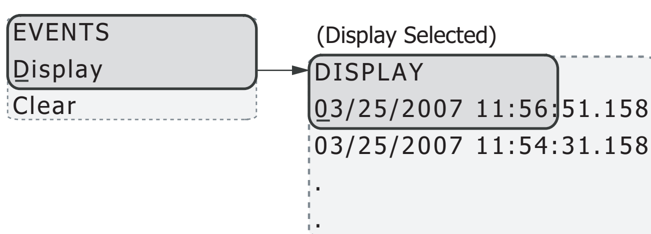


Figure 8.16 EVENTS Menu and DISPLAY Submenu

When you select Display and no event data are available, the relay displays as shown in *Figure 8.17*.

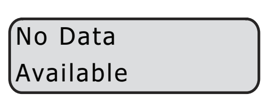


Figure 8.17 Relay Response When No Event Data Are Available

When you select `Clear` from the `EVENTS` menu and confirm the selection, the relay displays as shown in *Figure 8.18* after it clears the events data.

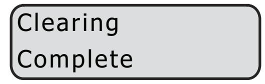


Figure 8.18 Relay Response When Events Are Cleared

Targets Menu. Select the `Targets` menu item on the `MAIN` menu as shown in *Figure 8.19* to view the binary state of the target rows. Each target row has eight Relay Word bits as shown in *Table L.1*.

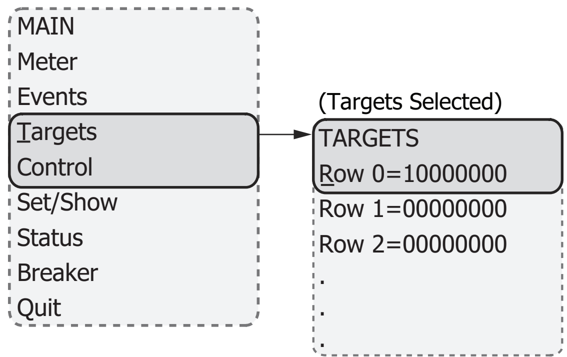


Figure 8.19 MAIN Menu and TARGETS Submenu

Select the target row to display two consecutive Relay Word bits with name and binary state as shown in *Figure 8.20*.

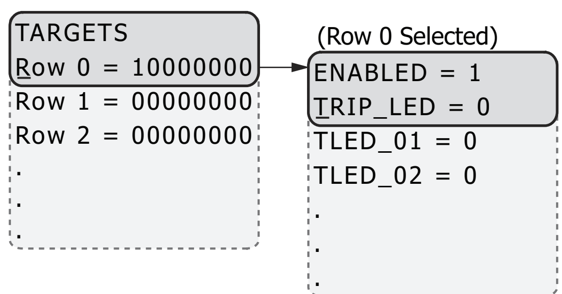


Figure 8.20 TARGETS Menu Navigation

Control Menu. Select the `Control` menu item on the `MAIN` menu as shown in *Figure 8.21* to go to the `CONTROL` menu.

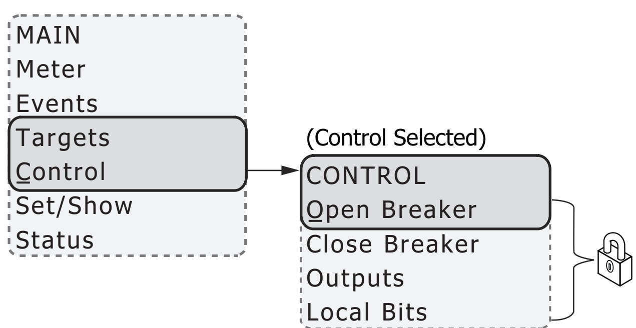


Figure 8.21 MAIN Menu and CONTROL Submenu

The `CONTROL` menu has `Open Breaker (1, 2, 3, or 4)`, `Close Breaker (1, 2, 3, or 4)`, `Outputs`, and `Local Bits` as menu items.

Select the `Open Breaker (1, 2, 3, or 4)` menu item to assert Relay Word bits OC1, OC2, OC3, or OC4, which opens breaker 1, 2, 3, or 4 via SELOGIC control equations TR1, TR2, TR3, or TR4. See *Table 4.40* for equations TR1, TR2, TR3, and TR4 and *Table L.2* for the definitions of Relay Word bits OC1, OC2, OC3, and OC4. Note that this requires Level 2 access.

Select the `Close Breaker (1, 2, 3, or 4)` menu item to assert Relay Word bits CC1, CC2, CC3, or CC4, which closes the breaker 1, 2, 3, or 4 via the CL1, CL2, CL3, or CL4 SELOGIC control equation (see *Figure 4.67*). Note that this requires Level 2 access.

Breaker control through the front panel is supervised by the position of the breaker jumper (refer to *Table 2.24*), the status of the LOCAL bit when EN_LRC := Y, and the access level (requires 2AC). When the local/remote supervision setting EN_LRC := Y and LOCAL := 0, control of the OC*n* (*n* = 1–4) and CC*n* bits from the front panel is blocked. When EN_LRC := N, breaker control from the front panel is always allowed. For the settings related to the local/ remote control function, refer to *Local/Remote Control* in *Section 9: Bay Control*.

Select the `Outputs` menu item from the `CONTROL` menu as shown in *Figure 8.22* to test (pulse) SEL-787 output contacts and associated circuits. Choose the output contact by navigating through the `OUTPUT` menu and test it by pressing the **ENT** pushbutton. Note that testing the output contact requires Level 2 access and reconfirmation.

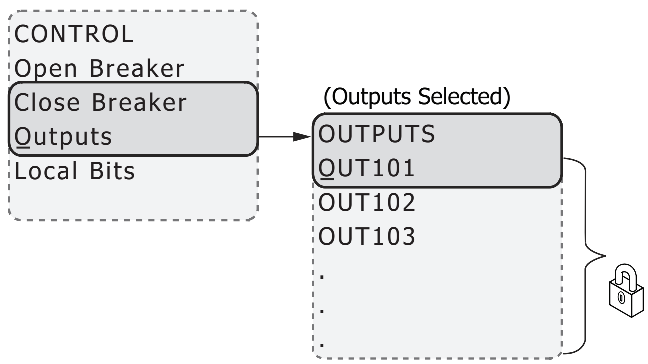


Figure 8.22 CONTROL Menu and OUTPUTS Submenu

Select the `Local Bits` menu item from the `CONTROL` menu for local control action. Local bits take the place of traditional panel switches, and perform isolation, open, close, or pulse operations.

With the settings as per the example in *Section 4* (see *Local Bits on page 4.150* for more information), local bit 1 replaces a supervisory switch. *Figure 8.23* shows the screens in closing the supervisory switch. In this operation, local bit LB01 is deasserted (SUPER SW = OPEN), and changes to asserted (SUPER SW = CLOSE) as shown in the final screen of *Figure 8.23*.

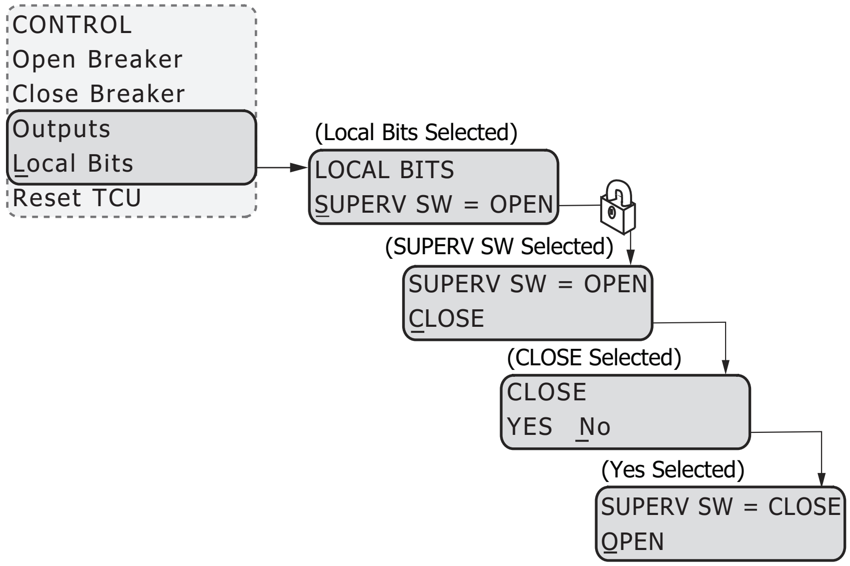


Figure 8.23 CONTROL Menu and LOCAL BITS Submenu

Set/Show Menu. Select the `Set/Show` menu item on the `MAIN` menu. The `Set/Show` menu is used to view or modify the settings (`Global`, `Group`, and `Port`), `Active Group`, `Date`, and `Time`. Note that modifying the settings requires Level 2 access.

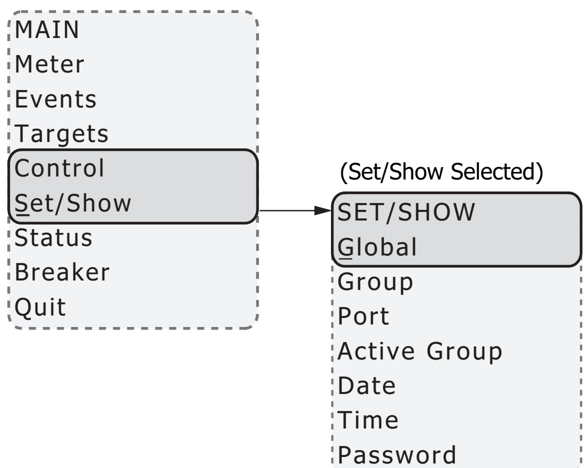


Figure 8.24 MAIN Menu and SET/SHOW Submenu

Each settings class (`Global`, `Group`, and `Port`) includes headings that create subgroups of associated settings as shown in the following illustration. Select the heading that contains the setting of interest, and then navigate to the particular setting. View or edit the setting by pressing the **ENT** pushbutton. For text settings, use the four navigation pushbuttons to scroll through the available alphanumeric and special character settings matrix. For numeric settings, use the **Left Arrow** and **Right Arrow** pushbuttons to select the digit to change and the **Up Arrow** and **Down Arrow** pushbuttons to change the value. Press the **ENT** pushbutton to enter the new setting.

Setting changes can also be made using ACSELERATOR QuickSet SEL-5030 Software or ASCII **SET** commands via a communications port.

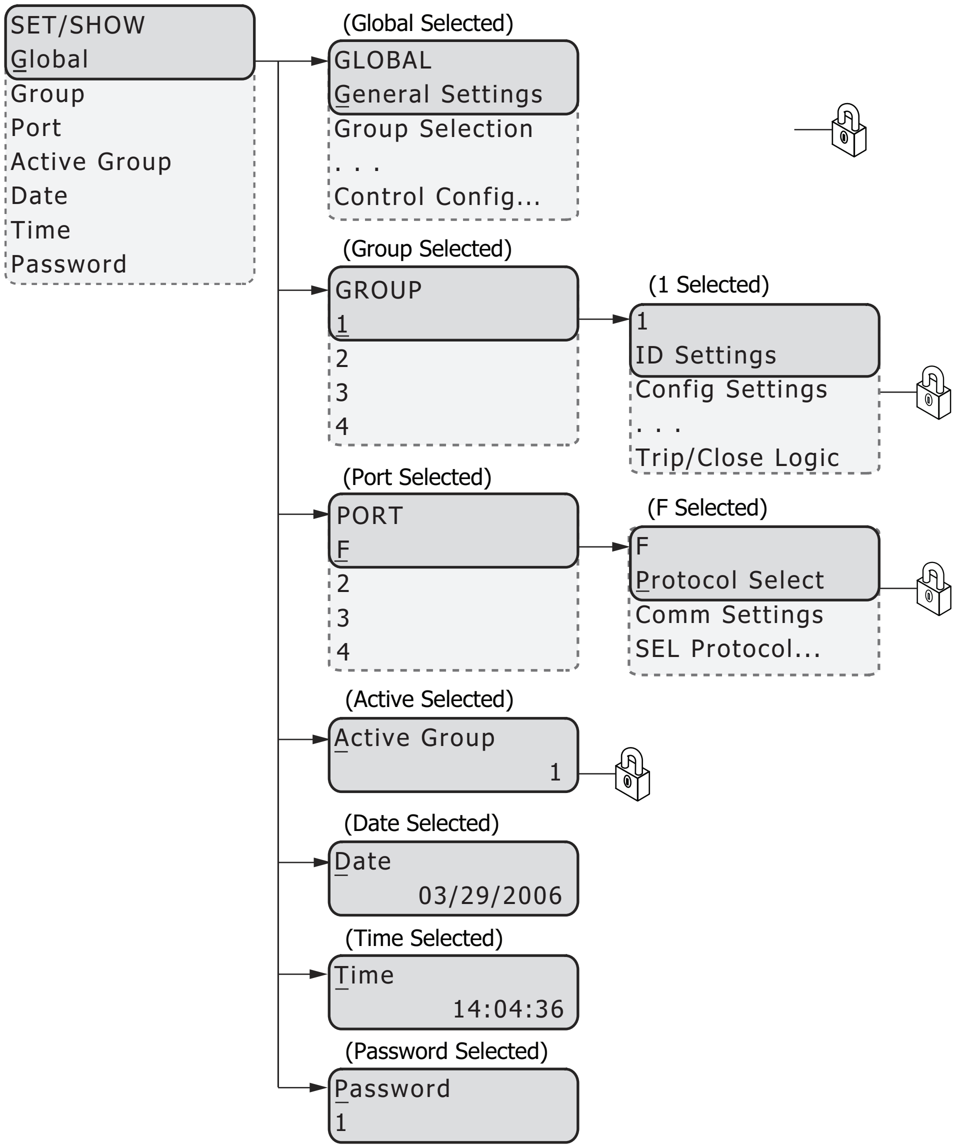


Figure 8.25 SET/SHOW Menu

Status Menu. Select the `Status` menu item on the `MAIN` menu as shown in *Figure 8.26* to access `Relay Status` data and `Reboot Relay`. See *STATUS Command (Relay Self-Test Status) on page 7.66* for the **STATUS** data field description.

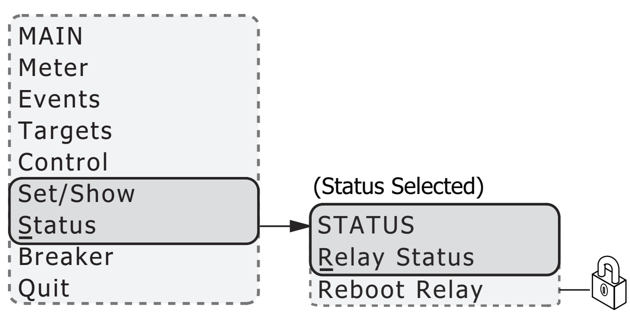


Figure 8.26 MAIN Menu and STATUS Submenu

Breaker Menu. Select the `Breaker` menu item on the `MAIN` menu as shown in *Figure 8.27* to access `Breaker Monitor` data or `Reset` the data. See *Breaker Monitor on page 5.25*, in *Section 5: Metering and Monitoring* for a detailed description.

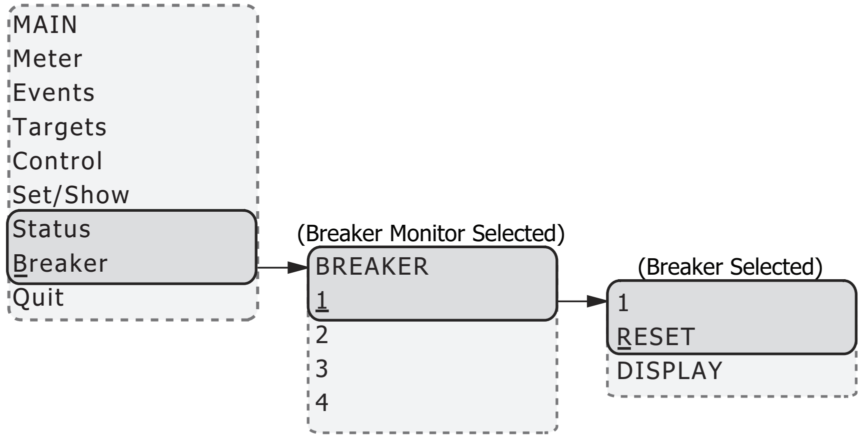


Figure 8.27 MAIN Menu and BREAKER Submenu

Quit. Use the `Quit` menu item of the `MAIN` menu to exit Access Level 2 and go to Access Level 1.

Figure 8.28 Quit Menu Item

Language Support

All of the HMI messages can be displayed in multiple languages (English or Spanish). The relay part number determines which language is displayed on the HMI. The HMI can display either ENGLISH or SPANISH. See *SEL-787-2, -3, -4 Relay Command Summary* for a list of the Spanish commands.

Operation and Target LEDs

Programmable LEDs

The SEL-787 provides quick confirmation of relay conditions via operation and target LEDs. *Figure 8.27* shows this region with factory-default text on the front-panel configurable labels for the SEL-787-2E/3E/3S models. To view the factory-default text of the front-panel configurable labels for the SEL-787-2X/21/4X models, refer to *Figure 8.2* through *Figure 8.5*. See

Target LED Settings on page 4.152 for the SELOGIC control equations and the tricolor LED color selection settings. The Relay Word bits associated with the target LEDs are TLED_01 to TLED_06.

NOTE: There are two configurations of the factory-default front-panel LEDs, depending on the relay model (see Figure 8.2 and Figure 8.5 for the SEL-787-2X/21/4X models and Figure 8.3 and Figure 8.4 for the SEL-787-2E/3E/3S models).

NOTE: The target LEDs are restored to their previous state after the relay is turned off and then turned back on.

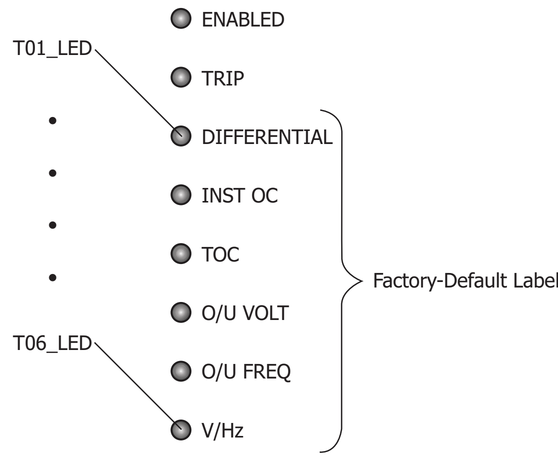


Figure 8.29 Factory-Default Front-Panel LEDs for the SEL-787-2E/3E/3S Models

You can reprogram all of these indicators except the **ENABLED** and **TRIP** LEDs to reflect operating conditions other than the factory-default programming described in this subsection.

Settings T0*n*_LED are SELOGIC control equations that work with the corresponding T0*n*LEDL latch settings to illuminate the LEDs shown in *Figure 8.27*. Use settings T0*n*LEDC to select the LED color (R: Red, G: Green, A: Amber). Parameter *n* is a number from 1 through 6 that indicates each LED. If the latch setting (T0*n*LEDL) for a certain LED is set to N, then the LED follows the status of the corresponding control equation (T0*n*_LED). When the equation asserts, the LED illuminates, and when the equation deasserts, the LED extinguishes. If the latch setting is set to Y, the LED asserts if a trip condition occurs and the T0*n*_LED equation is asserted within two cycles of the trip assertion. At this point, the LED latches in and can be reset using the **TARGET RESET** pushbutton or the **TAR R** command as long as the target conditions are absent. For a concise listing of the default programming on the front-panel LEDs, see *Table 4.80*.

The SEL-787 comes with blank slide-in labels for custom LED designations that match custom LED logic. The configurable label kit, which includes blank labels, a word processor template, and instructions, is provided when the SEL-787 is ordered.

The **ENABLED** LED indicates that the relay is powered correctly, is functional, and has no self-test failures. Trip events illuminate the **TRIP** LED. The prominent location of the **TRIP** LED in the top target area aids in recognizing trip events quickly.

The **TRIP** LED has an additional function that notifies you of warning conditions. When the **TRIP** LED is flashing, the warning conditions in *Table 8.3* are active when you set the corresponding relay element. For Relay Word bit definitions see *Appendix L: Relay Word Bits*.

Table 8.3 Possible Warning Conditions (Flashing TRIP LED)

HMI Message	Condition (Relay Word Bit)
RTD Warning	AMBALRM OR OTHALRM
RTD Failure	RTDFLT
Comm. Loss Warning	COMMLOSS
Comm. Idle Warning	COMMIDLE

TARGET RESET Pushbutton

Target Reset

For a trip event, the SEL-787 latches the trip-involved target LEDs except for the ENABLED LED. Press the TARGET RESET pushbutton to reset the latched target LEDs. When a new trip event occurs and the previously latched trip targets have not been reset, the relay clears the latched targets and displays the new trip targets. Pressing and holding the TARGET RESET pushbutton illuminates all the LEDs. Upon release of the TARGET RESET pushbutton, two possible trip situations can exist: the conditions that caused the relay to trip have cleared, or the trip conditions remain present at the relay inputs. If the trip conditions have cleared, the latched target LEDs turn off. If the trip event conditions remain, the relay re-illuminates the corresponding target LEDs. The TARGET RESET pushbutton also removes the trip automatic message displayed on the LCD menu screens if the trip conditions have cleared.

Figure 8.30 Target Reset Pushbutton

Lamp Test

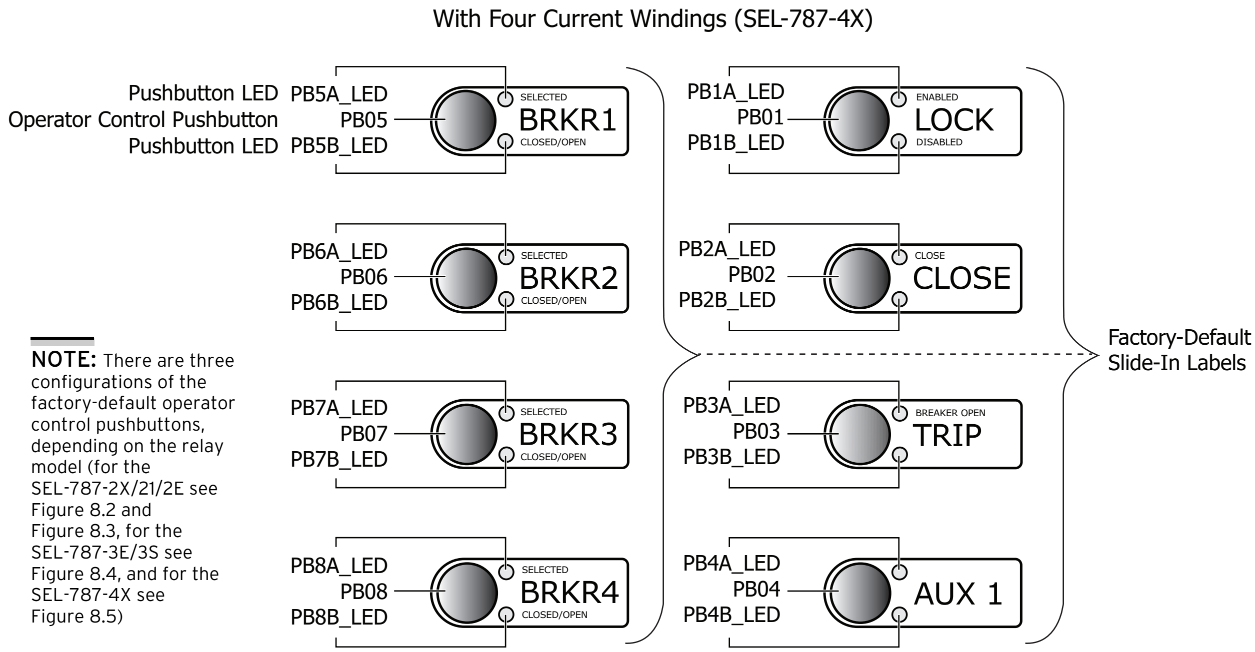
The TARGET RESET pushbutton also provides a front-panel lamp test. Pressing and holding TARGET RESET illuminates all the front-panel LEDs, and these LEDs remain illuminated for as long as TARGET RESET is pressed. The target LEDs return to a normal operational state after release of the TARGET RESET pushbutton.

Other Target Reset Options

Use the ASCII command **TAR R** to reset the target LEDs; see *Table 7.54* for more information. Programming specific conditions in the SELOGIC control equation RSTTRGT is another method for resetting target LEDs. Access RSTTRGT in *Global Settings (SET G Command)*, *Data Reset on page 4.135* for further information.

Front-Panel Operator Control Pushbuttons

The SEL-787 features eight operator-controlled pushbuttons, each with two programmable tricolor pushbutton LEDs, for local control as shown in *Figure 8.31*. To view factory-default operator control pushbuttons and LEDs for the SEL-787-2X/21/2E/3E/3S models, refer to *Figure 8.2* through *Figure 8.4*.



NOTE: There are three configurations of the factory-default operator control pushbuttons, depending on the relay model (for the SEL-787-2X/21/2E see Figure 8.2 and Figure 8.3, for the SEL-787-3E/3S see Figure 8.4, and for the SEL-787-4X see Figure 8.5)

Figure 8.31 Factory-Default Operator Control Pushbuttons and LEDs for the SEL-787-4X Model

Pressing any one of these eight pushbuttons asserts the corresponding PB*n* (*n* = 01 through 08) Relay Word bit, and the corresponding PB*n*_PUL Relay Word bit. The PB*n* Relay Word bit remains asserted as long as the pushbutton is pressed, but the PB*n*_PUL Relay Word bit asserts only for the initial processing interval, even if the button is still being pressed. Releasing the pushbutton, and then pressing the pushbutton again asserts the corresponding PB*n*_PUL Relay Word bit for another processing interval. The pushbutton LEDs are independent of the pushbutton.

Pushbutton LEDs are programmable using front-panel settings PB*nm*_LED (where *n* = 1 through 8 and *m* = A or B). PB*nm* _LED settings are SELOGIC control equations that, when asserted, illuminate the corresponding LED for as long as the input is asserted. When the input deasserts, the LED also deasserts without latching. Use PB*nm*LEDC settings to select the LED color (R–red, G–green, A–amber) for both the asserted and deasserted state of the LED.

Using SELOGIC control equations, you can readily change the default LED and pushbutton functions. Use the optional slide-in label to mark the pushbuttons and pushbutton LEDs with custom names to reflect any programming changes that you make. Included on the SEL-787 Product Literature CD are word processor templates for printing slide-in labels. See the instructions included in the Configurable Label kit for more information on changing the slide-in labels.

Table 8.4 describes front-panel operator controls based on the factory-default settings and operator control labels.

Table 8.4 SEL-787 Front-Panel Operator Control Functions (Sheet 1 of 2)

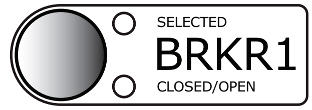
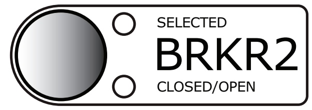
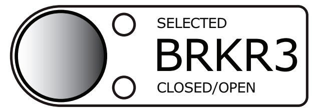
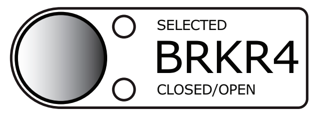
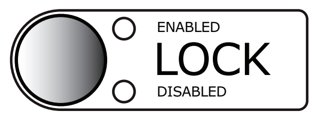
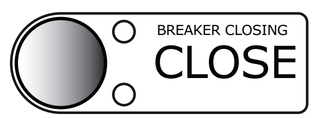
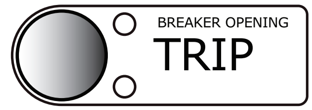
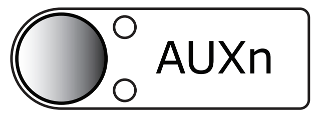
Control Functions	Labels
Press the BRKR*n* operator control pushbutton (where *n* = 1, 2, 3, or 4) to select the breaker to be controlled. When the BRKR*n* operator control pushbutton is pressed, the corresponding SELECTED LED illuminates. This notifies you which breaker is being controlled by the pushbuttons. The CLOSED/OPEN LED lets you know the state of the breaker by referring to Relay Word bit 52A*n* (where *n* = 1, 2, 3, or 4). If the corresponding breaker is CLOSED (SELOGIC control equation 52A*n* is asserted), the LED is green. If the corresponding breaker is OPEN (SELOGIC control equation 52A*n* is deasserted), the LED is red.	   
Continually press the **LOCK** operator control pushbutton for three (3) seconds to engage/disengage the lock function (Latch LT01 functions as Lock with the latch in reset state equivalent to the engaged lock). While this pushbutton is pressed, the corresponding LED flashes on and off, indicating a pending engagement or disengagement of the lock function. The LED illuminates constantly to indicate the state of the LOCK (ENABLED or DISABLED). While the lock function is engaged (ENABLED LED is illuminated), the following operator control is "locked in position" (assuming factory-default settings): **TRIP** or **CLOSE**. While "locked in position," this operator control cannot change state if pressed—the corresponding LEDs remain in the same state. When the lock function is engaged, the **TRIP**/**CLOSE** operator control cannot open/close breaker 1, 2, 3, or 4.	
Press the **CLOSE** operator control pushbutton to close the selected breaker. **Option:** Set a delay, so the operator can press the **CLOSE** operator control pushbutton and then move a safe distance away from the breaker before the SEL-787 issues a close (the **CLOSE** operator control comes with no set delay in the factory settings). With a set delay, press the **CLOSE** operator control pushbutton momentarily, and notice that the corresponding **BREAKER CLOSING** LED flashes on and off during the delay time, indicating a pending close. Abort the pending close by pressing the **CLOSE** operator control pushbutton again or by pressing the **TRIP** operator control pushbutton. This delay setting for the **CLOSE** operator control is SV03PU (range: 0 to 3000 seconds; factory set at 0—no delay). The delay is set via the **SET L** command. See *Table 4.46* for more information.	

Table 8.4 SEL-787 Front-Panel Operator Control Functions (Sheet 2 of 2)

Control Functions	Labels
Press the TRIP operator control pushbutton to trip the selected breaker (and take the control to the lockout state). **Option:** Set a delay, so the operator can press the TRIP operator control pushbutton and then move a safe distance away from the breaker before the SEL-787 issues a trip (the TRIP operator control comes with no set delay in the factory settings). With a set delay, press the TRIP operator control pushbutton momentarily and notice the corresponding BREAKER OPENING LED flashes on and off during the delay time, indicating a pending trip. Abort the pending trip by pressing the TRIP operator control pushbutton again or by pressing the CLOSE operator control pushbutton. This delay setting for the TRIP operator control is SV04PU (range: 0 to 3000 seconds; factory-set at 0—no delay). The delay is set via the **SET L** command. See *Table 4.46* for more information.	
Press the AUXn operator control pushbutton to enable/disable user-programmed auxiliary control. The corresponding LED can be programmed to illuminate during the enabled state. **NOTE:** The AUXn operator control does not perform any function with the factory settings. Also, AUX1, AUX2, and AUX3 pushbuttons do not perform any function in the factory-default settings. These pushbuttons are available to configure any application you may select.	

Touchscreen Display Front Panel

The SEL-787 Feeder Protection Relay can be ordered with an optional touchscreen display (5-inch, color, 800 x 480-pixels). The touchscreen display makes relay data metering, monitoring, and control quick and efficient. The touchscreen display option in the SEL-787 features a straightforward application-driven control structure and includes intuitive and graphical screen designs.

Front-Panel Layout

The touchscreen front panel is the same as the two-line display in regards to the target LEDs, operator control pushbuttons, and the **TARGET RESET** pushbutton. Refer to *Operation and Target LEDs on page 8.14* for a detailed description of these features. In addition, the touchscreen front panel features a **HOME** pushbutton.

Touchscreen Display HMI

NOTE: The touchscreen display updates every 250 ms.

This section explains the navigation of the front-panel touchscreen and all the features it supports.

The touchscreen display allows you to:

- View and control bay screens
- Access metering and monitoring data
- Inspect targets
- View event history, summary data, and SER information
- View relay status and configuration
- Control relay operations
- View and edit settings
- Enable the rotating display
- Program control pushbuttons to jump to a specific screen

Figure 8.32 shows the relay touchscreen display components and indicators.

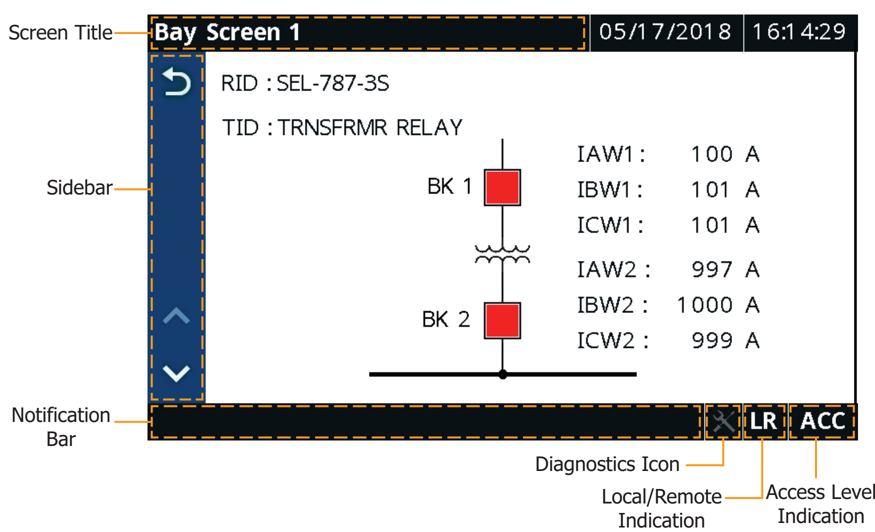
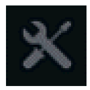


Figure 8.32 Touchscreen Display Components and Indicators

Table 8.5 Touchscreen Display Component and Indicator Descriptions

Display Components and Indicators	Function or Indication
Screen Title	Shows the display name of a screen (see *Figure 8.32*).
Sidebar	Shows the navigation icons (see *Figure 8.32*).
Notification Bar	Shows the notification messages and help text for screens (see *Figure 8.32*).
Diagnostics Icon	ON if there are any warning/diagnostic failures on the unit.
	Normal (no warnings or diagnostic failures present). Icon is OFF.
	Warning. Icon asserts in amber.
	Diagnostic failure. Icon asserts in red.
Local/Remote Indication	Indicates the status of the local/remote control. Refer to *Local/Remote Control on page 9.7* for more details.
L	When EN_LRC := Y and LOCAL := 1, relay control is in local mode, i.e., OC*n* and CC*n* (*n* = 1–4) bits can be processed via the front panel only.
R	When EN_LRC := Y and LOCAL := 0, relay control is in remote mode, i.e., OC*n* and CC*n* (*n* = 1–4) bits can be processed via remote sources/protocols only.
LR	When EN_LRC := N, relay control is in local/remote control, i.e., OC*n* and CC*n* (*n* = 1–4) bits can be processed from both the front panel and the remote sources/protocols.
Access Level Indication	Indicates the access level that the device is on at the time. Shows ACC if the device is on access level 1 and 2AC if on access level is 2.

Home Pushbutton

Use the **HOME** pushbutton to wake up the touchscreen after the inactivity timer expires and the screen goes dark. While the default mapping of the **HOME** pushbutton is the Home screen (see *Figure 8.33*), you can program the **HOME** pushbutton to jump to any screen. Refer to *Table 8.17* for a list of screens available for the **HOME** pushbutton. Use the FPHOME setting in the Touchscreen settings of QuickSet to program a specific screen.

Touchscreen Backlight

Adjustment

Touchscreen displays have an LED backlight that you can adjust to suit your viewing angle and lighting conditions. To change the backlight settings, tap the **Settings** folder and then tap the **Touchscreen** application. Use the FPBAB setting to adjust the brightness of the display. The backlight of the display goes dark 60 minutes after the inactivity timer (1–30 min) expires (setting FPTO).

Front-Panel Automatic Messages

The relay displays automatic messages that override the present display under the conditions described in *Table 8.6*. Relay failure messages have the highest priority, followed by trip and alarm. When the relay has a trip or alarm condition, the trip and diagnostic messages screen will appear on the display. These messages can also be accessed by tapping the **Trip & Diag. Messages** application in the Device Info folder.

Table 8.6 Front-Panel Automatic Messages

Condition	Front-Panel Message
Relay detects any failure	Displays the latest failure type (refer to *Section 11: Testing and Troubleshooting*).
Relay trip occurs	Displays the type or cause of the trip (refer to *Table 10.2* for a list of trip display messages).
Relay alarm condition occurs	Displays the type of alarm. The TRIP LED also flashes during an alarm condition (refer to *Table 8.3* for a list of the warning conditions).

Front-Panel Security

Use the **Access Level** folder on the Home screen for login/logout operations.

The SEL-787 front panel typically operates at Access Level 1 and allows you to view relay measurements and settings. Particular activities, such as editing settings and controlling output contacts, are restricted to those operators who know the Access Level 2 password.

When an activity requires Access Level 2, an authentication screen appears on the display, which requires you to enter the Access Level 2 password to proceed further. After you have correctly entered the password, you can perform other Access Level 2 operations without re-entering the password. You will have to re-enter the password if the front-panel inactivity timer, FPTO, expires.

See *PASSWORD Command (Change Passwords) on page 7.58* for the list of default passwords and for more information on changing the passwords.

Front-Panel Timeout

To help prevent unauthorized access to password-protected functions, the SEL-787 provides a front-panel time-out setting, FPTO, in the Touchscreen application in the Settings folder. The time-out resets each time you press a front-panel pushbutton or tap the display. Once the time out expires, the access level resets to Access Level 1. You can manually reset the access level by tapping **Logout** in the Access Level folder.

Touchscreen

Navigating the Touchscreen Folders and Applications

Use the front-panel touchscreen and pushbuttons to access data measured and stored by the relay and to perform relay operations. All relay information and operations are available through the touchscreen via folders, applications, and the buttons in the sidebar. *Table 8.7* describes the functions of the sidebar buttons.

Table 8.7 Sidebar Buttons

Button	Button Name	Function	Button	Button Name	Function
	Up	Pages up in applications with multiple screens; when on the first screen, this button is disabled.		Trigger Event	Triggers an event.
	Down	Pages down in applications with multiple screens; when on the last screen, this button is disabled.		Back	Returns to the preceding screen, e.g., from applications to folders.
	Left	Pages left on the home screen and in folders with multiple screens; this button is hidden if there is no screen to the left.		Pause	Stops updating the phasors.
	Right	Pages right on the home screen and in folders with multiple screens; this button is hidden if there is no screen to the right.		Play	Updates the phasor values from the relay as the screen refreshes.
	Reset	Resets the accumulating quantities, such as energy, to zero.		Refresh	Reloads the data when new data are available.
	Save	Saves the edited settings to the relay.		Search	Search tool (e.g., search for the status of a Relay Word bit).
	Cancel Save	Cancels the setting edits.		Trash	Deletes the records from the report.

The relay wakes up to the screen set in the FPHOME setting, unless the rotating display is enabled. If the rotating display is enabled and the inactivity time has expired, the relay wakes up to the rotating display. Pressing the **HOME** pushbutton a second time returns you to the screen set in the FPHOME setting.

You can navigate the touchscreen by tapping the folders and applications. Tap a folder or an application to view available applications or access an application, respectively. Folders and applications are labeled according to functionality.

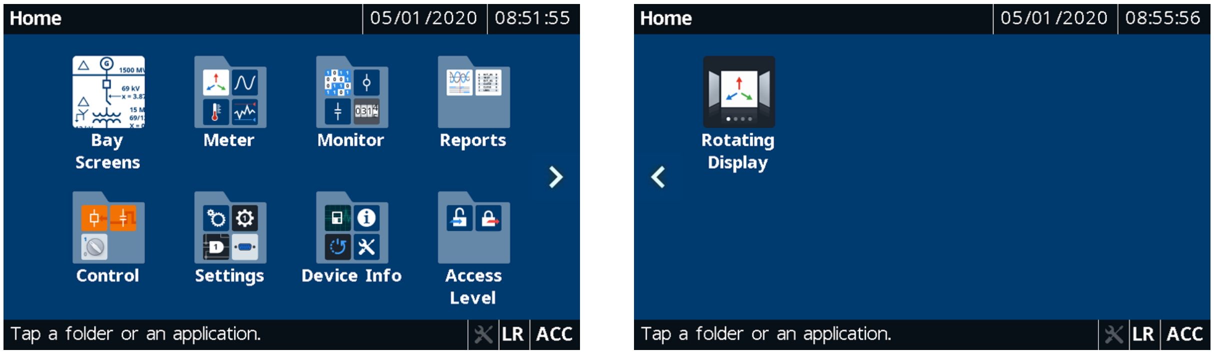


Figure 8.33 Home (Default FPHOME Setting)

Table 8.8 shows a list of folders and applications available on the Home screen.

Table 8.8 Home Folders and Applications

Screen Name	Folder or Application Name	Comments
Home	Bay Screens	Always available
	Meter	Always available
	Monitor	Always available
	Reports	Always available
	Control	Always available
	Settings	Always available
	Device Info	Always available
	Access Level	Always available
	Rotating Display	Always available

The applications shown in the folders are based on the part number. For example, if the relay does not support analog inputs, the Analog Inputs application is not shown in the Meter folder.

Descriptions of the folders and applications on the Home screen follow.

Bay Screens

NOTE: Five bay screens are always rendered on the touchscreen. Any unused screens are blank.

Tap this application to navigate to as many as five customer-designed screens (Bay Screen 1 through Bay Screen 5, see *Table 8.17*). You can design these screens using ACSELERATOR Bay Screen Builder SEL-5036 Software. Refer to *Section 9: Bay Control* for the procedure to create custom screens.

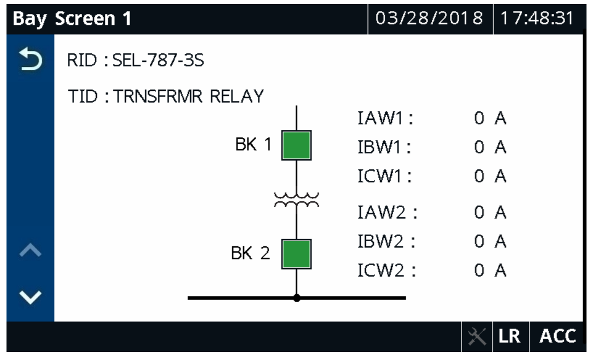


Figure 8.34 Bay Screens Application

Meter

Tapping this folder navigates you to the Meter screen, as shown in *Figure 8.35*. This screen lists all of the available metering applications. The applications on the Meter screen are part number dependent. Only those metering applications specific to your part number appear on the Meter screen. Tapping an application on the Meter screen shows you the report for that particular application.

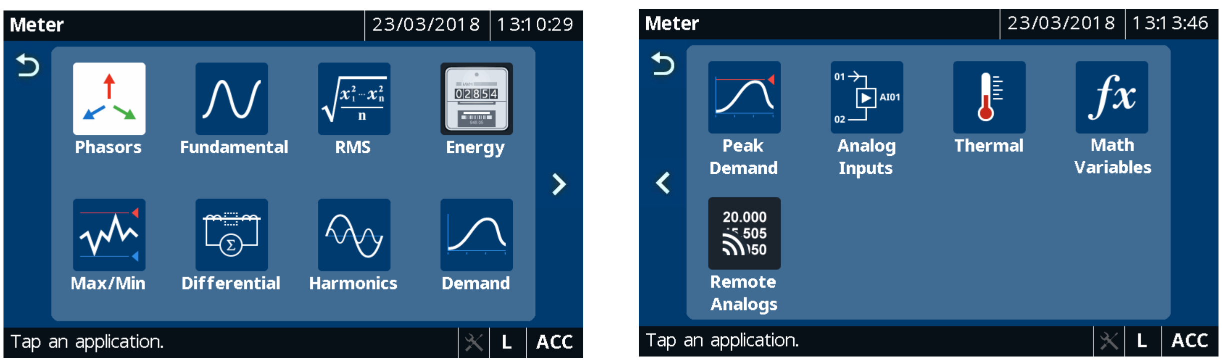


Figure 8.35 Meter Applications

Table 8.9 identifies all the applications available in the Meter folder.

Table 8.9 Meter Application Availability

Folder Name	Application Name	Comments[a]
Meter	Phasors	Always available
	Fundamental	Always available
	RMS	Always available
	Energy	Available if the relay supports voltages (SEL-787-2E/3E/3S)
	Max/Min	Always available
	Differential	Always available
	Harmonics	Always available
	Demand	Always available
	Peak Demand	Always available
	Analog Inputs	Shown when (Slot C = 6*x*) or (Slot D = 6*x*) or (Slot E = 6*x*)
	Thermal	Always available
	Math Variables	Always available
	Remote Analogs	Always available

[a] Refer to the relay part number.

Figure 8.36 and *Figure 8.37* show typical screens for phasor and fundamental metering.

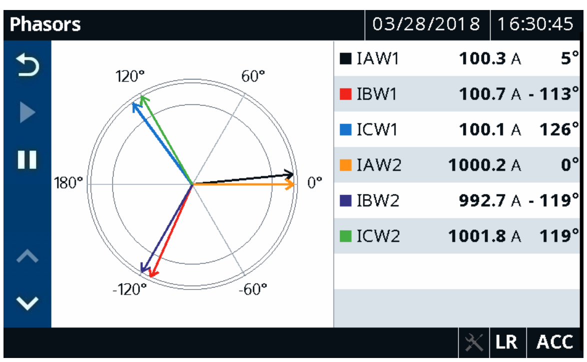


Figure 8.36 Meter Phasors

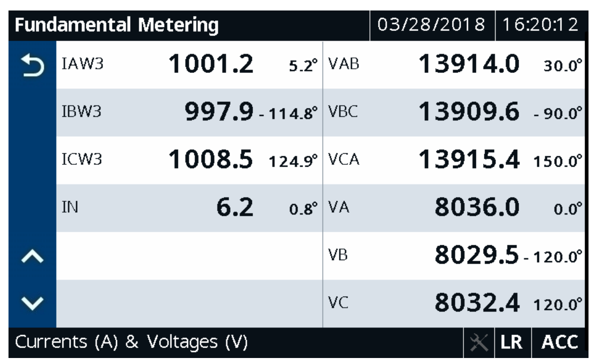


Figure 8.37 Meter Fundamental

A reset feature is provided for the Energy, Max/Min, Demand, and Peak Demand applications. Tap the **Reset** button to navigate to the reset confirmation screen. Once you confirm the reset, the data are reset to zero. *Figure 8.38* and *Figure 8.39* show typical screens for energy metering and reset confirmation.

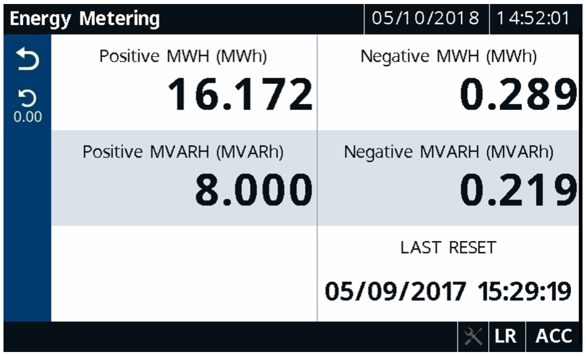


Figure 8.38 Meter Energy

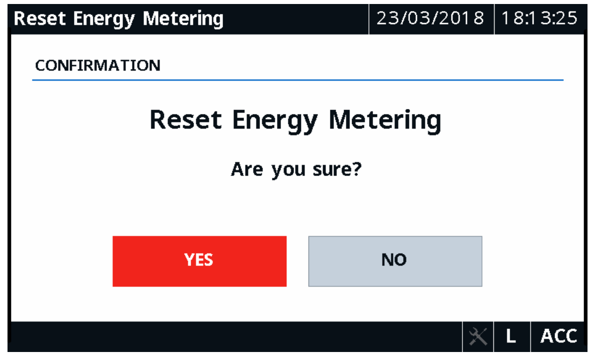


Figure 8.39 Meter Energy Reset

Figure 8.40 and *Figure 8.41* show typical screens for differential and harmonic metering.

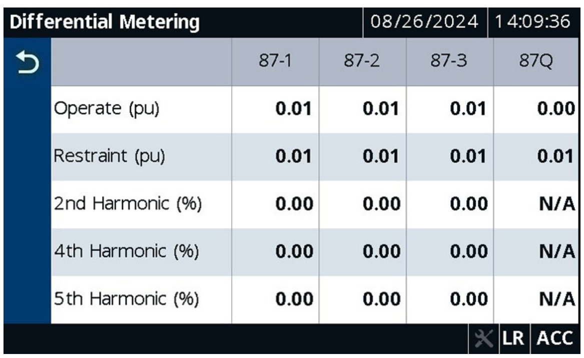


Figure 8.40 Meter Differential

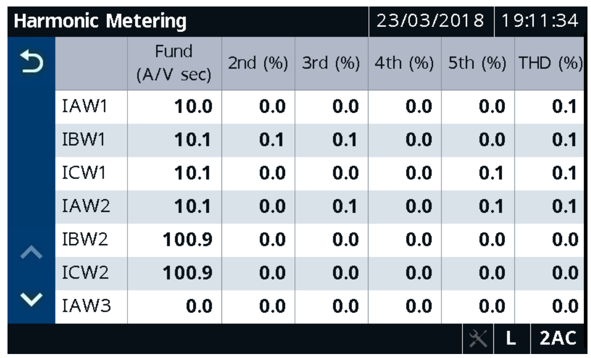


Figure 8.41 Meter Harmonics

Monitor

Tapping this folder navigates you to the Monitor screen, as shown in *Figure 8.42*. Monitor the status of the Relay Word bits (targets), digital outputs, digital inputs, SELOGIC counters, breaker wear data, and through fault data using the respective applications (Relay Word Bits, Digital Outputs, Digital Inputs, SELogic Counters, Breaker Wear, and Through Fault).

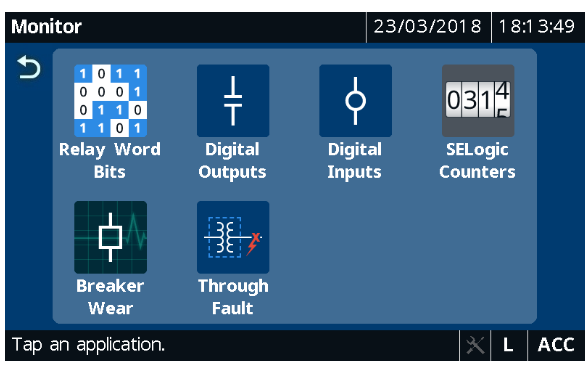


Figure 8.42 Monitor Applications

Table 8.10 identifies all the applications available in the Monitor folder.

Table 8.10 Monitor Application Availability

Folder Name	Application Name	Comments
Monitor	Relay Word Bits	Always available
	Digital Outputs	Always available
	Digital Inputs	Always available
	SELogic Counters	Always available
	Breaker Wear	Always available
	Through Fault	Always available

Tap the **Breaker Wear** application to view accumulated Breaker *n* (*n* = 1–4) wear/operations. You can reset the accumulated data by tapping the **Reset** button provided in the sidebar of the Breaker Wear application. Typical screens for the Breaker Wear application are shown in *Figure 8.43*, *Figure 8.44*, and *Figure 8.45*.

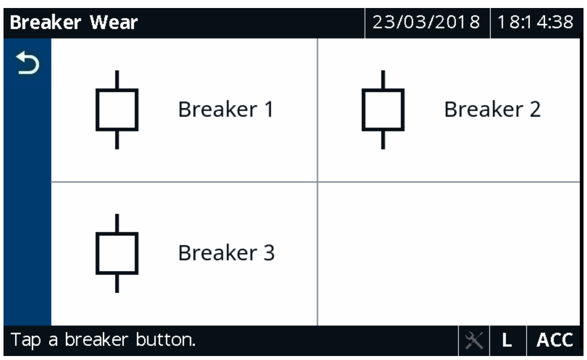


Figure 8.43 Breaker Selection

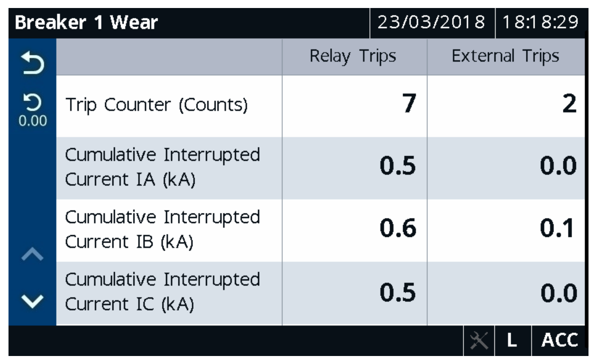


Figure 8.44 Breaker Wear Trips

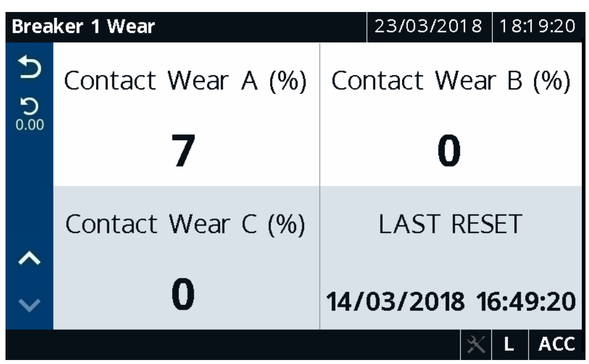


Figure 8.45 Breaker Wear A, B, C and Last Reset

Monitor the status of the Relay Word bits using the Relay Word Bits screen. Note that asserted Relay Word bits are highlighted in blue. You can use the **Search** button in the Relay Word Bits application to view the status of a Relay Word bit. To search for a Relay Word bit, you must enter the full name of the Relay Word bit in the screen Search Relay Word Bit SEARCH field. *Figure 8.46* and *Figure 8.47* show typical Relay Word bits monitoring screens.

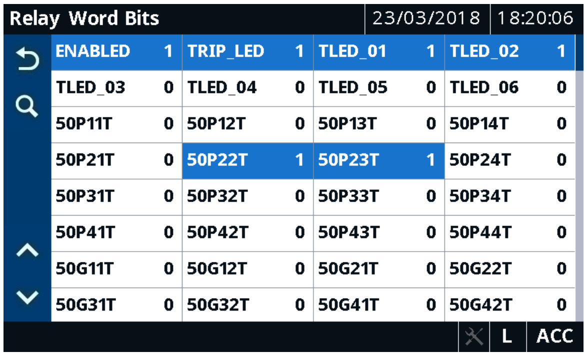


Figure 8.46 Monitor Relay Word Bits

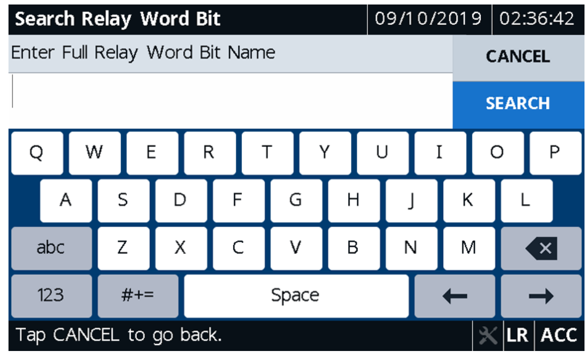


Figure 8.47 Search Relay Word Bits

Tap **Through Fault** to view the accumulated through fault data in the relay memory. You can reset the through fault data by tapping the **Reset** button provided in the sidebar of the Through Fault application. *Figure 8.48* shows a typical Through Fault screen.

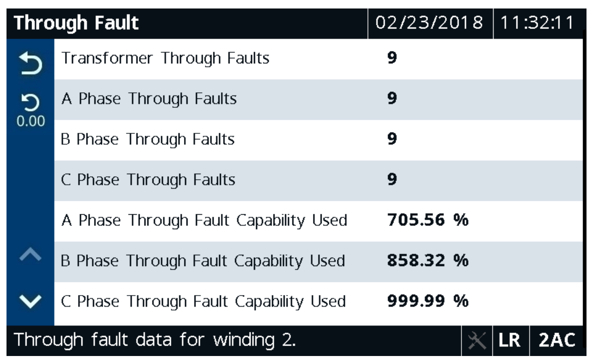


Figure 8.48 Monitor Through Fault

Reports

Tap **Report** to navigate to the Reports screen where you can access the Events and SER applications.

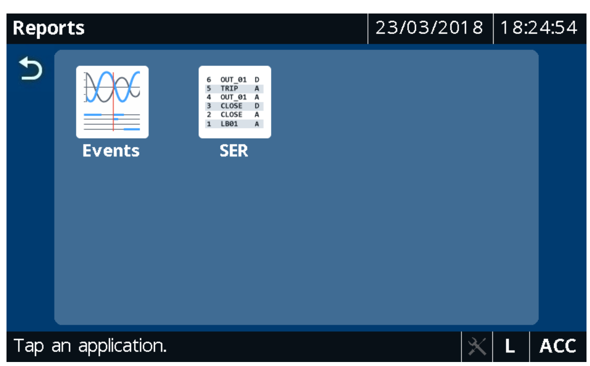


Figure 8.49 Reports Applications

Table 8.11 identifies all the applications available in the Reports folder.

Table 8.11 Reports Application Availability

Folder Name	Application Name	Comments
Reports	Events	Always available
	SER	Always available

To view the summary of a particular event record, tap the event record on the Event History screen. You can also trigger an event from the Event History screen by using the **Trigger Event** button. When new records become available while viewing any of the Reports screens (Events and SER), the up and down buttons are disabled and the footer displays a message to refresh the screen. Update the screen using the **Refresh** button. Tap the **Trash** button on the Event History and Sequential Events Recorder screens and confirm the delete action to remove the records from the relay. *Figure 8.50* through *Figure 8.52* show typical Event History, Event Summary, and Sequential Events Recorder screens.

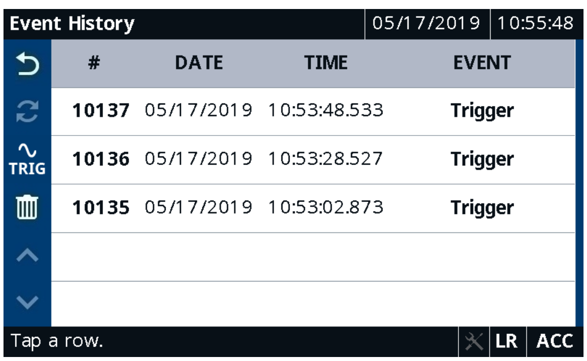


Figure 8.50 Event History

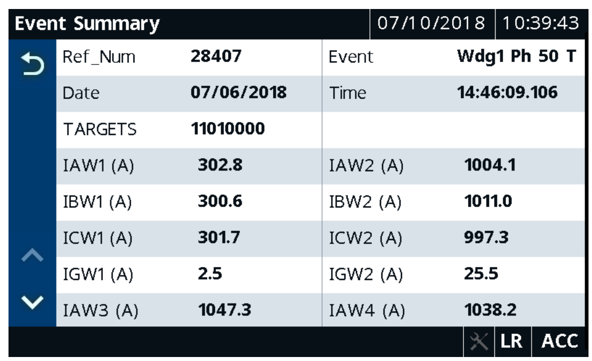


Figure 8.51 Event Summary

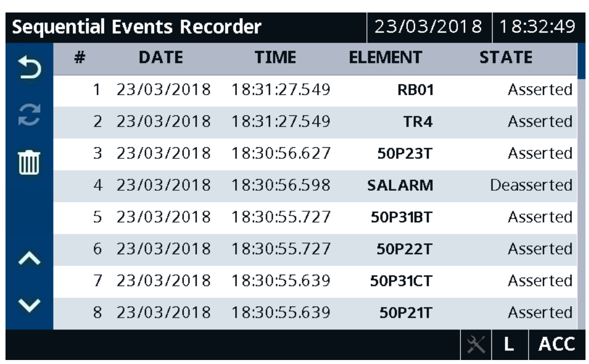


Figure 8.52 Sequential Events Recorder

Control

Tapping this folder navigates you to the Control screen, as shown in *Figure 8.53*. Use the Control folder applications Breaker Control, Output Pulsing, and Local Bits to perform breaker control operations, pulse output contacts, or control the local bits.

Breaker Control and Output Pulsing applications require that the breaker jumper be installed on the main board. Refer to *Password, Breaker Control, and SELBOOT Jumper Selection on page 2.26* for information on the breaker jumper.

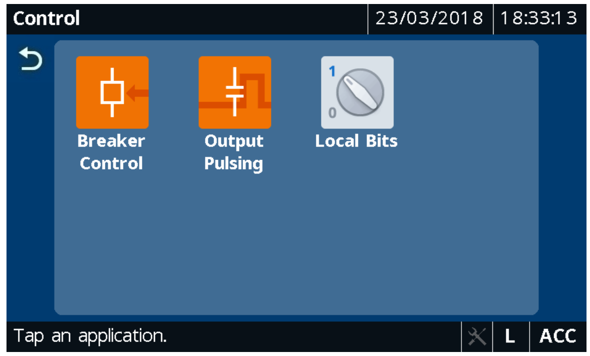


Figure 8.53 Control Applications

Table 8.12 identifies all the applications available in the Control folder.

Table 8.12 Control Application Availability

Folder Name	Application Name	Comments
Control	Breaker Control	Always available
	Output Pulsing	Always available
	Local Bits	Always available

To perform breaker control, tap the **Breaker Control** application, select the breaker you want to control, and then tap and confirm the control action. Breaker control through the touchscreen is supervised by (1) the status of the LOCAL bit when EN_LRC := Y, (2) the position of the breaker jumper, and (3) the access level (requires 2AC). When EN_LRC := N, supervision through the LOCAL bit is ignored, while supervision through the breaker jumper and access level are maintained.

When local/remote supervision setting EN_LRC := Y and LOCAL := 0, the OC*n* and CC*n* (*n* = 1–4) bits are not processed from the touchscreen (i.e., breaker control through the touchscreen is blocked). *Figure 8.54* and *Figure 8.55* show typical breaker control screens. For the settings related to the local/remote control function, refer to *Local/Remote Control on page 9.7*.

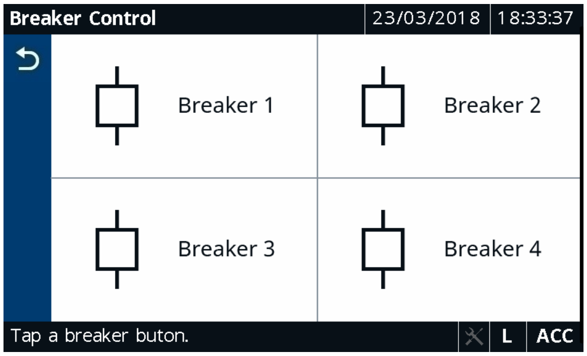


Figure 8.54 Breaker Control Selection

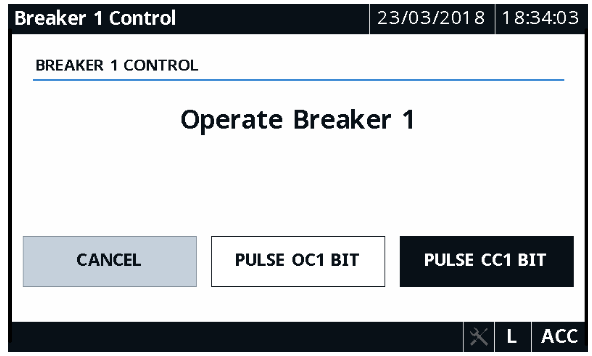


Figure 8.55 Breaker Control Operation

To pulse a digital output contact, tap the Output Pulsing application. Navigate to the desired output contact screen, tap the desired output, and confirm the control action. The output tile will be highlighted in blue on assertion, as shown in *Figure 8.56*. An output contact cannot be pulsed if it is already asserted. Pulsing the output contact requires that the breaker jumper be installed and that you have Level 2 access.

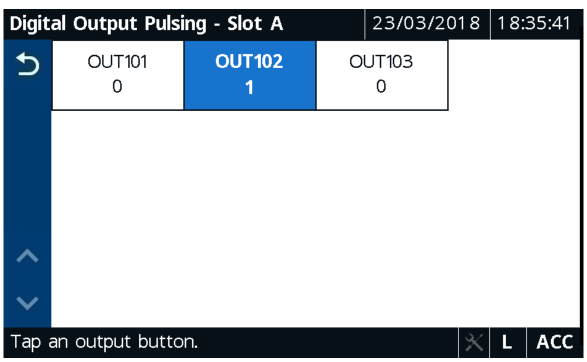


Figure 8.56 Digital Output Pulsing—Slot A

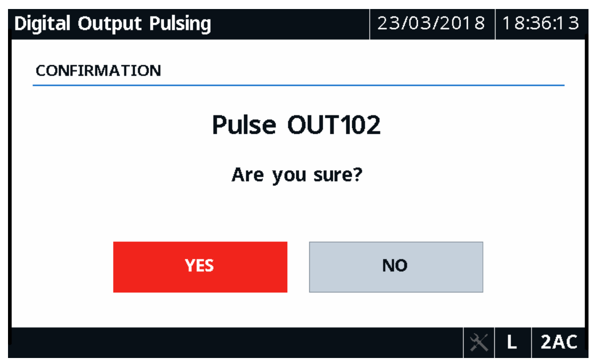


Figure 8.57 Digital Output Pulsing Confirmation

To control the local bits, tap the **Local Bits** application. You can control the desired local bit by tapping on the corresponding row. Depending on the state, tap and confirm the type of action you would like to perform. *Figure 8.58* through *Figure 8.60* show typical local bits control screens.

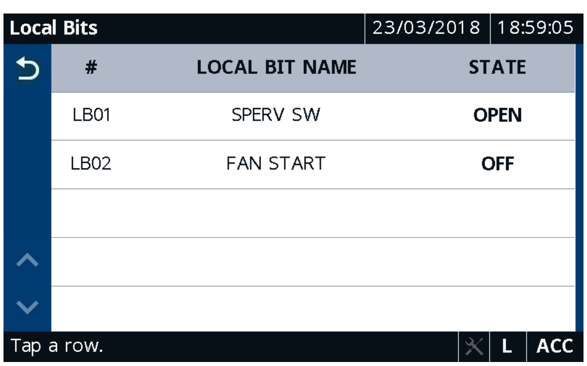


Figure 8.58 Local Bits

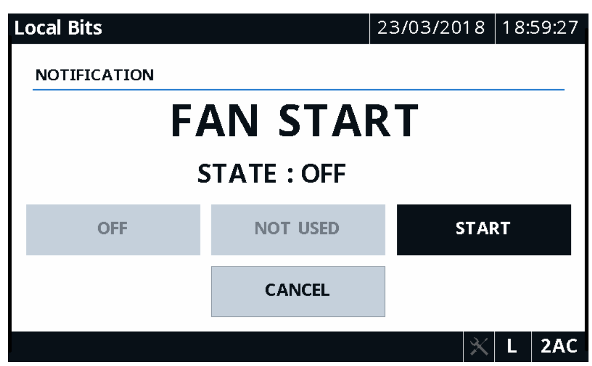


Figure 8.59 Local Bits Notification

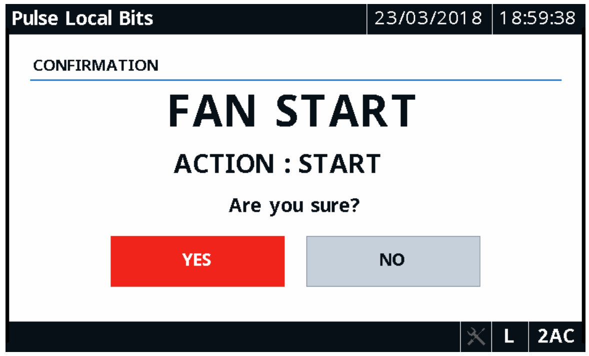


Figure 8.60 Local Bits Confirmation

Device Info

Tap the **Device Info** folder to navigate to the Device Info screen where you can access specific device information applications (Status, Configuration, and Trip & Diag. Messages) and the Reboot application.

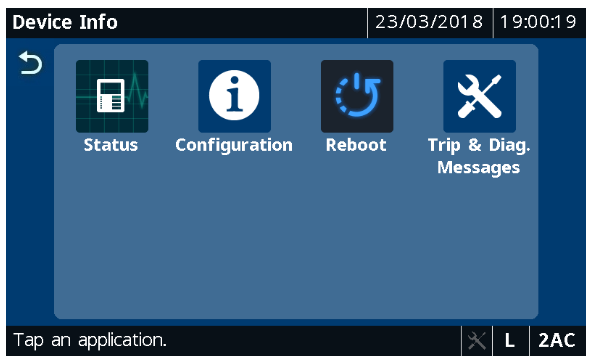


Figure 8.61 Device Info Applications

Table 8.13 identifies all the applications available in the Device Info folder.

Table 8.13 Device Info Application Availability

Folder Name	Application Name	Comments
Device Info	Status	Always available
	Configuration	Always available
	Reboot	Always available
	Trip & Diag. Messages	Always available

Tap the **Status** application to view the relay status, firmware version, part number, etc., as shown in *Figure 8.62*. Use the **Configuration** application to view port information, the jumper positions for the breaker, etc., as shown in *Figure 8.63*. If the relay detects any new card in one of the slots, it disables and directs you to accept the change in configuration, as shown in *Figure 8.64*. *Figure 8.62* through *Figure 8.64* show typical screens for device configuration, device status, and trip and diagnostic messages.

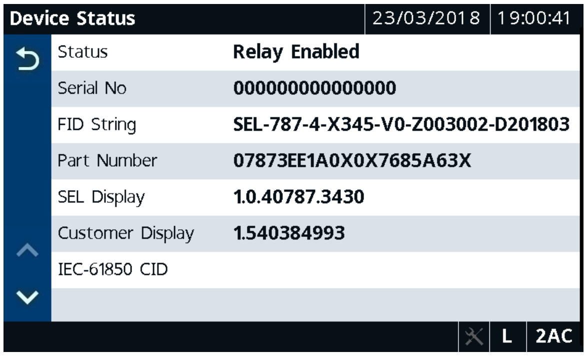


Figure 8.62 Device Status

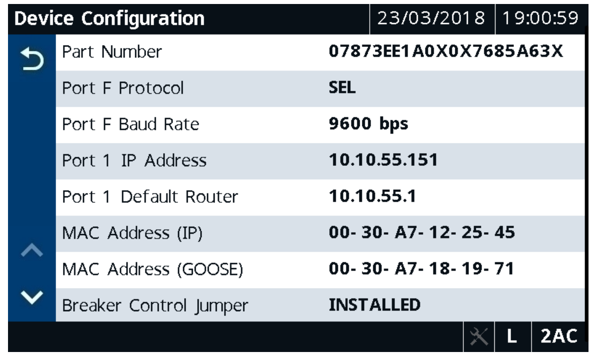


Figure 8.63 Device Configuration

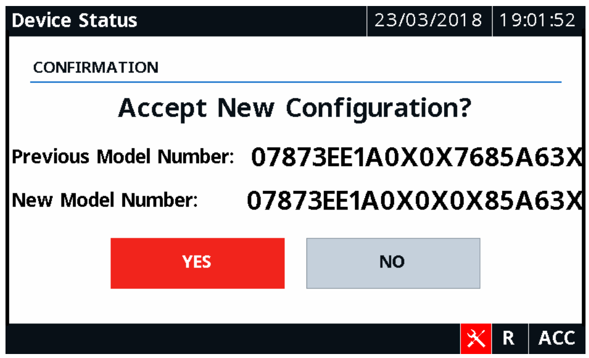


Figure 8.64 Model Number Confirmation

When a diagnostic failure, trip, or warning occurs, the relay displays the diagnostic message on the screen until it is either overridden by the restart of the rotating display or the inactivity timer expires. To view the trip and diagnostic messages, tap the **Trip & Diag. Messages** application in the Device Info folder.

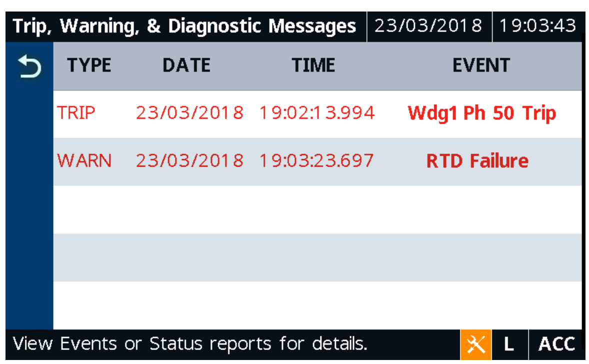


Figure 8.65 Trip and Diagnostic Messages

Access Level

Tapping this folder navigates you to the Access Level screen where you can either log in to or log out of the 2AC level.

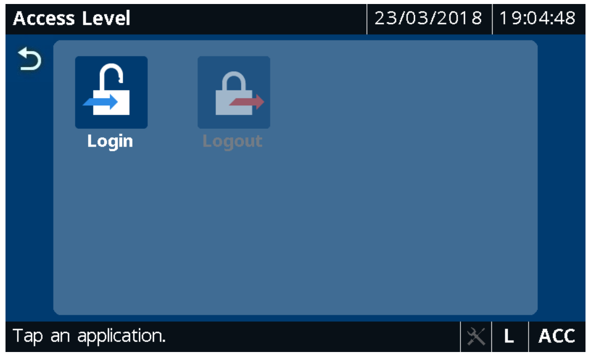


Figure 8.66 Access Level Applications

Table 8.14 identifies all of the applications available in the Access Level folder.

Table 8.14 Access Level Application Availability

Folder Name	Application Name	Comments
Access Level	Login	Always available
	Logout	Always available

Note that when an application requires the 2AC access level and the relay is at ACC, the relay automatically pops up the authentication screen requiring you to enter the password before performing a control operation, editing setting, etc.

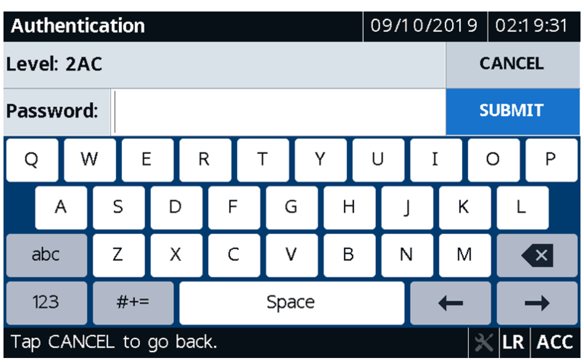


Figure 8.67 Authentication

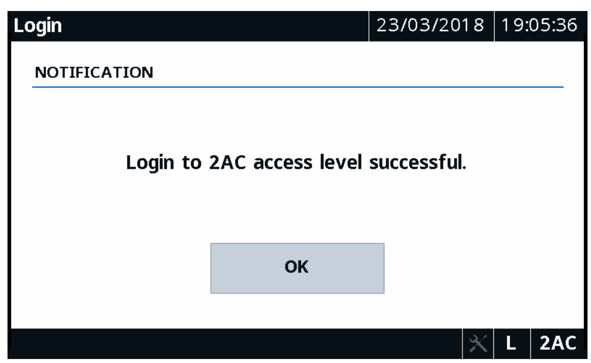


Figure 8.68 Login Confirmation

Settings

Tapping this folder navigates you to the Settings screen where you can access settings applications (Global, Touchscreen) or settings folders (Port, Group, Date and Time) through which you can set or show settings.

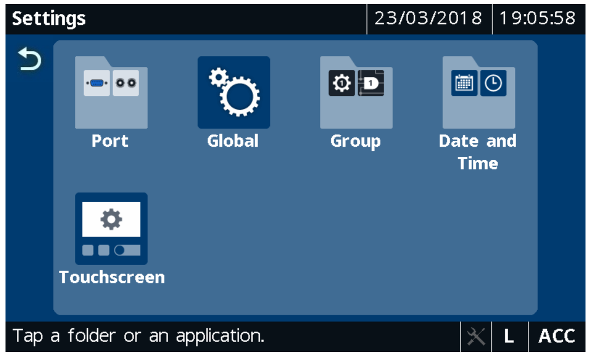


Figure 8.69 Settings Folders and Applications

Table 8.15 identifies all of the folders and applications available in the Settings folder.

Table 8.15 Settings Folder and Application Availability

Folder Name	Folder or Application Name	Comments
Settings	Port	Always available
	Global	Always available
	Group	Always available
	Date and Time	Always available
	Touchscreen	Always available

Table 8.16 identifies all the applications available in each folder (Port, Group, Date and Time) in the Settings folder.

Table 8.16 Settings Folders Port, Group, and Date and Time Application Availability

Folder Name	Application Name	Comments[a]
Port	Port F	Always available
	Port 1	Shown when Slot B ≠ *x*0*x* or *x*1*x*
	Port 2	Shown when E49RTD ≠ EXT
	Port 3	Always available
	Port 4	Shown when Slot C = A*x* or 0*x*, i.e., Slot C has a comms card or is empty
Group	Set 1	Always available
	Logic 1	Always available
	Set 2	Always available
	Logic 2	Always available
	Set 3	Always available
	Logic 3	Always available
	Set 4	Always available
	Logic 4	Always available
Date and Time	Date	Always available
	Time	Always available

[a] Refer to the relay part number.

Figure 8.70 and *Figure 8.71* show typical Port and Group Settings screens.

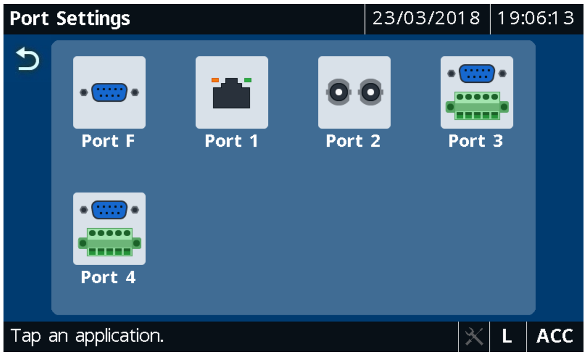


Figure 8.70 Port Settings

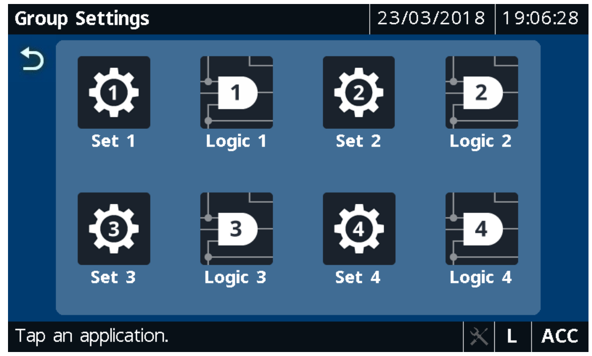


Figure 8.71 Group Settings

To edit a setting, tap on a setting row and enter the Access Level 2 password. If the access level is already at Access Level 2, the relay does not prompt for password authentication. After entering the value, tap the **Save** button to save your edit, or tap the **Cancel Save** button to cancel the edit (see *Table 8.7*). If the Save/Cancel Save buttons are not visible, tap the **Back** button until they appear. When editing a settings class (e.g., Set 1 in Group Settings), you cannot navigate to another class (e.g., Logic 1) without saving or discarding the settings change made in Set 1.

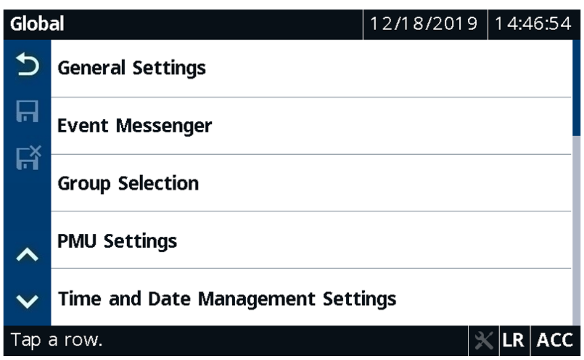


Figure 8.72 Global Settings

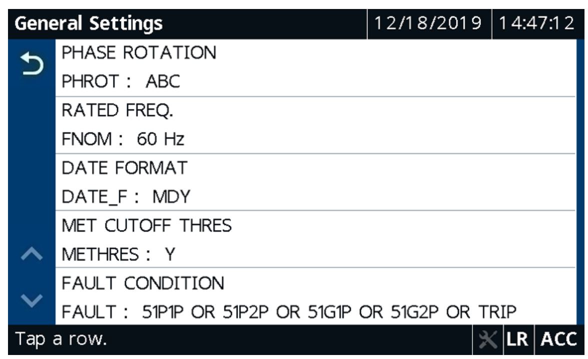


Figure 8.73 General Settings

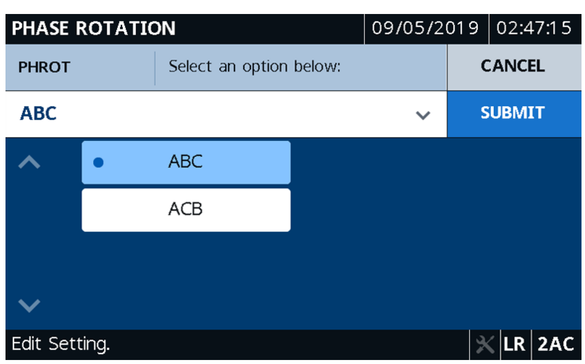


Figure 8.74 Set/Show Settings Edit

You can control the screen brightness, the screen inactivity timer settings, etc., through the Touchscreen application.

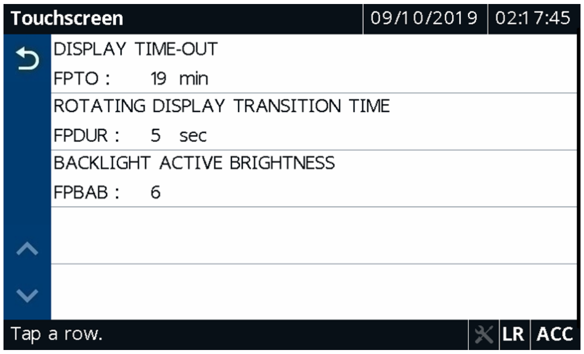


Figure 8.75 Touchscreen Settings

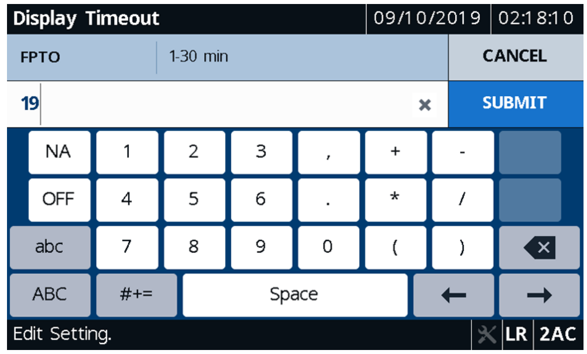


Figure 8.76 Touchscreen Settings Edit

Rotating Display

Tapping this application allows you to start the rotating display. You can pick as many as 16 screens through which the display can rotate after the inactivity timer expires. Refer to *Table 9.7* for the equivalent touchscreen display settings.

Tapping any screen while the display is rotating takes you to that particular screen. You can perform the needed operation and use the **Back** button to return to the Home screen.

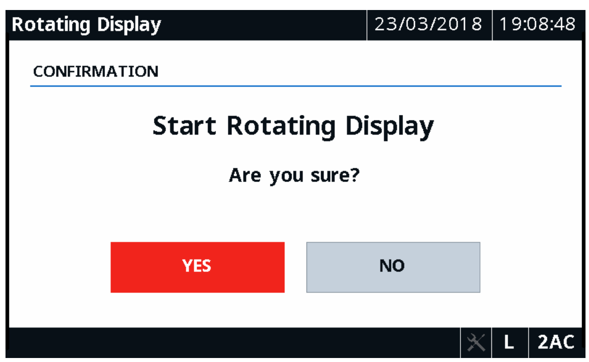


Figure 8.77 Rotating Display

Language Support

All of the HMI messages can be displayed in multiple languages (English or Spanish). The relay part number determines which language is displayed on the HMI. See the *SEL-787-2, -3, -4 Relay Command Summary* for a list of the commands.

Operation and Target LEDs

Programmable LEDs

The SEL-787 provides quick confirmation of relay conditions via operation and target LEDs. Refer to *Operation and Target LEDs on page 8.14* for details on the **ENABLED**, **TRIP**, programmable LEDs and their operation, and possible warning conditions on the relay.

TARGET RESET Pushbutton

Refer to *TARGET RESET Pushbutton on page 8.16* for the operation of the **TARGET RESET** pushbutton, the lamp test, and other target reset options.

Front-Panel Operator Control Pushbuttons

The SEL-787 touchscreen display features eight operator-controlled pushbuttons, each with two programmable tricolor pushbutton LEDs, for local control, as shown in *Table 8.4*. Refer to *Front-Panel Operator Control Pushbuttons on page 8.16* for details on operator control pushbuttons and LEDs and their programming.

You can use the front-panel operator control pushbuttons to jump to a specific screen while using them for LOCK/TRIP/CLOSE operations, etc. You can program the selectable operator pushbutton screen settings under the Touchscreen settings category in QuickSet and map the button to a specific screen. For example, PB03, which is used to trip a breaker by default, can be programmed to jump to a bay screen by mapping the pushbutton touchscreen setting FPPB03 to Bay Screen 1. When you press PB03, the display jumps to Bay Screen 1, where you can see a visual confirmation of the TRIP action.

Table 8.17 Screens Available for the Rotating Display, HOME Pushbutton[a], and Programmable Pushbuttons (Sheet 1 of 12)

Home Screen Folders and Applications	Folder and Application Names	Display Name	Quantities	Comments
Bay Screens				
		Bay Screen 1		Displays Bay Screen 1
		Bay Screen 2		Displays Bay Screen 2
		Bay Screen 3		Displays Bay Screen 3
		Bay Screen 4		Displays Bay Screen 4
		Bay Screen 5		Displays Bay Screen 5
Meter				
	Phasors			
		Phasor Screen 1	IAW1_MAG, IAW1_ANG, IBW1_MAG, IBW1_ANG, ICW1_MAG, ICW1_ANG, IAW2_MAG, IAW2_ANG, IBW2_MAG, IBW2_ANG, ICW2_MAG, ICW2_ANG	Always available
		Phasor Screen 2	IAW3_MAG, IAW3_ANG, IBW3_MAG, IBW3_ANG, ICW3_MAG, ICW3_ANG, IAW4_MAG, IAW4_ANG, IBW4_MAG, IBW4_ANG, ICW4_MAG, ICW4_ANG	Shown when the firmware option is 4X
		Phasor Screen 3	IAW3_MAG, IAW3_ANG, IBW3_MAG, IBW3_ANG, ICW3_MAG, ICW3_ANG	Shown when the firmware option is 3E or 3S

Table 8.17 Screens Available for the Rotating Display, HOME Pushbutton[a], and Programmable Pushbuttons (Sheet 2 of 12)

Home Screen Folders and Applications	Folder and Application Names	Display Name	Quantities	Comments
		Phasor Screen 4	IAW1_MAG, IAW1_ANG, IBW1_MAG, IBW1_ANG, ICW1_MAG, ICW1_ANG, VAB_MAG, VAB_ANG, VBC_MAG, VBC_ANG, VCA_MAG, VCA_ANG	Shown when the firmware option is 3E or 2E and VIWDG := 1 or when the firmware option is 3S and VS_VBAT = VBAT and VIWDG = 1
		Phasor Screen 5	IAW2_MAG, IAW2_ANG, IBW2_MAG, IBW2_ANG, ICW2_MAG, ICW2_ANG, VAB_MAG, VAB_ANG, VBC_MAG, VBC_ANG, VCA_MAG, VCA_ANG	Shown when the firmware option is 3E or 2E and VIWDG = 2 or when the firmware option is 3S and VS_VBAT = VBAT and VIWDG = 2
		Phasor Screen 6	IAW3_MAG, IAW3_ANG, IBW3_MAG, IBW3_ANG, ICW3_MAG, ICW3_ANG, VAB_MAG, VAB_ANG, VBC_MAG, VBC_ANG, VCA_MAG, VCA_ANG	Shown when the firmware option is 3E and VIWDG = 3 or when the firmware option is 3S and VS_VBAT = VBAT and VIWDG = 3
		Phasor Screen 7	IAW12MAG (if available), IAW12ANG (if available), IBW12MAG (if available), IBW12ANG (if available), ICW12MAG (if available), ICW12ANG (if available), IAW23MAG (if available), IAW23ANG (if available), IBW23MAG (if available), IBW23ANG (if available), ICW23MAG (if available), ICW23ANG (if available), VAB_MAG, VAB_ANG, VBC_MAG, VBC_ANG, VCA_MAG, VCA_ANG	Shown when the firmware option is 3E and VIWDG = 12 or when the firmware option is 3S and VS_VBAT = VBAT and VIWDG = 12 or 23
		Phasor Screen 8	IAW1_MAG, IAW1_ANG, IBW1_MAG, IBW1_ANG, ICW1_MAG, ICW1_ANG, VAB_MAG, VAB_ANG, VBC_MAG, VBC_ANG, VCA_MAG, VCA_ANG, VS_MAG, VS_ANG	Shown when the firmware option is 3S and VS_VBAT = VS and VIWDG = 1
		Phasor Screen 9	IAW2_MAG, IAW2_ANG, IBW2_MAG, IBW2_ANG, ICW2_MAG, ICW2_ANG, VAB_MAG, VAB_ANG, VBC_MAG, VBC_ANG, VCA_MAG, VCA_ANG, VS_MAG, VS_ANG	Shown when the firmware option is 3S and VS_VBAT = VS and VIWDG = 2

Table 8.17 Screens Available for the Rotating Display, HOME Pushbutton[a], and Programmable Pushbuttons (Sheet 3 of 12)

Home Screen Folders and Applications	Folder and Application Names	Display Name	Quantities	Comments
		Phasor Screen 10	IAW3_MAG, IAW3_ANG, IBW3_MAG, IBW3_ANG, ICW3_MAG, ICW3_ANG, VAB_MAG, VAB_ANG, VBC_MAG, VBC_ANG, VCA_MAG, VCA_ANG, VS_MAG, VS_ANG	Shown when the firmware option is 3S and VS_VBAT = VS and VIWDG = 3
		Phasor Screen 11	IAW12MAG (if available), IAW12ANG (if available), IBW12MAG (if available), IBW12ANG (if available), ICW12MAG (if available), ICW12ANG (if available), IAW23MAG (if available), IAW23ANG (if available), IBW23MAG (if available), IBW23ANG (if available), ICW23MAG (if available), ICW23ANG (if available), VAB_MAG, VAB_ANG, VBC_MAG, VBC_ANG, VCA_MAG, VCA_ANG, VS_MAG, VS_ANG	Shown when the firmware option is 3S and VS_VBAT = VS and VIWDG = 12 or 23
	Fundamental			
		Fundamental Screen 1	IAW1_MAG, IAW1_ANG, IBW1_MAG, IBW1_ANG, ICW1_MAG, ICW1_ANG, IN_MAG (if available), IN_ANG (if available), FREQ, IAW2_MAG, IAW2_ANG, IBW2_MAG, IBW2_ANG, ICW2_MAG, ICW2_ANG, IAW12MAG (if available), IAW12ANG (if available), IBW12MAG (if available), IBW12ANG (if available), ICW12MAG (if available), ICW12ANG (if available), IAW23MAG (if available), IAW23ANG (if available), IBW23MAG (if available), IBW23ANG (if available), ICW23MAG (if available), ICW23ANG (if available)	Always available IN quantities are shown when the firmware option is 21 or 2E; IAW12, IBW12, and ICW12 quantities are shown when CCW12 = Y or CCW23 = Y

Table 8.17 Screens Available for the Rotating Display, HOME Pushbutton[a], and Programmable Pushbuttons (Sheet 4 of 12)

Home Screen Folders and Applications	Folder and Application Names	Display Name	Quantities	Comments
		Fundamental Screen 2	IGW1_MAG, IGW1_ANG, I1W1_MAG, I1W1_ANG, 3I2W1MAG, 3I2W1ANG, IGW2_MAG, IGW2_ANG, I1W2_MAG, I1W2_ANG, 3I2W2MAG, 3I2W2ANG, IGW12MAG (if available), IGW12ANG (if available), I1W12MAG (if available), I1W12ANG (if available), 3I2W12MG (if available), 3I2W12AG (if available), IAW23MAG (if available), IAW23ANG (if available), IBW23MAG (if available), IBW23ANG (if available), ICW23MAG (if available), ICW23ANG (if available)	Always available IGW12, I1W12, and 3I2W12 quantities are shown when CCW12 = Y or CCW23 = Y
		Fundamental Screen 3	IAW3_MAG, IAW3_ANG, IBW3_MAG, IBW3_ANG, ICW3_MAG, ICW3_ANG, IAW4_MAG, IAW4_ANG, IBW4_MAG, IBW4_ANG, ICW4_MAG, ICW4_ANG, IAW34MAG (if available), IAW34ANG (if available), IBW34MAG (if available), IBW34ANG (if available), ICW34MAG (if available), ICW34ANG (if available)	Shown when the firmware option is 4X IAW34, IBW34, and ICW34 quantities are shown when CCW34 = Y
		Fundamental Screen 4	IGW3_MAG, IGW3_ANG, I1W3_MAG, I1W3_ANG, 3I2W3MAG, 3I2W3ANG, IGW4_MAG, IGW4_ANG, I1W4_MAG, I1W4_ANG, 3I2W4MAG, 3I2W4ANG, IGW34MAG (if available), IGW34ANG (if available), I1W34MAG (if available), I1W34ANG (if available), 3I2W34MG (if available), 3I2W34AG (if available)	Shown when the firmware option is 4X IGW34, I1W34, and 3I2W34 quantities are shown when CCW34 = Y
		Fundamental Screen 5	IAW3_MAG, IAW3_ANG, IBW3_MAG, IBW3_ANG, ICW3_MAG, ICW3_ANG, IN_MAG,IN_ANG,VA_MAG, VA_ANG, VB_MAG, VB_ANG, VC_MAG, VC_ANG, VAB_MAG, VAB_ANG, VBC_MAG, VBC_ANG, VCA_MAG, VCA_ANG	Shown when the firmware option is 3E and DELTA_Y = WYE

Table 8.17 Screens Available for the Rotating Display, HOME Pushbutton[a], and Programmable Pushbuttons (Sheet 5 of 12)

Home Screen Folders and Applications	Folder and Application Names	Display Name	Quantities	Comments
		Fundamental Screen 6	IGW3_MAG, IGW3_ANG, I1W3_MAG, I1W3_ANG, 3I2W3MAG, 3I2W3ANG, VG_MAG, VG_ANG, V1_MAG, V1_ANG, 3V2_MAG, 3V2_ANG, VHZ	Shown when the firmware option is 3E and DELTA_Y = WYE
		Fundamental Screen 7	IAW3_MAG, IAW3_ANG, IBW3_MAG, IBW3_ANG, ICW3_MAG, ICW3_ANG, IN_MAG, IN_ANG, VAB_MAG, VAB_ANG, VBC_MAG, VBC_ANG, VCA_MAG, VCA_ANG	Shown when the firmware option is 3E and DELTA_Y = DELTA
		Fundamental Screen 8	IGW3_MAG, IGW3_ANG, I1W3_MAG, I1W3_ANG, 3I2W3MAG, 3I2W3ANG, V1_MAG, V1_ANG, 3V2_MAG, 3V2_ANG, VHZ	Shown when the firmware option is 3E and DELTA_Y = DELTA
		Fundamental Screen 9	IAW3_MAG, IAW3_ANG, IBW3_MAG, IBW3_ANG, ICW3_MAG, ICW3_ANG, VA_MAG, VA_ANG, VB_MAG, VB_ANG, VC_MAG, VC_ANG, VAB_MAG, VAB_ANG, VBC_MAG, VBC_ANG, VCA_MAG, VCA_ANG, VS_MAG (if available), VS_ANG (if available), FREQS (if available)	Shown when the firmware option is 3S and DELTA_Y = WYE VS and FREQS quantities are shown when VS_VBAT = VS
		Fundamental Screen 10	IGW3_MAG, IGW3_ANG, I1W3_MAG, I1W3_ANG, 3I2W3MAG, 3I2W3ANG, VG_MAG, VG_ANG, V1_MAG, V1_ANG, 3V2_MAG, 3V2_ANG, VHZ, VDC (if available)	Shown when the firmware option is 3S and DELTA_Y = WYE The VDC quantity is shown when VS_VBAT = VBAT
		Fundamental Screen 11	IAW3_MAG, IAW3_ANG, IBW3_MAG, IBW3_ANG, ICW3_MAG, ICW3_ANG, VAB_MAG, VAB_ANG, VBC_MAG, VBC_ANG, VCA_MAG, VCA_ANG, VS_MAG (if available), VS_ANG (if available), FREQS (if available)	Shown when the firmware option is 3S and DELTA_Y = DELTA VS and FREQS quantities are shown when VS_VBAT = VS
		Fundamental Screen 12	IGW3_MAG, IGW3_ANG, I1W3_MAG, I1W3_ANG, 3I2W3MAG, 3I2W3ANG, V1_MAG, V1_ANG, 3V2_MAG, 3V2_ANG, VHZ, VDC (if available)	Shown when the firmware option is 3S and DELTA_Y = DELTA The VDC quantity is shown when VS_VBAT = VBAT

Table 8.17 Screens Available for the Rotating Display, HOME Pushbutton[a], and Programmable Pushbuttons (Sheet 6 of 12)

Home Screen Folders and Applications	Folder and Application Names	Display Name	Quantities	Comments
		Fundamental Screen 13	VA_MAG, VA_ANG, VB_MAG, VB_ANG, VC_MAG, VC_ANG, VAB_MAG, VAB_ANG, VBC_MAG, VBC_ANG, VCA_MAG, VCA_ANG, VG_MAG, VG_ANG, V1_MAG, V1_ANG, 3V2_MAG, 3V2_ANG, VHZ	Shown when the firmware option is 2E and DELTA_Y = WYE
		Fundamental Screen 14	VAB_MAG, VAB_ANG, VBC_MAG, VBC_ANG, VCA_MAG, VCA_ANG, V1_MAG, V1_ANG, 3V2_MAG, 3V2_ANG, VHZ	Shown when the firmware option is 2E and DELTA_Y = DELTA
		Fundamental Screen 15	P, Q, S, PF, PFL	Shown when the firmware option is 3E, 3S, or 2E
		Fundamental Screen 16	PA, QA, SA, PFA, PFAL, PB, QB, SB, PFB, PFBL, PC, QC, SC, PFC, PFCL	Shown when the firmware option is 3E, 3S, or 2E and DELTA_Y = WYE and (W*n*CT = WYE), where *n* = 1, 2, 3, 12 based on the VIWDG setting
	RMS			
		RMS Screen 1	IAW1RMS, IBW1RMS, ICW1RMS, INRMS (if available), IAW2RMS, IBW2RMS, ICW2RMS	Always available INRMS is shown when the firmware option is 21 or 2E
		RMS Screen 2	IAW3RMS, IBW3RMS, ICW3RMS, IAW4RMS, IBW4RMS, ICW4RMS	Shown when the firmware option is 4X
		RMS Screen 3	IAW3RMS, IBW3RMS, ICW3RMS, INRMS, VARMS, VBRMS, VCRMS	Shown when the firmware option is 3E and DELTA_Y = WYE
		RMS Screen 4	IAW3RMS, IBW3RMS, ICW3RMS, INRMS, VABRMS, VBCRMS, VCARMS	Shown when the firmware option is 3E and DELTA_Y = DELTA
		RMS Screen 5	IAW3RMS, IBW3RMS, ICW3RMS, VARMS, VBRMS, VCRMS, VSRMS (if available)	Shown when the firmware option is 3S and DELTA_Y = WYE VSRMS is shown when VS_VBAT = VS
		RMS Screen 6	IAW3RMS, IBW3RMS, ICW3RMS, VABRMS, VBCRMS, VCARMS, VSRMS (if available)	Shown when the firmware option is 3S and DELTA_Y = DELTA VSRMS is shown when VS_VBAT = VS
		RMS Screen 7	VARMS, VBRMS, VCRMS	Shown when the firmware option is 2E and DELTA_Y = WYE
		RMS Screen 8	VABRMS, VBCRMS, VCARMS	Shown when the firmware option is 2E and DELTA_Y = DELTA

Table 8.17 Screens Available for the Rotating Display, HOME Pushbutton[a], and Programmable Pushbuttons (Sheet 7 of 12)

Home Screen Folders and Applications	Folder and Application Names	Display Name	Quantities	Comments
	Max/Min			
		Max/Min Screen 1	IAW1MX, IAW1MN, IBW1MX, IBW1MN, ICW1MX, ICW1MN, IGW1MX, IGW1MN, IAW2MX, IAW2MN, IBW2MX, IBW2MN, ICW2MX, ICW2MN, IGW2MX, IGW2MN, IAW3MX, IAW3MN, IBW3MX, IBW3MN, ICW3MX, ICW3MN, IGW3MX, IGW3MN, IAW4MX, IAW4MN, IBW4MX, IBW4MN, ICW4MX, ICW4MN, IGW4MX, IGW4MN, INMX, INMN, VABMX, VABMN, VBCMX, VBCMN, VCAMX, VCAMN, VAMX, VAMN, VBMX, VBMN, VCMX, VCMN, KVA3PMX, KVA3PMN, KW3PMX, KW3PMN, KVAR3PMX, KVAR3PMN, FREQMX, FREQMN, RTD1MX–RTD12MX, RTD1MN–RTD12MN, AI301MX–AI304MX, AI301MN–AI304MN, AI401MX–AI404MX, AI401MN–AI404MN, AI501MX–AI504MX, AI501MN–AI504MN, MM_LRD	Winding currents, voltages, RTD, and analog inputs quantities are part number dependent
		Max/Min Reset Screen	Reset max/min data	Always available
	Energy			
		Energy Screen 1	MWHP, MWHN, MVARHP, MVARHN, EM_LRD	Available if the relay supports voltages
		Energy Reset Screen	Reset energy data	
	Differential			
		Differential Screen 1	IOP1, IOP2, IOP3, IOPQ, IRT1, IRT2, IRT3, IRTQ, IOP1F2, IOP2F2, IOP3F2, IOP1F4, IOP2F4, IOP3F4, IOP1F5, IOP2F5, IOP3F5	Always available

Table 8.17 Screens Available for the Rotating Display, HOME Pushbutton[a], and Programmable Pushbuttons (Sheet 8 of 12)

Home Screen Folders and Applications	Folder and Application Names	Display Name	Quantities	Comments
	Harmonic			
		Harmonic Screen 1	IAW*n*_MAG, IBW*n*_MAG, ICW*n*_MAG, IN_MAG, VA_MAG, VB_MAG, VC_MAG, VAB_MAG, VBC_MAG, VCA_MAG [FUND, 2ND, 3RD, 4TH, 5TH], IAW*n*_THD, IBW*n*_THD, ICW*n*_THD, IN_THD, VA_THD, VB_THD, VC_THD, VAB_THD, VBC_THD, VCA_THD; where *n* = 1, 2, 3 or 4	Always available
	Demand			
		Demand Screen 1	IAD, IBD, ICD, IGD, 3I2D, DM_LRD	Shown when EDEM ≠ OFF
		Demand Reset Screen	Reset demand data	Always available
	Peak Demand			
		Peak Demand Screen 1	IAPD, IBPD, ICPD, IGPD, 3I2PD, PM_LRD	Shown when EDEM ≠ OFF
		Peak Demand Reset Screen	Reset peak demand data	Always available
	Analog Inputs			
		Analog Inputs Screen 1	AI301–AI304, AI401–AI404, AI501–AI504	Available if the relay supports analog inputs
	Thermal			
		Thermal Screen 1	RTDAMB, RTDOTHMX	Shown when E49RTD ≠ NONE
		Thermal Screen 2	RTD1– RTD12	Shown when E49RTD ≠ NONE
	Math Variables			
		Math Variables Screen 1	MV01–MV32	Shown when EMV ≠ N Shows 12 math variables per page
	Remote Analogs			
		Remote Analogs Screen 1	RA001–RA012	Always available
		Remote Analogs Screen 2	RA013–RA024	Always available
		Remote Analogs Screen 3	RA025–RA036	Always available
		Remote Analogs Screen 4	RA037–RA048	Always available
		Remote Analogs Screen 5	RA049–RA060	Always available
		Remote Analogs Screen 6	RA061–RA072	Always available

Table 8.17 Screens Available for the Rotating Display, HOME Pushbutton[a], and Programmable Pushbuttons (Sheet 9 of 12)

Home Screen Folders and Applications	Folder and Application Names	Display Name	Quantities	Comments
		Remote Analogs Screen 7	RA073–RA084	Always available
		Remote Analogs Screen 8	RA085–RA096	Always available
		Remote Analogs Screen 9	RA097–RA108	Always available
		Remote Analogs Screen 10	RA109–RA120	Always available
		Remote Analogs Screen 11	RA121–RA128	Always available
Monitor				
	Relay Word Bits			
		Relay Word Bits Screen 1	Shows status of all the relay word bits	Shows 32 Relay Word bits per page
	Digital Inputs			
		Digital Inputs Screen 1	IN101, IN102	Slot A inputs (always available)
		Digital Inputs Screen 2	IN301, IN302, IN303, IN304	Shown when Slot C = D*x*, 1*x*, or C*x*
		Digital Inputs Screen 3	IN301, IN302, IN303	Shown when Slot C = B*x*
		Digital Inputs Screen 4	IN301, IN302, IN303, IN304, IN305, IN306, IN307, IN308	Shown when Slot C = 3*x*
		Digital Inputs Screen 5	IN301, IN302, IN303, IN304, IN305, IN306, IN307, IN308, IN309, IN310, IN311, IN312, IN313, IN314	Shown when Slot C = 4*x*
		Digital Inputs Screen 6	IN401, IN402, IN403, IN404	Shown when Slot D = D*x*, 1*x*, or C*x*
		Digital Inputs Screen 7	IN401, IN402, IN403	Shown when Slot D = B*x*
		Digital Inputs Screen 8	IN401, IN402, IN403, IN404, IN405, IN406, IN407, IN408	Shown when Slot D = 3*x*
		Digital Inputs Screen 9	IN401, IN402, IN403, IN404, IN405, IN406, IN407, IN408, IN409, IN410, IN411, IN412, IN413, IN414	Shown when Slot D = 4*x*
		Digital Inputs Screen 10	IN501, IN502, IN503, IN504	Shown when Slot E = D*x*, 1*x*, or C*x*
		Digital Inputs Screen 11	IN501, IN502, IN503	Shown when Slot E = B*x*
		Digital Inputs Screen 12	IN501, IN502, IN503, IN504, IN505, IN506, IN507, IN508	Shown when Slot E = 3*x*
		Digital Inputs Screen 13	IN501, IN502, IN503, IN504, IN505, IN506, IN507, IN508, IN509, IN510, IN511, IN512, IN513, IN514	Shown when Slot E = 4*x*

Table 8.17 Screens Available for the Rotating Display, HOME Pushbutton[a], and Programmable Pushbuttons (Sheet 10 of 12)

Home Screen Folders and Applications	Folder and Application Names	Display Name	Quantities	Comments
	Digital Outputs			
		Digital Outputs Screen 1	OUT101, OUT102, OUT103	Slot A outputs (always available)
		Digital Outputs Screen 2	OUT301, OUT302, OUT303, OUT304	Shown when Slot C = B*x*, 1*x*, or C*x*
		Digital Outputs Screen 3	OUT301, OUT302, OUT303	Shown when Slot C = D*x*
		Digital Outputs Screen 4	OUT301, OUT302, OUT303, OUT304, OUT305, OUT306, OUT307, OUT308	Shown when Slot C = 2*x*
		Digital Outputs Screen 5	OUT401, OUT402, OUT403, OUT404	Shown when Slot D = B*x*, 1*x*, or C*x*
		Digital Outputs Screen 6	OUT401, OUT402, OUT403	Shown when Slot D = D*x*
		Digital Outputs Screen 7	OUT401, OUT402, OUT403, OUT404, OUT405, OUT406, OUT407, OUT408	Shown when Slot D = 2*x*
		Digital Outputs Screen 8	OUT501, OUT502, OUT503, OUT504	Shown when Slot E = B*x*, 1*x*, or C*x*
		Digital Outputs Screen 9	OUT501, OUT502, OUT503	Shown when Slot E = D*x*
		Digital Outputs Screen 10	OUT501, OUT502, OUT503, OUT504, OUT505, OUT506, OUT507, OUT508	Shown when Slot E = 2*x*
	SELogic Counters			
		SELogic Counters Screen 1	SC01–SC32	Shown when ESC ≠ N Shows 12 SELogic counters per page
	Breaker Wear			
		Breaker Wear Screen 1	INTTW1, EXTTW1, INTIAW1, INTIBW1, INTICW1, EXTIAW1, EXTIBW1, EXTICW1	Shown when EBMON1 = Y
		Breaker Wear Screen 2	WEARAW1, WEARBW1, WEARCW1, BR1_LRD	Shown when EBMON1 = Y
		Breaker Wear Screen 3	INTTW2, EXTTW2, INTIAW2, INTIBW2, INTICW2, EXTIAW2, EXTIBW2, and EXTICW2	Shown when EBMON2 = Y
		Breaker Wear Screen 4	WEARAW2, WEARBW2, WEARCW2, and BR2_LRD	Shown when EBMON2 = Y
		Breaker Wear Screen 5	INTTW3, EXTTW3, INTIAW3, INTIBW3, INTICW3, EXTIAW3, EXTIBW3, and EXTICW3	Shown when the firmware option is 3E, 3S, or 4X and EBMON3 = Y

Table 8.17 Screens Available for the Rotating Display, HOME Pushbutton[a], and Programmable Pushbuttons (Sheet 11 of 12)

Home Screen Folders and Applications	Folder and Application Names	Display Name	Quantities	Comments
		Breaker Wear Screen 6	WEARAW3, WEARBW3, WEARCW3, and BR3_LRD	Shown when the firmware option is 3E, 3S, or 4X and EBMON3 = Y
		Breaker Wear Screen 7	INTTW4, EXTTW4, INTIAW4, INTIBW4, INTICW4, EXTIAW4, EXTIBW4, and EXTICW4	Shown when the firmware option is 4X and EBMON4 = Y
		Breaker Wear Screen 8	WEARAW4, WEARBW4, WEARCW4, and BR4_LRD	Show when the firmware option is 4X and EBMON4 = Y
	Through Fault			
		Through Fault Screen 1		Shown when THFLTD ≠ N Shows all the through fault monitoring data in the relay
Reports				
	Events			
		Event History Screen 1		Shows the event records in the relay
	SER			
		SER Screen 1		Shows the Sequential Event Recorder (SERs) in the relay
Device Info				
	Status			
		Status Screen 1	Status, serial number, FID string, part number, SEL display, customer display, IEC 61850 CID	Always available
		Status Screen 2	CARD_C, CARD_D, CARD_E, CARD_Z, FPGA, GPSB, HMI, RAM, ROM, CR_RAM, NON_VOL, CLOCK, RTD, CID_FILE, +0.9V CHK (V), +1.2V CHK (V), +1.5V CHK (V), +1.8V CHK (V), +2.5V CHK (V), +3.3V CHK (V), +3.75V CHK (V), +5.0V CHK (V), –1.25V CHK (V), –5.0V CHK (V), BATT CHK (V)	Always available Diagnostic status for the relay cards and power supply rails

Table 8.17 Screens Available for the Rotating Display, HOME Pushbutton[a], and Programmable Pushbuttons (Sheet 12 of 12)

Home Screen Folders and Applications	Folder and Application Names	Display Name	Quantities	Comments
		Status Screen 3	DN_MAC_ID, ASA, DN_RATE, DN_STATUS	Shown if the DeviceNet option is available
		Status Screen 4	IAW1, IBW1, ICW1, IAW2, IBW2, ICW2, IAW3, IBW3, ICW3, IAW4, IBW4, ICW4, IN, VA, VB, VC, VS	DC offsets are part number dependent
	Configuration			
		Configuration Screen 1	Part number, Port F protocol, Port F baud rate, Port 1 IP address, Port 1 default router, MAC address (IP), MAC address (GOOSE), breaker control jumper, password bypass jumper, rated frequency, phase rotation, W*n* nominal phase CT rating, nominal neutral CT rating, W*n* phase CT connection, PT connection, date format	Some of the quantities are part number dependent and will be hidden if the part number does not support them
	Trip & Diag. Messages			
		Trip and Diagnostic Screen 1	Diagnostic failures, trip event types, and warnings	Always available

[a] In addition to the listed screens, the Home screen is available for the HOME pushbutton. By default, the HOME pushbutton is programmed to the Home screen.

Section 9
Bay Control

Overview

The SEL-787 Relay with the touchscreen display option provides you with the ability to design bay configuration screens to meet your system needs. The bay configuration can be displayed as a single-line diagram (SLD) on the touchscreen. You can create as many as five bay screens with four controllable breakers, as many as sixteen two-position disconnects, and as many as two three-position disconnects. ANSI and IEC symbols, along with analog and digital labels, are available for you to create detailed single-line diagrams of the bay to indicate the status of the breaker and disconnects, bus voltages, and power flow through the breaker. In addition to single-line diagrams, you can design the screens to show the status of various relay elements via Relay Word bits or to show analog quantities for commissioning or day-to-day operations. These screens can be designed with the help of ACSELERATOR Bay Screen Builder SEL-5036 Software in conjunction with ACSELERATOR QuickSet SEL-5030 Software. Note that the bay screen related settings can only be set via QuickSet (setting via an ASCII terminal is not supported).

This section covers all aspects of the SEL-787 relay bay control.

- *Circuit Breaker Symbol Settings and Status Logic on page 9.1*
- *Disconnect Control Settings on page 9.2*
- *Local/Remote Control on page 9.7*
- *Breaker/Disconnect Control Via Touchscreen on page 9.8*
- *Bay Screens Design Using QuickSet and Bay Screen Builder on page 9.10*
- *Bay Control Application Example on page 9.19*

Circuit Breaker Symbol Settings and Status Logic

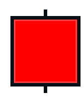
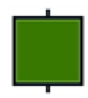
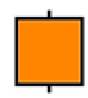
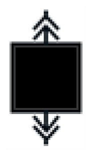
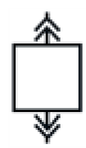
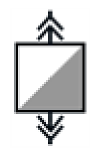
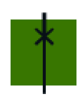
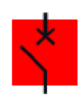
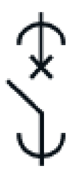
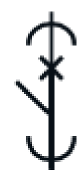
The SEL-787 supports four breakers that can be controlled and monitored via the bay screen. Use the SELOGIC control equation settings 52A*n* and 52B*n* (*n* = 1, 2, 3, or 4 for Breakers 52-1, 52-2, 52-3, and 52-4, respectively) to map the respective breaker auxiliary contacts to the relay. Because the 52B*n* contact is not always available in all applications, the breaker status logic does not include the 52B*n* contact. The relay uses the 52A*n* Relay Word bit as the status of the breaker in conjunction with the protection elements and trip and close logic. The default setting for 52B*n* is NOT 52A*n*. Map 52A*n* and 52B*n* Relay Word bits to the settings associated with the breaker symbol under the Bay Control settings in QuickSet to display the status of the breaker on the bay screen.

Use SELOGIC to create dual-point status of the breaker with breaker alarm indication. Refer to *Table 9.7* for the **Bay Control** breaker settings. Refer to *Bay Control Application Example on page 9.19* for example settings. Refer to *Table 4.40* and *52A and 52B Breaker Status Conditions SELOGIC Control*

Equations on page 4.103 for 52A*n* and 52B*n* settings and descriptions. Refer to *Trip/Close Logic on page 4.100* for more information on the breaker trip and close logic.

Table 9.1 provides typical ANSI and IEC breaker symbols that are supported by Bay Screen Builder. Column 1 identifies the standard (ANSI/IEC) and the type of breaker. Columns 3, 4, and 5 identify closed, open, and alarm states of the breaker image, respectively. Bay Screen Builder allows you to set the breaker color sequence property (identified in Column 2) for each of these states. Select the breaker color sequence based on your system convention. For a complete list of ANSI and IEC circuit breaker symbols available to use with the bay screens, refer to the *ACSELERATOR Bay Screen Builder SEL-5036 Software Instruction Manual*, available in the **Help > Contents** menu of Bay Screen Builder.

Table 9.1 Circuit Breaker Symbols

Type	Breaker Color Sequence	State 1 (Closed)	State 2 (Open)	State 3 (Alarm)
ANSI Breaker	Red, Green, Amber			
ANSI Truck Operated Breaker	Black, White, Grey			
IEC Breaker	Green, Red, Amber			
IEC Truck Operated Breaker	Transparent			

Disconnect Control Settings

The SEL-787 supports control of as many as sixteen two-position and two three-position disconnects. Refer to *Table 9.2* and *Table 9.3* for the two- and three-position disconnect settings. The following description applies to both the two- and three-position disconnects enabled by the 89EN2P and 89EN3P settings, respectively. Generic setting names are used in the following description. For example, the label setting for two-position Disconnect 1 (89NM2P1) is represented by 89NM*km*, where *k* is the disconnect type (*k* = 2P, 3PL, or 3PE) and *m* is the disconnect number (*m* = 1–16 if *k* = 2P and *m* = 1–2 if *k* = 3PL or 3PE).

Use the 89NM*km* setting and a maximum of 16 characters to name the disconnect. The 89A*km* and 89B*km* SELOGIC control equation settings represent the normally open and normally closed disconnect auxiliary contacts. Typically, these SELOGIC control equation settings are set to SEL-787 inputs that are wired to the corresponding auxiliary contacts. *Figure 9.1* shows the dual-point disconnect status logic. Relay Word bits 89CL*km* and 89OP*km* indicate whether the disconnect is in a fully closed or fully opened state, respectively. The alarm bit 89AL*km* indicates the alarm status of the disconnect and asserts when the disconnect is in an undetermined state for longer than the 89A*km*D time setting. The 89AL*km* alarm bit also asserts if the disconnect fails to start a close or open operation after a successful command is issued. Set the 89A*km*D timer to a value longer than the longest expected operation time (undetermined state).

Table 9.2 Two-Position Disconnect Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
EN 2P DISC	N, 1–16	89EN2P := 16
Disconnect m[a]		
2P DISC *m* NAME	16 characters	89NM2P*m* := 2P*m*
DIS *m* N/O CONT	SELOGIC	89A2P*m* := 0
DIS *m* N/C CONT	SELOGIC	89B2P*m* := NOT 89A2P*m*
DIS *m* ALM PU	0.00–300.00 sec	89A2P*m*D := 5.00
DIS *m* SEALIN	OFF, 0.00–300.00 sec	89S2P*m*D := 4.67
DIS *m* IMMOBI	OFF, 0.00–300.00 sec	89I2P*m*D := 0.33
DIS *m* CL CONT	SELOGIC	89RC2P*m* := 89CC2P*m*
DIS *m* CL BLK	SELOGIC	89CB2P*m* := 89AL2P*m*
DIS *m* CL RST	SELOGIC	89CR2P*m* := 89CL2P*m* OR 89CS2P*m* OR 89ALP2*m*
DIS *m* CL IM RS	SELOGIC	89CT2P*m* := NOT 89OP2P*m*
DIS *m* OP CONT	SELOGIC	89RO2P*m* := 89OCP*m*
DIS *m* OP BLK	SELOGIC	89OB2P*m* := 89AL2P*m*
DIS *m* OP RST	SELOGIC	89OR2P*m* := 89OP2P*m* OR 89OS2P*m* OR 89AL2P*m*
DIS *m* OP IM RS	SELOGIC	89OT2P*m* := NOT 89CL2P *m*

[a] The value of m can be set to any number between 1 and the value of setting 89EN2P.

Table 9.3 Three-Position Disconnect Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
EN 3P DISC	N, 1–2	89EN3P := N
Disconnect m[a]		
3P DISC *m* NAME	16 characters	89NM3P*m* := 3P*m*
In-Line Disconnect		
LDIS *m* N/O CONT	SELOGIC	89A3PL*m* := 0
LDIS *m* N/C CONT	SELOGIC	89B3PL*m* := NOT 89A3PL*m*
LDIS *m* ALM PU	0.00–300.00 sec	89A3PL*m*D := 5.00
LDIS *m* SEALIN	OFF, 0.00–300.00 sec	89S3PL*m*D := 4.67
LDIS *m* IMMOBI	OFF, 0.00–300.00 sec	89I3PL*m*D := 0.33
LDIS *m* CL CONT	SELOGIC	89RC3PL*m* := 89CC3PL*m*
LDIS *m* CL BLK	SELOGIC	89CB3PL*m* := 89CL3PE*m* OR 89AL3PL*m* OR 89 AL3PE*m*

Table 9.3 Three-Position Disconnect Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
LDIS *m* CL RST	SELOGIC	89CR3PL*m* := 89CL3PL*m* OR 89CS3PL*m* OR 89AL3PL*m*
LDIS *m* CL IM RS	SELOGIC	89CT3PL*m* := NOT 89OP3PL*m*
LDIS *m* OP CONT	SELOGIC	89RO3PL*m* := 89OC3PL*m*
LDIS *m* OP BLK	SELOGIC	89OB3PL*m* := 89CL3PE*m* OR 89AL3PL*m* OR 89AL3PE*m*
LDIS *m* OP RST	SELOGIC	89OR3PL*m* := 89OP3PL*m* OR 89OS3PL*m* OR 89AL3PL*m*
LDIS *m* OP IM RS	SELOGIC	89OT3PL*m* := NOT 89CL3PL*m*
Earthing Disconnect		
EDIS *m* N/O CONT	SELOGIC	89A3PE*m* := 0
EDIS *m* N/C CONT	SELOGIC	89B3PE*m* := NOT 89A3PE*m*
EDIS *m* ALM PU	0.00–300.00 sec	89A3PE*m*D := 5.00
EDIS *m* SEALIN	OFF, 0.00–300.00 sec	89S3PE*m*D := 4.67
EDIS *m* IMMOBI	OFF, 0.00–300.00 sec	89I3PE*m*D := 0.33
EDIS *m* CL CONT	SELOGIC	89RC3PE*m* := 89CC3PE*m*
EDIS *m* CL BLK	SELOGIC	89CB3PE*m* := 89CL3PL*m* OR 89AL3PL*m* OR 89AL3PE*m*
EDIS *m* CL RST	SELOGIC	89CR3PE*m* := 89CL3PE*m* OR 89CS3PE*m* OR 89AL3PE*m*
EDIS *m* CL IM RS	SELOGIC	89CT3PE*m* := NOT 89OP3PE*m*
EDIS *m* OP CONT	SELOGIC	89RO3PE*m* := 89OC3PE*m*
EDIS *m* OP BLK	SELOGIC	89OB3PE*m* := 89CL3PL*m* OR 89AL3PL*m* OR 89AL3PE*m*
EDIS *m* OP RST	SELOGIC	89OR3PE*m* := 89OP3PE*m* OR 89OS3PE*m* OR 89AL3PE*m*
EDIS *m* OP IM RS	SELOGIC	89OT3PE*m* := NOT 89CE3PL*m*

[a] The value of m can be set to any number between 1 and the value of setting 89EN3P.

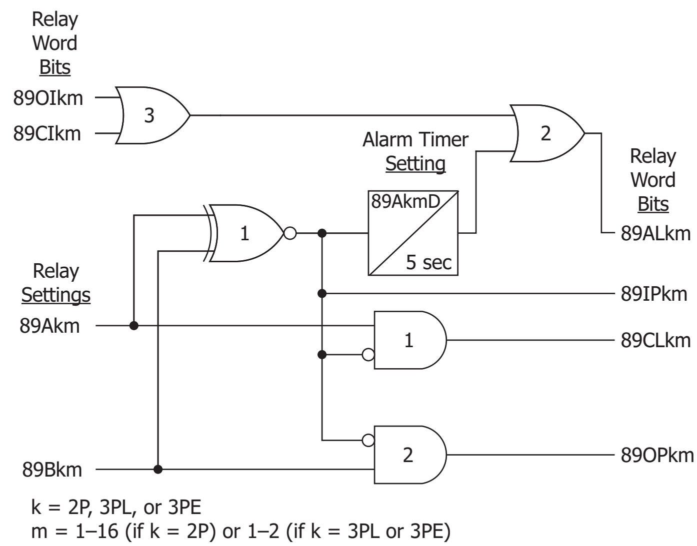


Figure 9.1 Dual-Point Disconnect Status Logic

The close and open logics shown in *Figure 9.2* and *Figure 9.3* are primarily for control of motor-operated disconnects. The settings and control described are not intended for manually operated disconnects and can be ignored. The description of close and open control logics apply to all two- and three-position motor-operated disconnects that are enabled.

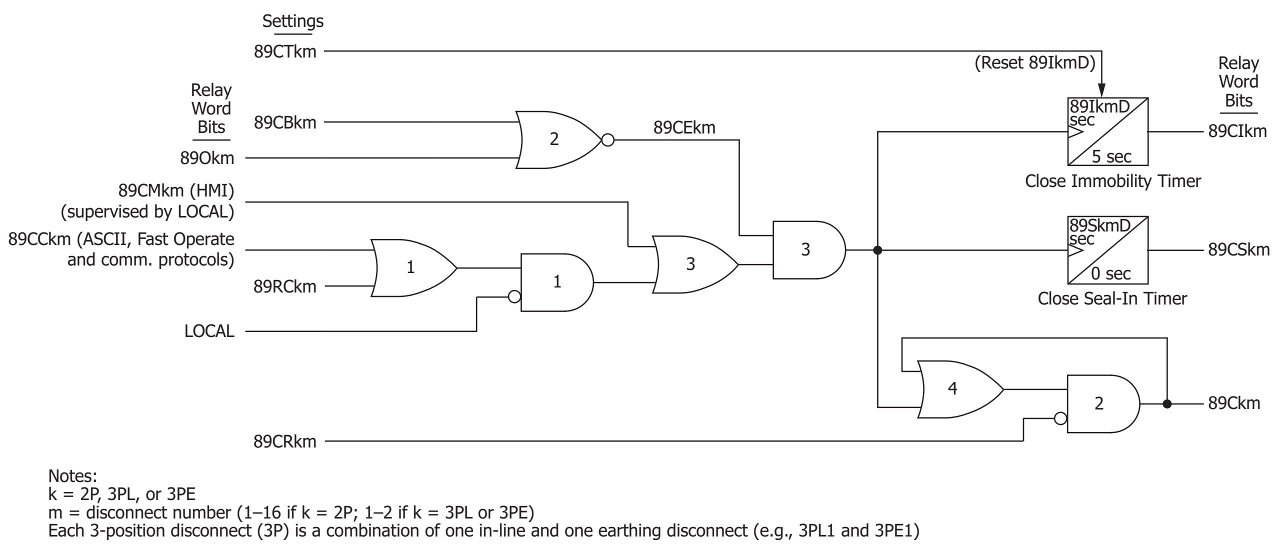
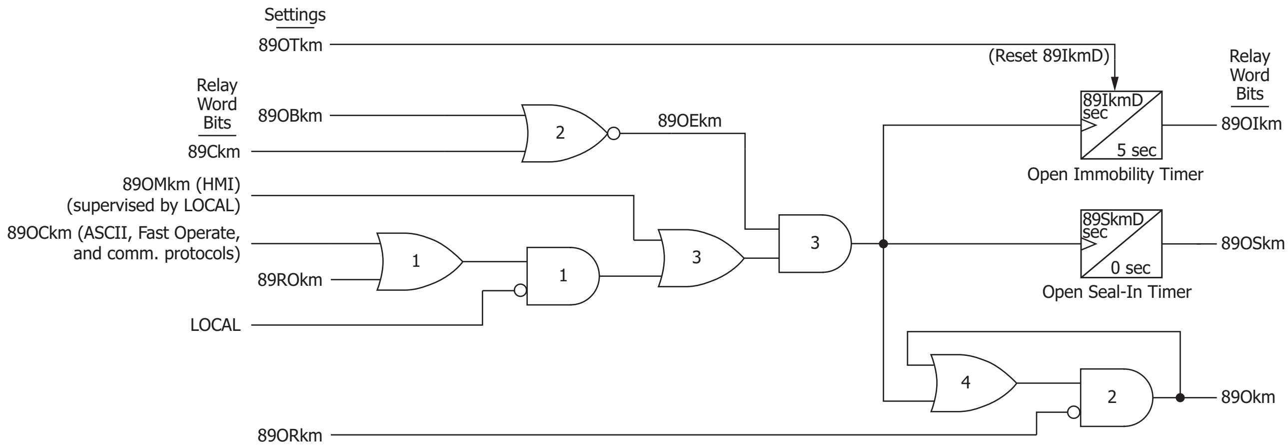


Figure 9.2 Disconnect Close Logic

Close control action of a disconnect can be initiated via the Bay Screens application on the touchscreen HMI (Relay Word bit 89CM*km*) or via remote means, including communications protocols (Relay Word bit 89CC*km*) or SELOGIC control equation settings (89RC*km*). Close control from the HMI requires that local control be enabled (Relay Word bit LOCAL asserted). When Relay Word bit LOCAL is asserted, remote close control is blocked. Use the 89CB*km* SELOGIC control equation settings to block both local and remote control, if required. The logic automatically seals in a successful close signal (Relay Word bit 89C*km*) until the user-defined reset Relay Word bit 89CR*km* asserts. By default, the relay uses the seal-in timer output to avoid a premature reset of the close signal. An immobility timer detects if the disconnect remains in the fully open position for longer than the 89I*km*D time setting after the close signal is issued (89C*km* asserts) by asserting Relay Word bit 89CI*km*.



Notes:
k = 2P, 3PL, or 3PE
m = disconnect number (1–16 if k = 2P; 1–2 if k = 3PL or 3PE)
Each 3-position disconnect (3P) is a combination of one in-line and one earthing disconnect (e.g., 3PL1 and 3PE1)

Figure 9.3 Disconnect Open Logic

Similarly, open control action of a disconnect can be initiated via the Bay Screens application on the touchscreen HMI (Relay Word bit 89OM*km*) or via remote means, including communications protocols (Relay Word bit 89OC*km*) or SELOGIC control equation settings (89RO*km*). Open control from the HMI requires that local control be enabled (Relay Word bit LOCAL asserted). When Relay Word bit LOCAL is asserted, remote close is blocked. Use the 89OB*km* SELOGIC control equation setting to block both local and remote control, if required. The logic automatically seals in a successful open signal (Relay Word bit 89O*km*) until the user-defined reset Relay Word bit 89OR*km* asserts. By default, the relay uses the seal-in timer output to avoid a premature reset of the open signal. An immobility timer detects if the disconnect remains in the fully closed position for longer than the 89I*km*D time setting after the open signal is issued (89O*km* asserts) by asserting Relay Word bit 89OI*km*.

Table 9.4 Disconnect Control Setting Guidelines

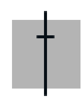
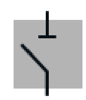
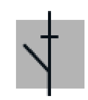
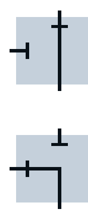
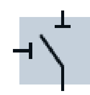
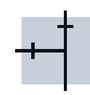
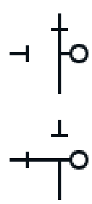
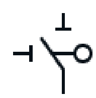
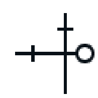
Setting	Remarks
89EN*k*	Enable required number of two- and three-position disconnects
89NM*km*	Label each disconnect with a unique name
89A*km*	SELOGIC control equation for normally open auxiliary contact of the disconnect
89B*km*	SELOGIC control equation for normally closed auxiliary contact of the disconnect
89A*km*D	Operate alarm delay; set longer than the highest expected operate time of the disconnect
89S*km*D	Seal-in delay; set longer than the highest expected operate time of the motor-operated disconnect

The factory-default values of all the other settings should be suitable for most applications; however, they must be reviewed and edited for specific requirements.

Refer to *Table 9.5* for the bay control disconnect settings. Refer to *Bay Control Application Example on page 9.19* for example settings.

Table 9.5 provides typical ANSI and IEC disconnect symbols that are available to use in bay screen design. Column 1 identifies the standard (ANSI/IEC) and the type of disconnect. Column 2 identifies the interior color property of the disconnect. Columns 3, 4, and 5 identify closed, open, and alarm states of the disconnect. For a complete list of ANSI and IEC disconnect symbols available to use with the bay screens, refer to the *ACSELERATOR Bay Screen Builder SEL-5036 Software Instruction Manual*.

Table 9.5 Two- and Three-Position Disconnect Symbols

Type	Interior Color	State 1 (Closed)	State 2 (Open)	State 3 (Alarm)
ANSI and IEC Disconnect (Two-Position)	Gray			
ANSI and IEC Motor-Operated Disconnect (Two-Position)	Transparent			
ANSI and IEC Disconnect (Three-Position)	Gray			
ANSI and IEC Motor-Operated Disconnect (Three-Position)	Transparent			

Local/Remote Control

The Local/Remote control function and associated settings are common and apply to breakers and disconnects. The SEL-787 supports the local/remote breaker control functionality through supervision of the OC*n* and CC*n* (*n* = 1, 2, 3, or 4) breaker control Relay Word bits and the local/remote disconnect control functionality through supervision of the disconnect open and close control logic (see *Figure 9.2* and *Figure 9.3*). The supervision can be enabled or disabled with Global setting EN_LRC (see *Table 9.6*). To enable local/remote supervision of the breakers and disconnects, set EN_LRC := Y. When EN_LRC := Y, the LOCAL SELOGIC control equation is available.

Table 9.6 Local/Remote Control Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE LOC REM CON	Y, N	EN_LRC := N
LOCAL CONTROL[a]	SELOGIC	LOCAL := 0

[a] This setting is hidden when EN_LRC := N.

The relay controls the status of the LOCAL Relay Word bit based on the EN_LRC setting.

- When EN_LRC := Y and LOCAL := 1, the relay processes the open and close commands from the front panel (two-line display or touchscreen). The commands from remote sources/protocols (ASCII terminal, SEL Fast Operate, DNP, Modbus, EtherNet/IP, IEC 61850, etc.) are blocked.
- When EN_LRC := Y and LOCAL := 0, the relay processes the open and close commands from remote sources/protocols (ASCII terminal, SEL Fast Operate, DNP, Modbus, EtherNet/IP, IEC 61850, etc.). The commands from the front panel are blocked (two-line display or touchscreen).
- When EN_LRC := N, the relay processes the open and close commands from both the front panel (two-line display or touchscreen) and remote sources/protocols (ASCII terminal, SEL Fast Operate, DNP, Modbus, EtherNet/IP, IEC 61850, etc.).

Enable local/remote control for proper supervision of breaker/disconnect control and operator safety. Map the LOCAL SELOGIC control equation to the status of the local/remote switch on the panel, if available. Alternatively, program one of the front-panel pushbuttons and an LED in conjunction with a SELOGIC latch to mimic the local/remote switch and map it to the LOCAL SELOGIC control equation.

When EN_LRC := Y, the status of local/remote control is indicated on the footer of the touchscreen as "L" for local (LOCAL = 1) and "R" for remote (LOCAL = 0). If you do not intend to use the built-in local/remote function, and prefer to create your own control function using SELOGIC and remote bits, set EN_LRC := N. When EN_LRC := N, "LR," as shown in *Figure 9.4*, indicates that OC*n* and CC*n* bits are processed from both the touchscreen and remote sources/protocols. Local/remote indication is only available on the SEL-787 touchscreen display model. Refer to *Bay Control Application Example on page 9.19* for example settings.

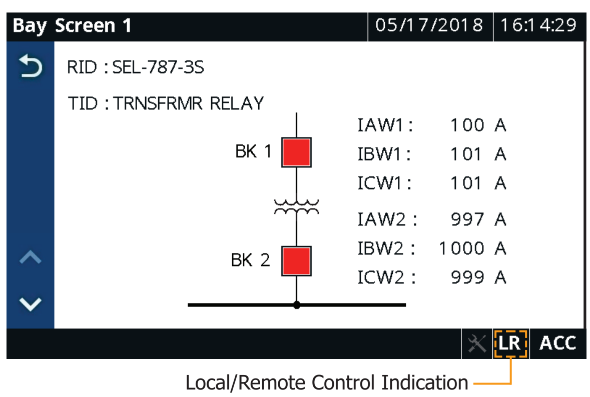


Figure 9.4 Local/Remote Control Mode Indication

Breaker/Disconnect Control Via Touchscreen

The SEL-787 enables you to control breakers from the touchscreen or the two-line LCD and the disconnects from the touchscreen. Breakers and disconnects can also be controlled through the front-panel operator control pushbuttons. Refer to *Front-Panel Operator Control Pushbuttons on page 8.16* for a discussion on breaker/disconnect control via the control pushbuttons. Refer to *Control Menu on page 8.10* for instructions on breaker control via the two-line LCD. This section discusses breaker and disconnect control via touchscreen.

The touchscreen allows you to control the breaker via two applications: Bay Screens and Breaker Control; however, only the Bay Screens application allows you to control the disconnects. The Bay Screens application is available on the Home screen. Breaker and disconnect control via the Bay Screens application requires you to design a bay control single-line diagram. *Figure 9.5* shows a sample single-line diagram with two controllable breakers and analog quantities. For details on how to design a bay screen, refer to *Bay Control Application Example*.

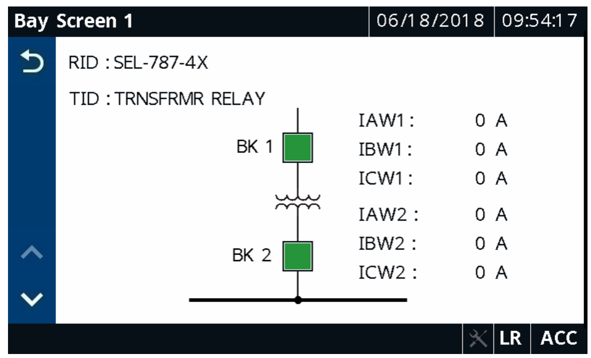


Figure 9.5 Bay Screens Application Display With a Single-Line Diagram

You can also control the breaker via the Breaker Control application, which is available in the Control folder. This application is built-in and is always available for you to perform breaker control. *Figure 9.6* shows the Breaker Control application display.

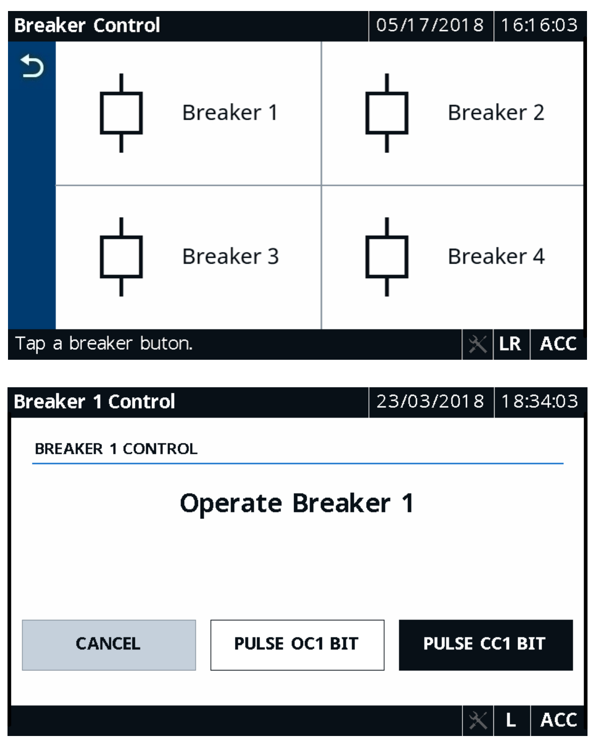


Figure 9.6 Breaker Control Application

The Bay Screens and Breaker Control applications use the OC*n* and CC*n* bits and require you to program the OC*n* and CC*n* bits into their respective trip (TR*n*) and close (CL*n*) SELOGIC control equations to perform breaker control. For details on how to program these bits, refer to *Bay Control Application Example*. Also, the Bay Screens application uses the 89OM*km* and 89CM*km* bits to perform disconnect control (see *Figure 9.2* and *Figure 9.3* for details). The relay checks for the following conditions, in the order shown, in both applications. Only when the conditions are satisfied can you perform breaker and/or disconnect control.

1. EN_LRC := Y and Relay Word bit LOCAL is asserted. If EN_LRC := N, then this check is ignored.

2. The breaker control jumper on the main board is installed. The Relay Word bit BKJMP stays asserted when the breaker control jumper is installed. Refer to *Password, Breaker Control, and SELBOOT Jumper Selection on page 2.26* for information on the breaker jumper.

3. You are at Access Level 2. The relay prompts for the Access Level 2 password if you are not at Access Level 2.

When the conditions are satisfied, the application pulses the OC*n* or CC*n* bit, respectively, depending on your selection for breaker open or close.

Bay Screens Design Using QuickSet and Bay Screen Builder

QuickSet and Bay Screen Builder provide user-friendly interfaces to set the touchscreen settings. The touchscreen settings are not available for setting via ASCII terminal, unlike the other relay settings. The touchscreen settings are only available if the relay part number is configured with the touchscreen display under the **Front-Panel Options** drop-down list as shown in *Figure 9.7*. *Figure 9.8* shows the **Touchscreen** settings in QuickSet.

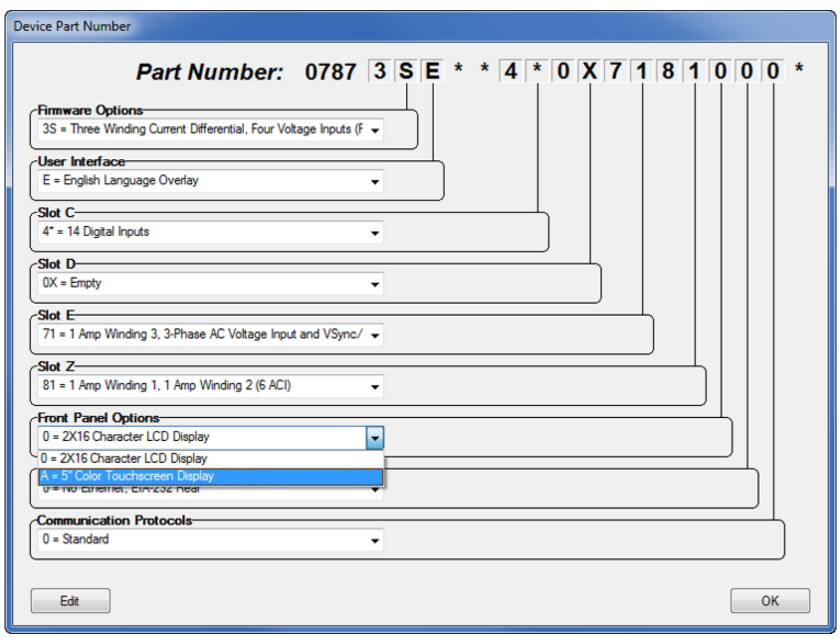


Figure 9.7 QuickSet Front-Panel Options

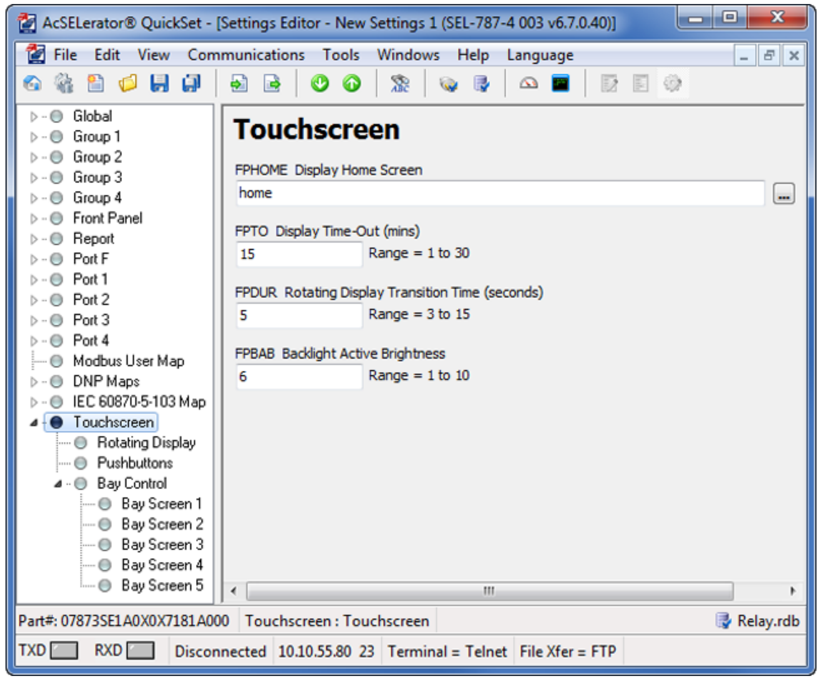


Figure 9.8 QuickSet Touchscreen Settings

Table 9.7 Touchscreen Settings (Sheet 1 of 3)

NOTE: The settings in Table 9.7 are populated under each of the custom screens (sld1–sld5) based on the dynamic symbols you choose.

Setting Prompt	Setting Range	Setting Name := Factory Default
Display Settings		
Display Home Screen	See *Table 8.17*	FPHOME := HOME
Display Time-Out	1–30 min	FPTO := 15
Rotating Display Transition Time	3–15 sec	FPDUR := 5
Backlight Active Brightness	1–10	FPBAB := 6
Rotating Display Screen Settings		
Rotating Display 01	See *Table 8.17*	FPRD01 := Bay Screen 1
Rotating Display 02	See *Table 8.17*	FPRD02 :=
• • •	• • •	• • •
Rotating Display 15	See *Table 8.17*	FPRD15 :=
Rotating Display 16	See *Table 8.17*	FPRD16 :=
Pushbutton Settings (nn = 01–08)		
Pushbutton *nn* HMI Screen	OFF, See *Table 8.17*	FPPB*nn* := OFF
Bay Control Breaker Settings		
Breaker Trip Type	3	BK01TTY := 3
Breaker Mode	CONTROL, MONITOR	BK01MOD := MONITOR
Breaker 1 Close Status	Relay Word Bit	BK01CS := 52A1

Table 9.7 Touchscreen Settings (Sheet 2 of 3)

Setting Prompt	Setting Range	Setting Name := Factory Default
Breaker 1 Open Status	Relay Word Bit	BK01OS := 52B1
Breaker 1 Alarm Status	Relay Word Bit	BK01AS := NA
Breaker 1 HMI Close Command	Relay Word Bit	BK01CLC := NA
Breaker 1 HMI Open Command	Relay Word Bit	BK01OPC := NA
Breaker 2 Close Status	Relay Word Bit	BK02CS := 52A2
Breaker 2 Open Status	Relay Word Bit	BK02OS := 52B2
Breaker 2 Alarm Status	Relay Word Bit	BK02AS := NA
Breaker 2 HMI Close Command	Relay Word Bit	BK02CLC := NA
Breaker 2 HMI Open Command	Relay Word Bit	BK02OPC := NA
Breaker 3 Close Status	Relay Word Bit	BK03CS := 52A3
Breaker 3 Open Status	Relay Word Bit	BK03OS := 52B3
Breaker 3 Alarm Status	Relay Word Bit	BK03AS := NA
Breaker 3 HMI Close Command	Relay Word Bit	BK03CLC := NA
Breaker 3 HMI Open Command	Relay Word Bit	BK03OPC := NA
Breaker 4 Close Status	Relay Word Bit	BK04CS := 52A4
Breaker 4 Open Status	Relay Word Bit	BK04OS := 52B4
Breaker 4 Alarm Status	Relay Word Bit	BK04AS := NA
Breaker 4 HMI Close Command	Relay Word Bit	BK04CLC := NA
Breaker 4 HMI Open Command	Relay Word Bit	BK04OPC := NA
Bay Control Two-Position Disconnect Settings (m = 1–16)		
Two-Position Disconnect Close Status	Relay Word bit	2DS*m*CS :=
Two-Position Disconnect Open Status	Relay Word Bit	2DS*m*OS :=
Two-Position Disconnect In-Progress Status	Relay Word Bit	2DS*m*IS := NA
Two-Position Disconnect Alarm Status	Relay Word Bit	2DS*m*AS := NA
Two-Position Disconnect HMI Close Command	89CM2P1–89CM2P16	2DS*m*CL := NA
Two-Position Disconnect HMI Open Command	89OM2P1–89OM2P16	2DS*m*OP := NA
Bay Control Three-Position Disconnect Settings (m = 1–2)		
Three-Position In-Line Disconnect Close Status	Relay Word bit	3ID*m*CS :=
Three-Position In-Line Disconnect Open Status	Relay Word Bit	3ID*m*OS :=

Table 9.7 Touchscreen Settings (Sheet 3 of 3)

Setting Prompt	Setting Range	Setting Name := Factory Default
Three-Position In-Line Disconnect In-Progress Status	Relay Word Bit	3ID*m*IS := NA
Three-Position In-Line Disconnect Alarm Status	Relay Word Bit	3ID*m*AS := NA
Three-Position In-Line Disconnect HMI Close Command	89CM3PL1–89CM3PL2	3ID*m*CL := NA
Three-Position In-Line Disconnect HMI Open Command	89OM3PL1–89OM3PL2	3ID*m*OP := NA
Three-Position Earthing Disconnect Close Status	Relay Word Bit	3ED*m*CS :=
Three-Position Earthing Disconnect Open Status	Relay Word Bit	3ED*m*OS :=
Three-Position Earthing Disconnect In-Progress Status	Relay Word Bit	3ED*m*IS := NA
Three-Position Earthing Disconnect Alarm Status	Relay Word Bit	3ED*m*AS := NA
Three-Position Earthing Disconnect HMI Close Command	89CM3PE1–89CM3PE2	3ED*m*CL := NA
Three-Position Earthing Disconnect HMI Open Command	89OM3PE1–89OM3PE2	3ED*m*OP := NA
Bay Control Analog Label Settings (qq = 01–32)		
Analog Quantity	Analog Quantity	ALAB01 := STRING_RID
Analog Quantity	Analog Quantity	ALAB02 := STRING_TID
Analog Quantity	Analog Quantity	ALAB03 := IAW1_MAG
Analog Quantity	Analog Quantity	ALAB04 := IBW1_MAG
Analog Quantity	Analog Quantity	ALAB05 := ICW1_MAG
Analog Quantity	Analog Quantity	ALAB06 := IAW2_MAG
Analog Quantity	Analog Quantity	ALAB07 := IBW2_MAG
Analog Quantity	Analog Quantity	ALAB08 := ICW2_MAG
Analog Quantity	Analog Quantity	ALAB*qq* :=
Bay Control Digital Label Settings (qq = 01–32)		
Relay Word Bit	Relay Word Bit Name	DLAB*qq* :=

Display Settings

Use these settings to configure the touchscreen. The selection of the **HOME** pushbutton on the front panel takes you to the screen configured as part of the FPHOME setting. By default, FPHOME is set to the Home screen, which displays the Home screen folders and applications. You can set FPHOME to any screen that you like to view when the **HOME** pushbutton is pressed (see *Table 8.17* for the list of available screens).

To help prevent unauthorized access to password-protected functions, the SEL-787 provides a front-panel timeout setting, FPTO. The timeout resets each time you press a front-panel pushbutton or the screen detects a touch. When the timeout expires, the access level resets to Access Level 1 and switches to the rotating display if at least one screen is configured as part of the rotating display settings, FPRD*kk* (*kk* = 01–16), if not, the display switches to the Home screen. The rotating display transition time setting FPDUR defines the duration that each screen is displayed on the rotating display. Set FPDUR to a transition time most suitable to your application.

Use the FPBAB setting to control the backlight active brightness.

Rotating Display Settings

The SEL-787 allows you to configure as many as 16 screens for the rotating display. Configure the settings FPRD*kk* (*kk* = 01–16) to the screens most suitable to your application. Refer to *Table 8.17* for the list of screens available as part of the FPRD*kk* settings.

Pushbutton Settings

The pushbutton settings FPPB*nn* (*nn* = 01–08) allow you to quickly navigate to a specific screen by pressing the programmed pushbutton. Refer to *Table 8.17* for the list of screens available for the FPPB*nn* settings. Note that a given pushbutton can be configured to navigate to a specific screen but can also be used in SELOGIC (e.g., PB08 Relay Word bit). The relay does not prevent you from configuring a pushbutton for two purposes. Make sure to set dual-purpose pushbuttons with care to ensure safe operation.

Bay Control Breaker Settings

Bay control breaker settings are only available if the designed single-line diagram has a breaker symbol. When QuickSet detects a breaker symbol as part of the single-line diagram, it populates the corresponding settings. The SEL-787 supports four three-pole breakers. The setting BK*nn*TTY (*nn* = 01, 02, 03, or 04) is forced to 03 by default and is not settable. The breaker on the single-line can be configured as monitor-only or controllable. Set BK*nn*MOD = MONITOR if you do not want to allow breaker control via the touchscreen. Set BK*nn*MOD = CONTROL if you want to allow breaker control via the touchscreen. Set BK*nn*CS and BK*nn*OS settings to the corresponding Relay Word bits that indicate the close and open status of the breaker. The relay does not support breaker alarm logic, but it can be programmed using SELOGIC. To display breaker alarm status, set the breaker alarm status setting BK*nn*AS to the corresponding SELOGIC bit. When BK*nn*MOD := CONTROL, set BK*nn*CLC and BK*nn*OPC settings to the corresponding CC*n* and OC*n* Relay Word bits. It is possible that the designation of the breaker in the relay is different from the breaker on your system. Exercise caution in mapping the respective Relay Word bits 52A*n*, 52B*n*, CC*n*, and OC*n* per your system configuration to BK*nn*CS, BK*nn*OS, BK*nn*CLC, and BK*nn*OPC settings for control of corresponding breakers. Refer to *Bay Control Application Example on page 9.19* for sample breaker settings.

Bay Control Disconnect Settings

The bay control disconnect settings are only available if the designed single-line diagram has at least one disconnect symbol. When QuickSet detects one or more disconnect symbols as part of the single-line diagram, it populates the corresponding settings. The SEL-787 supports sixteen two-position and two three-position disconnects. Set the DS*n*CS and DS*n*OS settings to the corresponding Relay Word bits that indicate the closed and open status of the disconnect. Map the output of the disconnect alarm logic, 89AL*km* (see *Figure 9.1*), to the corresponding DS*n*AS setting. A successful close or open command from the HMI asserts the corresponding 89CM*km* or 89OM*km* Relay Word bit used in *Figure 9.2* and *Figure 9.3*, respectively. Refer to *Bay Control Application Example on page 9.19* for example disconnect settings.

Bay Control Analog Label Settings

The analog label settings are only available if the designed bay screen has at least one analog label. When QuickSet detects one or more analog labels as part of the bay screen, it populates the corresponding settings. The SEL-787 supports as many as 32 analog labels. Set ALAB*qq* (*qq* = 01–32) to display the desired analog quantity on the bay screen. Refer to the display points column of *Table M.1* for the list of analog quantities available to program into analog labels.

Bay Control Digital Label Settings

The digital label settings are only available if the designed bay screen has at least one digital label. When QuickSet detects one or more digital labels as part of the bay screen, it populates the corresponding settings. The SEL-787 supports as many as 32 digital labels. Set DLAB*qq* (*qq* = 01–32) to display the desired Relay Word bits on the bay screen. Refer to *Table L.1* for the list of Relay Word bits available to program into digital labels.

Bay Screen Builder Software

NOTE: Refer to the Product Literature CD for a list of UTF-8 characters that can be rendered on the bay screen in Bay Screen Builder.

The Bay Screen Builder Software provides an intuitive and powerful interface to design bay screens to meet your application needs. This instruction manual provides only a brief overview of the Bay Screen Builder Software. For more details, refer to the *ACSELERATOR Bay Screen Builder SEL-5036 Software Instruction Manual* available from the **Help** > **Contents** menu in Bay Screen Builder or at selinc.com.

Several of the settings identified in *Table 9.7* are available for you to set depending on the symbols chosen for your single-line diagram. *Figure 9.9* shows the layout of Bay Screen Builder and identifies different menus, panes, and information.

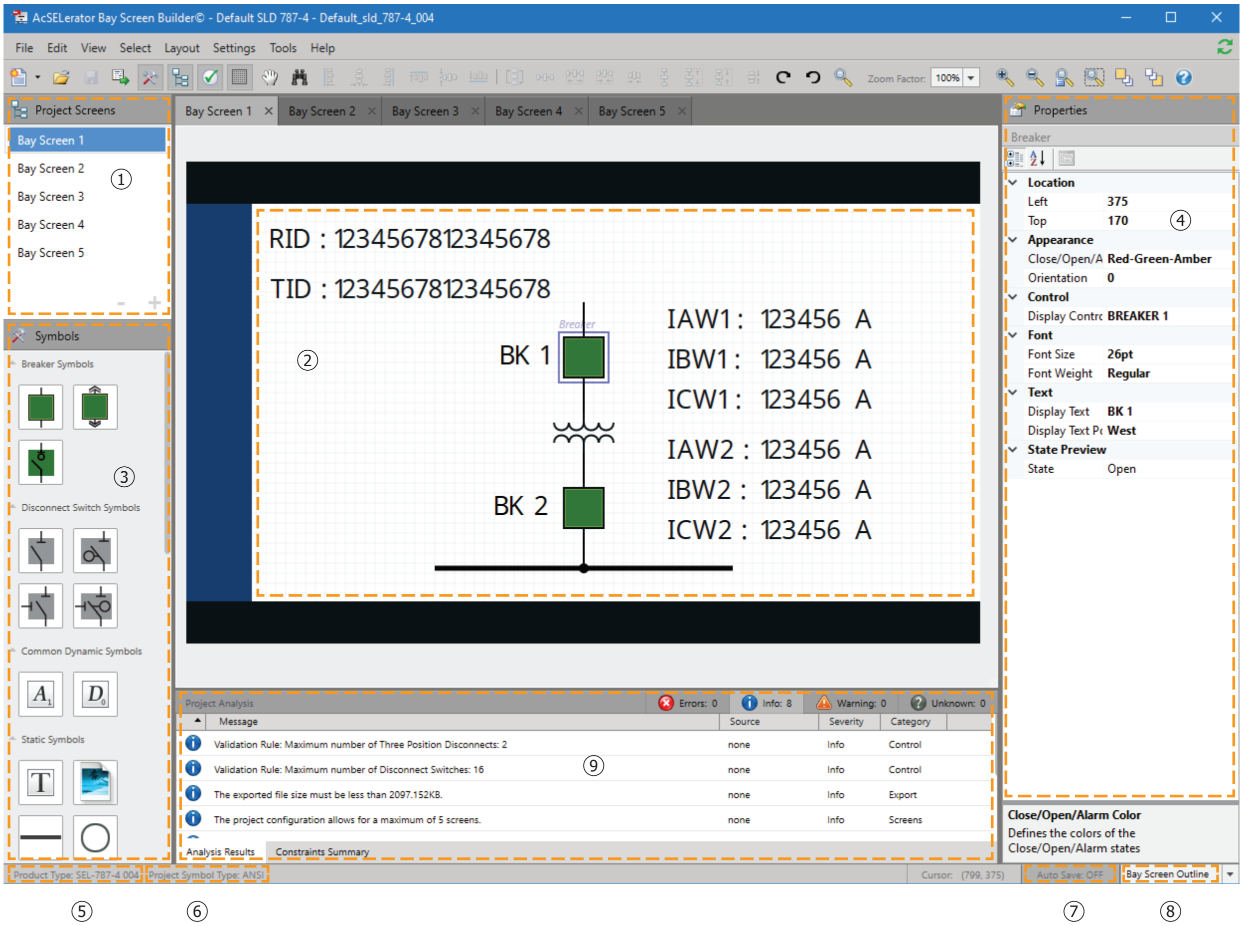


Figure 9.9 Layout of Bay Screen Builder

Descriptions of the different menus, panes, and information in Bay Screen Builder are as follows:

① **Project Screens Pane:** Displays the names of the screens (as many as five) present in a project. Click a screen name to open the screen, and double-click or right-click a screen name to access additional options for that screen.

② **Screen Area:** Displays the selected project screen and its symbols. Create a single-line diagram or a metering or status screen by dragging and dropping symbols from the **Symbols** pane.

③ **Symbols Pane:** Displays the symbols available for selection. Bay Screen Builder supports several static and a limited number of dynamic ANSI and IEC symbols. Note that for a given project, you can only use either ANSI *or* IEC symbols, not both. While there are no constraints on the number of static symbols, Bay Screen Builder limits the number of dynamic symbols. The following table provides the number of breakers, disconnects, analog labels, and digital labels supported in a given project.

Symbols	Number of Supported Symbols per Project
Breakers	4
Two-Position Disconnects	16
Three-Position Disconnects	2
Analog Labels	32
Digital Labels	32

④ **Properties Pane:** Displays the properties of a selected symbol. Edit the symbol properties as needed for your application. For instance, the breaker color sequence property identified in *Table 9.1* can be set via the appearance property of the breaker symbol (refer to *Edit Symbol Properties on page 9.23*). Bay Screen Builder supports UTF-8 character encoding. Refer to the Product Literature CD for a complete list of UTF-8 characters that can be rendered on the touchscreen display.

⑤ **Product Type:** Displays the name of the QuickSet driver version of the product associated with the selected project (e.g., SEL-787-4 003, as shown in *Figure 9.9*). Select the product type in Bay Screen Builder when you create a new project independent of QuickSet. View **Product Type** though **Settings** > **Project Settings**. If a project is edited via QuickSet, Bay Screen Builder inherits the product type from the QuickSet settings file.

⑥ **Project Symbol Type:** Displays the symbol type (IEC or ANSI) associated with the selected project as shown in *Figure 9.9*. Select the symbol type when you create a new project. If a project is edited via QuickSet, the ANSI symbol type is selected by default.

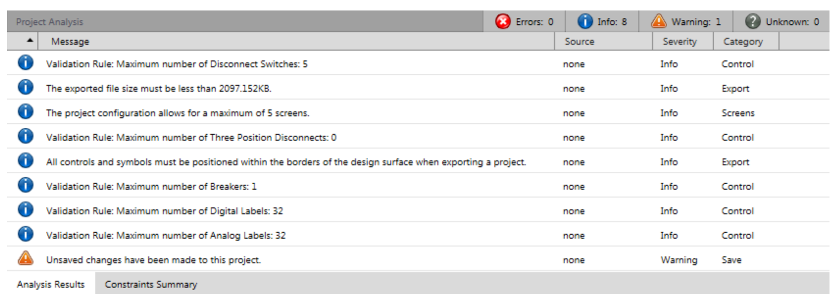
⑦ **Auto Save:** Provides a shortcut for changing the auto save setting for the application. Enable **Auto Save** to allow Bay Screen Builder to automatically save your project periodically. Your auto save setting preference is saved when you exit the application and is applied the next time you launch Bay Screen Builder. You can also set **Auto Save** through **Settings** > **Application Settings** > **File Handling**.

⑧ **Bay Screen Outline:** Displays the drop-down list of symbols on the presently open screen. Click a symbol from the list to make it active. The bay screen outline provides an alternate way to select the symbols and is most useful in cases where symbols are crowded or stacked.

⑨ **Project Analysis Pane:** Displays troubleshooting information/ messages about the project (Errors, Info, Warning, Unknown). The project analysis pane supports two tabs: Analysis Results and Constraints Summary.

The Analysis Results tab displays details about the error, information, warning, and unknown messages for the project (see *Figure 9.10*). You can use these messages for troubleshooting. Select a message type button to view the messages for that category. For example, click the **Errors** button to view the error messages for the project. Click a column header to sort by the information in that column.

The Constraints Summary tab provides information about the rules that apply to the present project (see *Figure 9.11*). All conditions listed under Symbol Constraints must be satisfied for a project to be valid. You can only publish a valid project, but you can save a project with errors.



Message	Source	Severity	Category
Validation Rule: Maximum number of Disconnect Switches: 5	none	Info	Control
The exported file size must be less than 2097.152KB.	none	Info	Export
The project configuration allows for a maximum of 5 screens.	none	Info	Screens
Validation Rule: Maximum number of Three Position Disconnects: 0	none	Info	Control
All controls and symbols must be positioned within the borders of the design surface when exporting a project.	none	Info	Export
Validation Rule: Maximum number of Breakers: 1	none	Info	Control
Validation Rule: Maximum number of Digital Labels: 32	none	Info	Control
Validation Rule: Maximum number of Analog Labels: 32	none	Info	Control
Unsaved changes have been made to this project.	none	Warning	Save

Figure 9.10 Project Analysis Pane: Analysis Results Tab

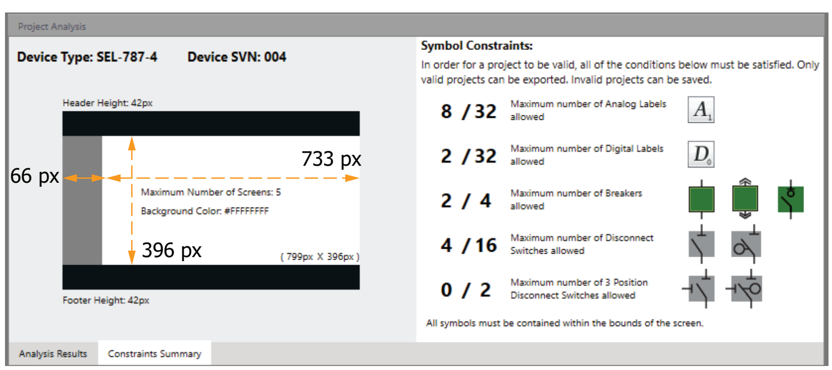


Figure 9.11 Project Analysis Pane: Constraints Summary Tab

NOTE: The Constraints Summary tab shows the usage and limits of dynamic symbols for an entire project (all screens). Although not constrained, it is recommended that you limit the dynamic symbols to 32 symbols per screen for faster screen updates.

You can adjust the size of the panes in the application. If you reconfigure the size of any of these panes, the new size is saved when you exit the application and applies the next time you launch Bay Screen Builder.

Bay Control Application Example

Specific components of bay screens are covered in *Bay Screens Design Using QuickSet and Bay Screen Builder*. This section provides a summarized application example tying all the components together. Refer to the *ACSELERATOR Bay Screen Builder SEL-5036 Software Instruction Manual*, available from the **Help** > **Contents** menu in Bay Screen Builder or at selinc.com, for more specific details regarding bay screen creation and symbol properties.

The SEL-787 supports as many as five custom screens. You can edit the predefined bay screen (Bay Screen 1) and the blank screens (Bay Screen 2, Bay Screen 3, Bay Screen 4, Bay Screen 5) (see *Figure 9.14*). You can also import one of the five predefined bay control single-line diagrams from the instruction manual CD. Refer to *Predefined Bay Control Single-Line Diagrams on page 9.31* for more details.

Consider if you were to create the single-line diagram shown in *Figure 9.12* as part of your application. Use the following step-by-step approach to design the single-line diagram beginning with the predefined bay screen (Bay Screen 1).

Before creating your own diagram, ensure that the number of dynamic symbols in your schematic does not exceed the number allowed by the SEL-787 (see *Figure 9.9* and the symbols pane description).

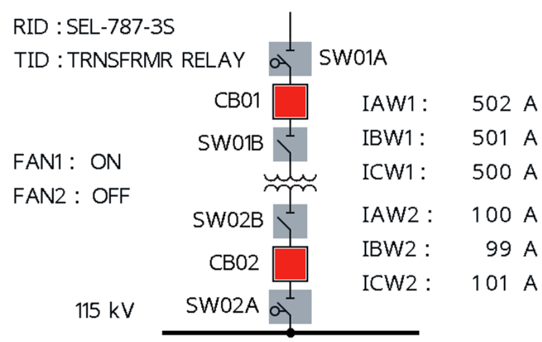


Figure 9.12 Bay Control Single-Line Diagram Schematic

Configure QuickSet for Bay Screen Builder

NOTE: The touchscreen display option is only available for SEL-787 QuickSet drivers 003 and higher.

To use QuickSet and Bay Screen Builder to create bay screens for the SEL-787, your relay must have the touchscreen MOT configuration (an "A" in the 18th place of the part number). When your relay is configured for the touchscreen option, perform the following steps to configure QuickSet to work with Bay Screen Builder.

Step 1. Create an SEL-787 settings file configured for the touchscreen display. Use the Front-Panel Options drop down to select the touchscreen option (see *Figure 9.13*).

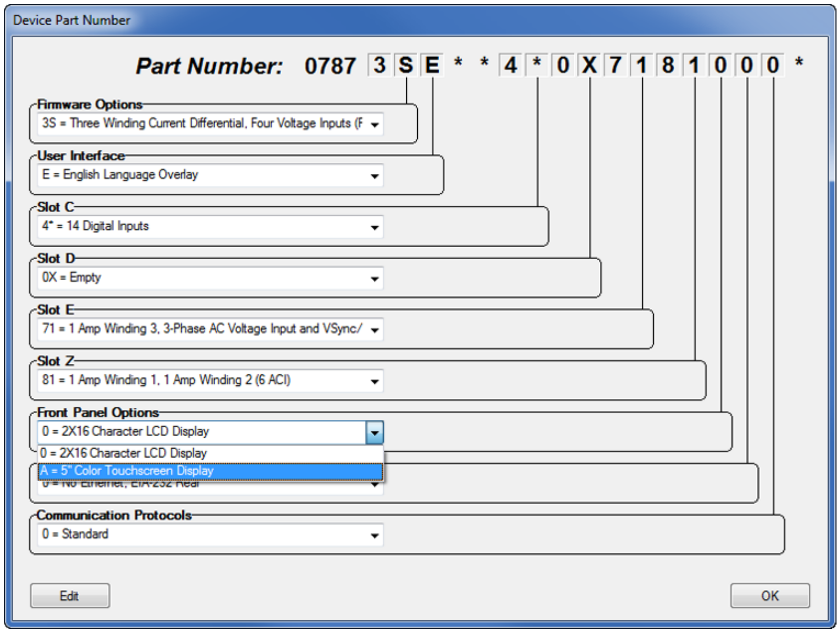


Figure 9.13 Device Part Number Touchscreen Configuration Option

Step 2. Click **OK**.

Step 3. Expand the Touchscreen settings class.

Step 4. Click **Bay Control**.

QuickSet displays project management buttons and a project preview that includes a small-scale view of five project screens (one screen with a predefined single-line diagram and four blank screens) and an enlarged view of the predefined single-line diagram, which is selected by default (see *Figure 9.14*).

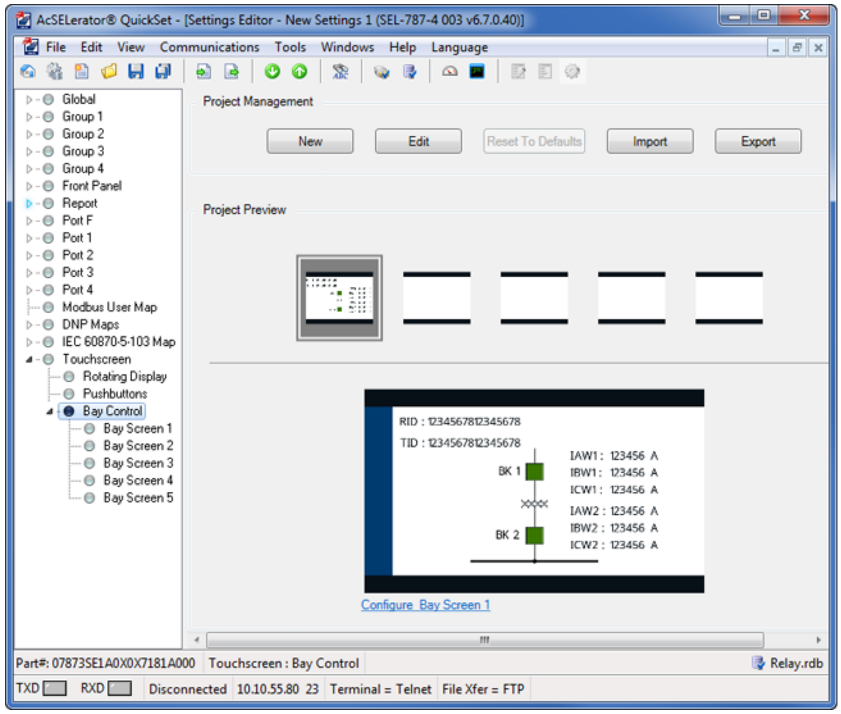


Figure 9.14 QuickSet Bay Control Project Management and Project Preview Display

Build Single-Line Diagrams in Bay Screen Builder

Use Bay Screen Builder to create single-line diagrams to load onto the SEL-787 Relay through QuickSet. To create the single-line diagram shown in *Figure 9.12*, perform the following steps.

Step 1. Select the screen with the predefined single-line diagram shown in *Figure 9.15* as a starting point for your single-line diagram.

Step 2. Click **Edit** (*Figure 9.15*) to open the screen with the predefined single-line diagram in Bay Screen Builder.

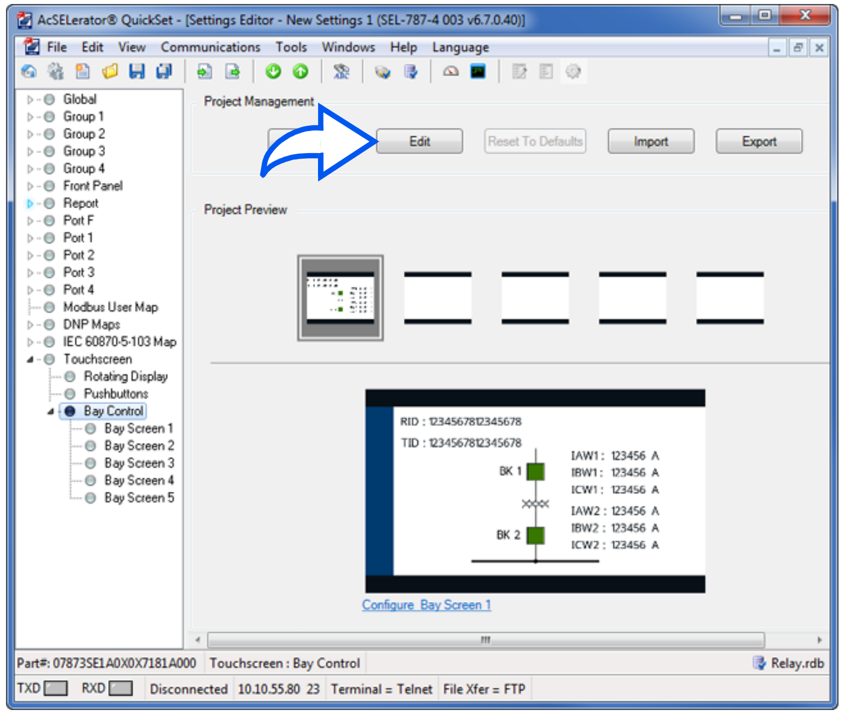


Figure 9.15 Open Single-Line Diagram in Bay Screen Builder

Step 3. Drag-and-drop the additional symbols required for your single-line diagram onto the screen area from the Symbols pane (see *Figure 9.16*).

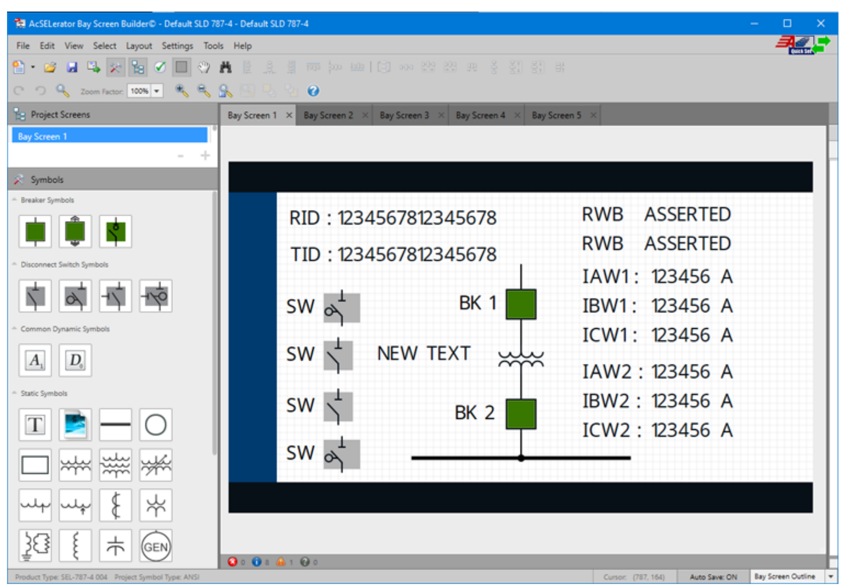
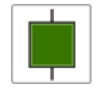
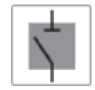
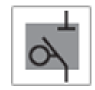
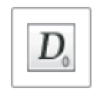
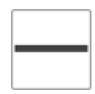


Figure 9.16 Drag-and-Drop Symbols

Table 9.8 lists the number of each symbol required to draw the single-line diagram shown in *Figure 9.12*.

Table 9.8 Symbols Required for the Single-Line Diagram Schematic in Figure 9.12

Symbols Required	Number of Symbols Required	Symbol
Breakers	2	
Two-position disconnects	2	
Two-position disconnects (motor-operated)	2	
Analog labels (display voltages, currents, and power)	6	
Digital label (display breaker SF6 gas pressure OK or LOW)	2	
Text boxes (identify the relay, feeder name, nominal bus voltage)	1	
Line (draw the bus and connections)	As Needed	

Edit Symbol Properties

All of the symbols in Bay Screen Builder include editable properties. These properties allow you to customize the symbols to your specific application. These properties appear in the right Properties pane of Bay Screen Builder either when you drag a symbol from the left Symbols pane and drop it in the screen area or when a symbol in the screen area is selected.

For example, you can use the Close/Open/Alarm Color property in the Appearance tab of the breaker properties to select a color scheme for your single-line diagram breaker.

Step 1. Select the existing breaker symbol in the predefined single-line diagram to display the breaker symbol properties in the Properties pane, as shown in *Figure 9.17*.

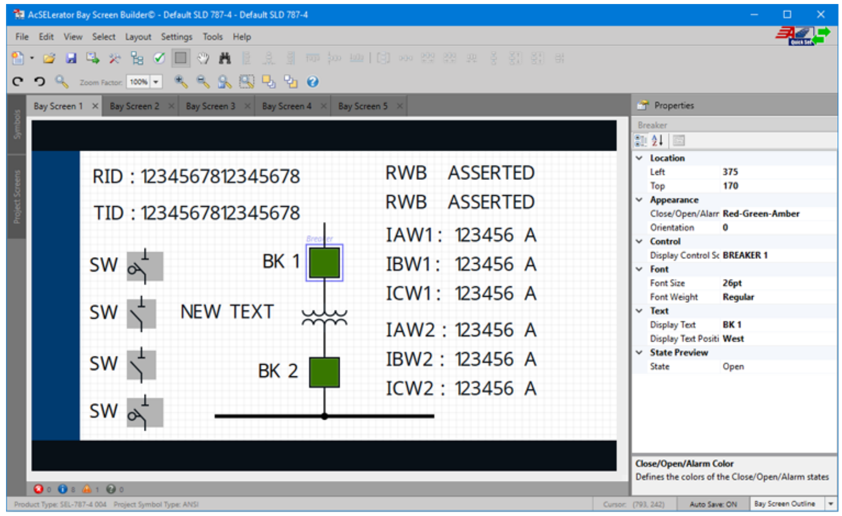


Figure 9.17 Selected Breaker Symbol Settings Displayed in the Properties Pane

Step 2. Select a color option from the drop down menu to edit the Close/Open/Alarm Color property in the Appearance tab (see *Figure 9.18*).

Table 9.1 lists the available options and breaker appearance in each state based on the selected property.

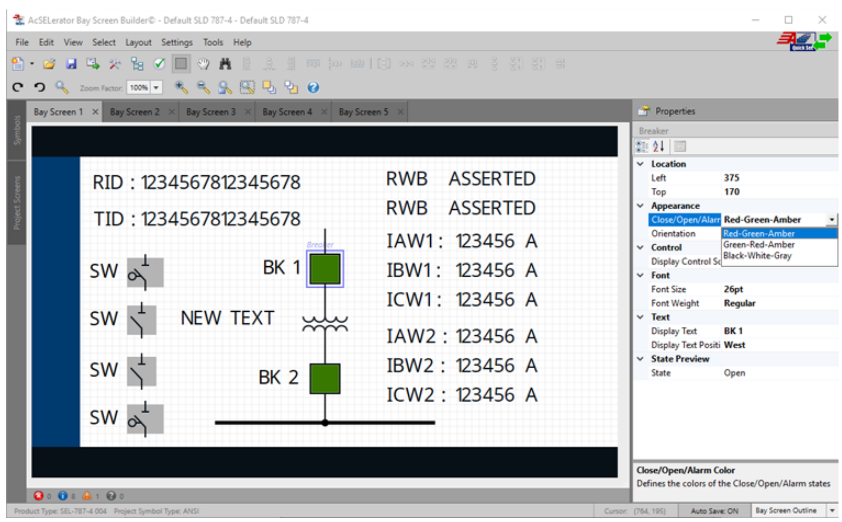


Figure 9.18 Close/Open/Alarm Color Property Drop Down Menu

Step 3. Use the State Preview tab to view your breaker close, open, and alarm state color selections.

Step 4. Edit the additional properties as needed for your application.

NOTE: If sufficient width is not provided for the value field of the analog label, the label is rendered as "$$$$$."

NOTE: The assignment of breaker Relay Word bits (e.g., 52An, 52Bn) to breaker symbols, or analog quantities (e.g., VA_MAG) to analog labels, cannot be made in Bay Screen Builder. These assignments can only be made in QuickSet.

Select and edit the disconnects, dynamic labels (analog and digital labels), and static symbols, similar to the breaker symbol. Note that some of the symbols have the Text tab that can be edited for custom labeling.

In this example, only Bay Screen 1 has been modified in the project. You can also modify the other screens to add analog/digital labels to monitor the status of the quantities, if necessary. Publish the project using the following process after saving your edits.

Publish Bay Screen Builder Project

When you have completed your single-line diagram in Bay Screen Builder, you are ready to publish your project to QuickSet.

Step 1. Click **File** > **Save Project** in the File menu to save your project.

Step 2. Click **File** > **Publish Package** in the File menu to publish your project (see *Figure 9.19*). Bay Screen Builder exports the project into QuickSet.

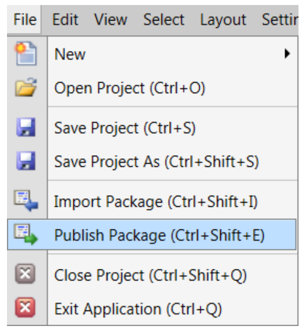


Figure 9.19 Publish Bay Screen Builder Project to QuickSet

Step 3. Allow a few seconds for Bay Screen Builder to publish the project to QuickSet. Respond to the QuickSet prompt, if presented. QuickSet then populates the settings of the updated single-line diagram (see *Figure 9.20*).

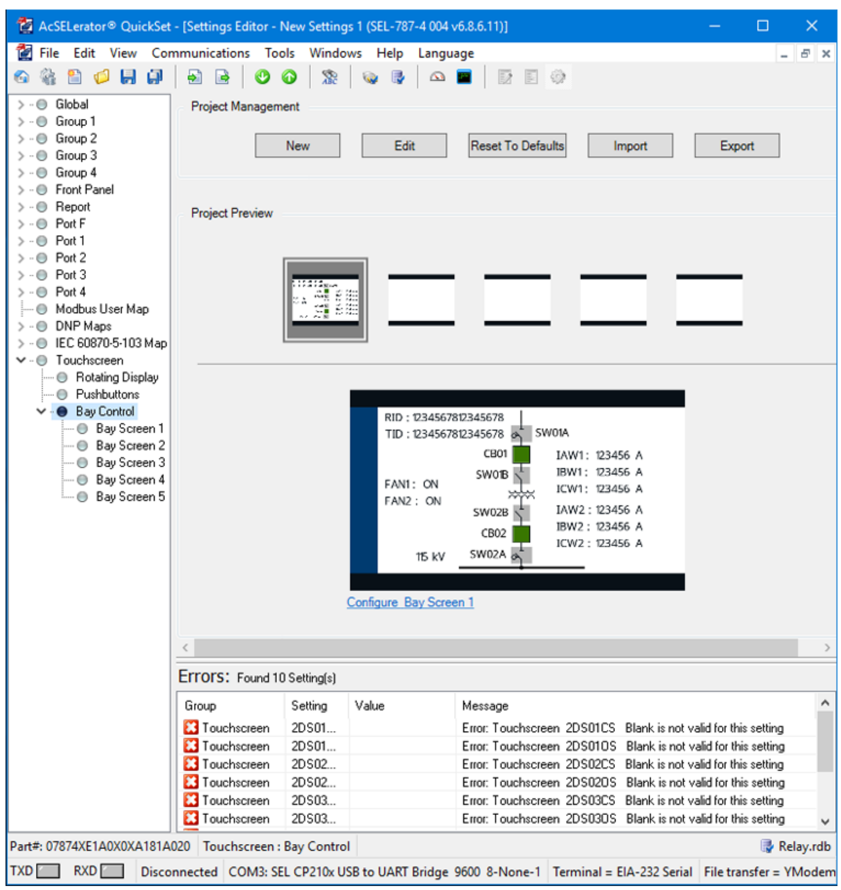


Figure 9.20 QuickSet Updated Single-Line Diagram and Corresponding Settings

Enter QuickSet Settings

The breaker, disconnect, analog and digital label, local/remote, and trip and close settings that follow are the settings applicable to the single-line diagram shown in *Figure 9.12*. Enter the following settings:

Breaker Settings

For *Figure 9.12*, assume the breaker auxiliary contacts 52A1 and 52B1 are wired to digital inputs IN101 and IN102 and 52A2 and 52B2 are wired to digital inputs IN309 and IN310, respectively. SELOGIC control equation settings SV01–SV03 and SV04–SV06 are programmed to create dual-point breaker status with alarm to mimic the logic shown in *Figure 9.1* for Breaker 1 and Breaker 2. Breaker settings are included in more than one settings class in QuickSet (Set 1 and Logic 1 in Group, Bay Control). Enter the following settings:

NOTE: The relay does not support dual-point breaker status (see Bay Control Breaker Settings) and uses the 52An Relay Word bit as the state of the breaker in several of the protection elements, including trip and close logic. If you intend to indicate dual-point status on the bay control single-line diagram, make use of SELOGIC to program this logic similar to the one shown in Figure 9.1.

Setting	Example Setting	Comment
Group 1 > Set 1 > Trip and Close Logic		
52A1	IN101	
52B1	IN102	
52A2	IN309	
52B2	IN310	
Group 1 > Logic 1 > SELOGIC Variables and Timers		
SV01	(52A1 AND 52B1) OR (NOT 52A1 AND NOT 52B1)	XNOR gate
SV01PU	0.5	Set pickup time to indicate alarm for undetermined breaker state
SV01DO	0.0	
SV02	NOT SV01 AND 52A1	Indicates breaker close status when asserted
SV02PU	0.0	
SV02DO	0.0	
SV03	NOT SV01 AND 52B1	Indicates breaker open status when asserted
SV03PU	0.0	
SV03DO	0.0	
SV04	(52A2 AND 52B2) OR (NOT 52A2 AND NOT 52B2)	XNOR gate
SV04PU	0.5	Set pickup time to indicate alarm for undetermined breaker state
SV04DO	0.0	
SV05	NOT SV04 AND 52A2	Indicates breaker close status when asserted
SV05PU	0.0	
SV05DO	0.0	
SV06	NOT SV04 AND 52B2	Indicates breaker open status when asserted
SV06PU	0.0	

Setting	Example Setting	Comment
SV06DO	0.0	
Touchscreen > Bay Control > Bay Screen 1		
Breaker 1 Mode	CONTROL	Controllable breaker
Breaker 1 Close Status	SV02T	
Breaker 1 Open Status	SV03T	
Breaker 1 Alarm Status	SV01T	
Breaker 1 HMI Close Command	CC1	
Breaker 1 HMI Open Command	OC1	
Breaker 2 Mode	CONTROL	Controllable breaker
Breaker 2 Close Status	SV05T	
Breaker 2 Open Status	SV06T	
Breaker 2 Alarm Status	SV04T	
Breaker 2 HMI Close Command	CC2	
Breaker 2 HMI Open Command	OC2	

Disconnect Settings

For this example, the relay has an 14 DI card in Slot C. Also, the disconnect auxiliary contacts 89A and 89B for each of the four disconnects are wired to digital inputs IN301, IN302, IN303, IN304, IN305, IN306, IN307, and IN308. Disconnect settings other than those specified in the table are set to the factory-default values. Refer to *Table 9.2* for all the disconnect setting prompts and factory-default values. Disconnect settings are included in more than one settings class in QuickSet (Global, Bay Control). Enter the following settings:

Setting	Example Setting	Comment
Global > Two-Position Disconnect Settings		
89A2P1	IN301	Disconnect 1, A contact
89B2P1	IN302	Disconnect 1, B contact
89NM2P1	SW01A	Disconnect 1, name
89A2P2	IN303	Disconnect 2, A contact
89B2P2	IN304	Disconnect 2, B contact
89NM2P2	SW01B	Disconnect 2, name
89A2P3	IN305	Disconnect 3, A contact
89B2P3	IN306	Disconnect 3, B contact
89NM2P3	SW02A	Disconnect 3, name
89A2P4	IN307	Disconnect 4, A contact
89B2P4	IN308	Disconnect 4, B contact
89NM2P4	SW02B	Disconnect 4, name

Setting	Example Setting	Comment
Touchscreen > Bay Control > Bay Screen 1		
Two-position disconnect close status	89CL2P1	Disconnect SW01A
Two-position disconnect open status	89OP2P1	
Two-position disconnect alarm status	89AL2P1	
Two-position disconnect in-progress status	89IP2P1	
Two-position disconnect HMI close command	89CM2P1	
Two-position disconnect HMI open command	89OM2P1	
Two-position disconnect close status	89CL2P2	Disconnect SW01B
Two-position disconnect open status	89OP2P2	
Two-position disconnect alarm status	89AL2P2	
Two-position disconnect in-progress status	89IP2P2	
Two-position disconnect HMI close command	89CM2P2	
Two-position disconnect HMI open command	89OM2P2	
Two-position disconnect close status	89CL2P3	Disconnect SW02A
Two-position disconnect open status	89OP2P3	
Two-position disconnect alarm status	89AL2P3	
Two-position disconnect in-progress status	89IP2P3	
Two-position disconnect HMI close command	89CM2P3	
Two-position disconnect HMI open command	89OM2P3	
Two-position disconnect close status	89CL2P4	Disconnect SW02B
Two-position disconnect open status	89OP2P4	
Two-position disconnect alarm status	89AL2P4	
Two-position disconnect in-progress status	89IP2P4	
Two-position disconnect HMI close command	89CM2P4	
Two-position disconnect HMI open command	89OM2P4	

Analog Label Settings

Enter the following Bay Control, Bay Screen 1 settings:

Setting	Example Setting
IAW1	IAW1_MAG
IBW1	IBW1_MAG
ICW1	ICW1_MAG
IAW2	IAW2_MAG
IBW2	IBW2_MAG
ICW2	ICW2_MAG
RID	STRING_RID
TID	STRING_TID

Digital Label Settings

In *Figure 9.12*, the status of Cooling Fans 1 and 2 are wired to IN311 and IN312, respectively.

Enter the following Bay Control, Bay Screen 1 setting:

Setting	Example Setting	Comment
FAN1	IN311	Cooling Fan 1
FAN2	IN312	Cooling Fan 2

Local/Remote Control Setting

Figure 9.12 is programmed with the local/remote functionality.

Enter the following Global, Control Configuration setting:

Setting	Example Setting	Comment
EN_LRC	Y	Enable local/remote control

Application With Handheld Local Remote Breaker Control Switch

Assume that the handheld local remote breaker control switch status is wired to IN313 of the relay. In this particular application, when IN313 is asserted, it implies that the breaker control is in LOCAL mode (or SCADA is cut off).

Enter the following Global, Control Configuration setting:

Setting	Example Setting	Comment
LOCAL	IN313	Local/remote control selection

Application Without Handheld Local Remote Breaker Control Switch

Assume that no handheld local remote breaker control switch is available. In such case you can program one of the programmable pushbuttons (e.g., PB04) in conjunction with SELOGIC to switch the breaker control between local and remote. Enter the following settings:

Setting	Example Setting	Comment
Group 1 > Logic 1 > SELOGIC Variables and Timers		
ELAT	1	
SET09	PB04_PUL AND NOT LT09	Local when LT09 is asserted
RST09	PB04_PUL AND LT09	Remote when LT09 is deasserted
Front Panel[a]		
PB4ALEDC	GO	
PB4A_LED	LT09	
PB4BLEDC	GO	
PB4B_LED	NOT LT09	

Setting	Example Setting	Comment
Global > Control Configuration		
LOCAL	LT09	

[a] Use configurable labels to assign PB4A LED to LOCAL and PB4B LED to REMOTE.

Trip and Close Settings

To be able to perform breaker control from the touchscreen or two-line display, program the OC1/OC2 and CC1/CC2 bits in the trip and close SELOGIC control equations, respectively.

Enter the following Group settings:

Setting	Example Setting	Comment
TR1	50P11T OR 51P1T OR 51Q1T OR LT05 AND SV04T OR OC1	Trip logic
CL1	SV03T AND LT05 OR CC1	Close logic
TR2	51P2T OR 51Q2T OR LT06 AND SV04T OR OC2	Trip logic
CL2	SV03T AND LT06 OR CC2	Close logic

Send all active settings to the relay.

To view the designed bay control single-line diagram on the touchscreen display, perform the following steps:

Step 1. Navigate to the Home screen.

Step 2. Select the **Bay Screens** application.

Step 3. Use the **Up** and **Down** arrows to view your screens.

With all the previous settings applied to the relay, you have a bay control single-line diagram that provides the status of the breaker and disconnects and provides you with the ability to perform breaker control via the touchscreen, as shown in *Figure 9.21*. In addition, you have the ability to monitor the flow of currents through the breaker, and the status of the cooling fans.

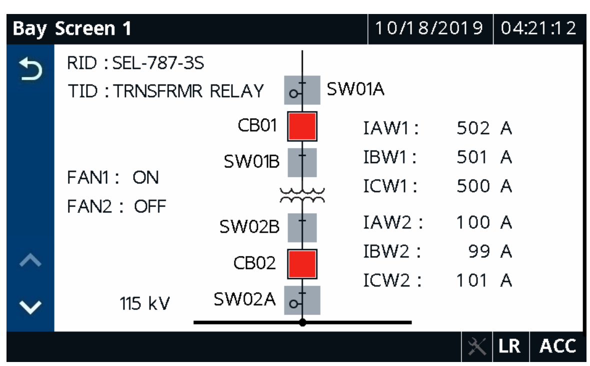


Figure 9.21 Final Bay Screen Builder Rendering

Export/Import Bay Screen Builder Project File

If you plan to use the same Bay Screen Builder project file (*.ldme) across multiple relays, export the file as shown in *Figure 9.22* and save the file to import it to another relay. The *.ldme file does not save the settings associated with the bay control symbols.

Alternatively, QuickSet allows you to save the Bay Screen as well as all of the corresponding analog and digital quantities settings (**Tools** > **Settings** > **Export** > **Touchscreen**).

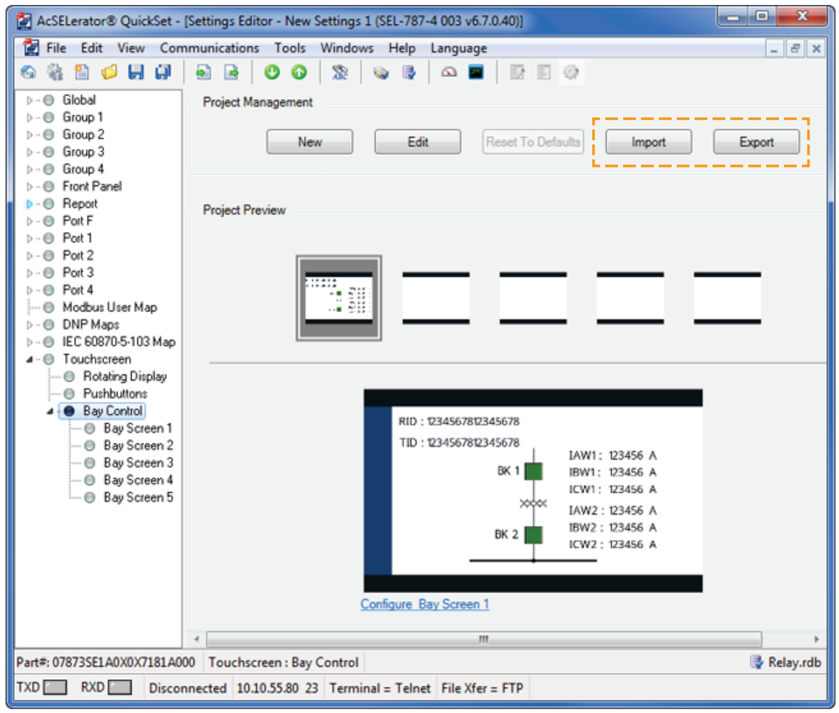


Figure 9.22 Import/Export of the Bay Control Screen in QuickSet

Reset to Defaults

Click **Reset to Defaults** in the QuickSet Project Management section to restore the default project in QuickSet.

Predefined Bay Control Single-Line Diagrams

You can import a predefined single-line diagram from the instruction manual CD. You can use the predefined single-line diagram as is or edit it to fit your specific application. All of the predefined single-line diagrams are created with either ANSI or IEC symbols. Any one of the following single-line diagrams can be imported into Bay Screen Builder. Use the **Import** button in the Project Management section of QuickSet to import one of the screens provided on the instruction manual CD.

ANSI and IEC

The following predefined single-line diagrams are constructed using ANSI or IEC symbols and are provided on the instruction manual CD as .ldme files.

- SEL-787-2E
- SEL-787-2X With Disconnects
- SEL-787-3E
- SEL-787-3E With Disconnects
- SEL-787-4X With Disconnects

Figure 9.23 shows the ANSI predefined bay control single-line diagram for an application of the SEL-787-4X with disconnects.

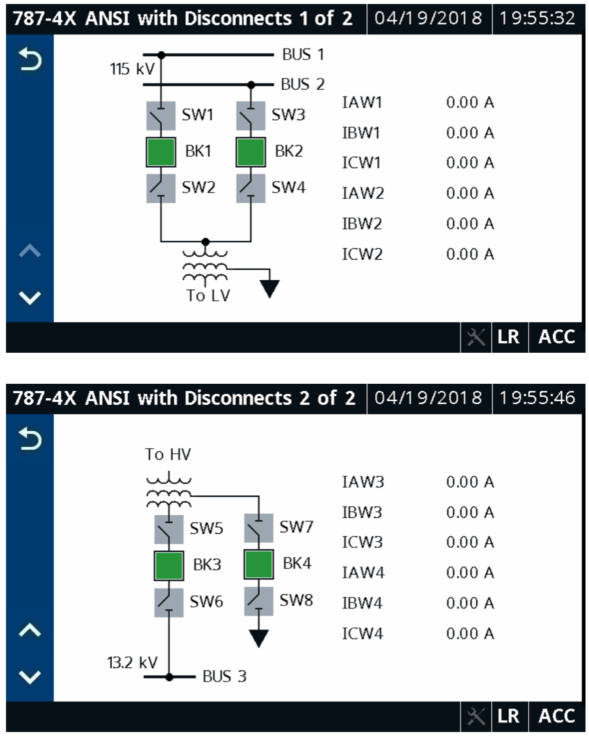


Figure 9.23 ANSI SEL-787-4X With Disconnects

Figure 9.24 shows the IEC predefined bay control single-line diagram for an application of the SEL-787-4X with disconnects.

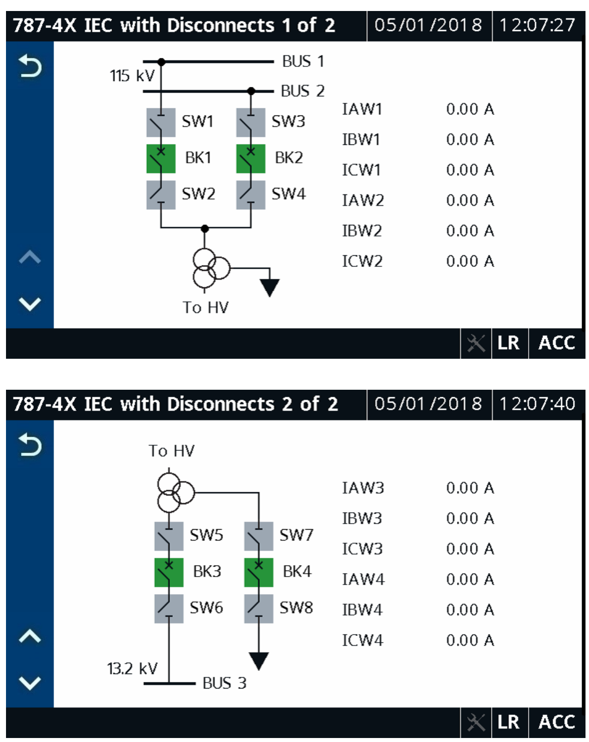


Figure 9.24 IEC SEL-787-4X With Disconnects

Section 10
Analyzing Events

Overview

The SEL-787 Transformer Protection Relay provides several tools (listed below) to analyze the cause of relay operations. Use these tools to help diagnose the cause of the relay operation and more quickly restore the protected transformer to service.

- Event Reporting
  - Event Summary Reports
  - Event History Reports
  - Event Reports
- Sequential Events Recorder Report
  - Resolution: 1 ms
  - Accuracy: ±1/4 cycle

All reports are stored in nonvolatile memory, ensuring that a loss of power to the SEL-787 does not result in lost data. The SEL-787 offers four types of event reports: Standard ASCII (EVE) reports, Compressed ASCII (CEV) reports, Binary COMTRADE reports, and Sequential Event Recorder (SER) reports.

Event Reporting

Analyze events with the following event reporting functions:

- Event Summaries—Enable automatic messaging to allow the relay to send event summaries out a serial port when port setting AUTO := Y. A summary provides a quick overview of an event. The summaries may also be retrieved by using the **SUMMARY** command.
- Event History—The relay keeps an index of stored nonvolatile event reports. Use the **HISTORY** command to obtain this index. The index includes some of the event summary information so that the appropriate event report can be identified and retrieved.
- Event Reports—These detailed reports are stored in nonvolatile memory for later retrieval and detailed analysis.

NOTE: Models without voltage inputs will not show voltage values in the event reports.

Each time an event occurs, a new summary, history record, and report are created. Event report information includes:

- Date and time of the event
- Individual sample analog inputs (currents and voltages)
- Digital states of selected Relay Word bits (listed in *Table L.1*)
- Event summary, including the front-panel target states at the time of tripping and fault type

- Group, Logic, Global, and Report settings (that were in service when the event was triggered)
- Relay part number and serial number to identify the relay model type

Compressed Event Reports

The SEL-787 provides Compressed ASCII and COMTRADE event reports to facilitate event report storage and display. SEL communications processors and SEL-5601-2 SYNCHROWAVE Event Software take advantage of the Compressed ASCII and COMTRADE formats. Use the **CHIS** command to display Compressed ASCII event history information. Use the **CSUM** command to display Compressed ASCII event summary information. Use the **CEVENT** command to display Compressed ASCII event reports.

For accurate event report analysis, use the Compressed Event report with raw (unfiltered) data (**CEV R** command). The regular ASCII Event report is useful for a quick check. See *Table C.2* for further information.

Compressed ASCII Event Reports contain *all* of the Relay Word bits.

Sequential Events Recorder (SER)

The SER report captures digital element state changes over time. Settings allow as many as 96 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 information is stored when state changes occur.

SER report data are useful in commissioning tests and during operation for system monitoring and control.

Event Reporting

Length

IMPORTANT: Changing the LER setting clears all events in memory. Be sure to save critical event data prior to changing the LER setting.

The SEL-787 provides selectable event report length (LER) and prefault length (PRE). Event report length is selectable. The choices for event report length are 15, 64, or 180 cycles. Prefault length is 1–10 cycles for LER = 15, 1–59 cycles for LER = 64, and 1–175 cycles for LER = 180. Prefault length is the first part of the total event report length and precedes the event report triggering point (*Figure 10.1*). Changing the PRE setting has no effect on the stored reports. The relay stores as many as 5 of the most recent 180-cycle, 18 of the most recent 64-cycle, or 50 of the most recent 15-cycle event reports in nonvolatile memory. Refer to the **SET R** command in *SET Command (Change Settings) on page 7.62* and *Report Settings (SET R Command) on page 4.155*.

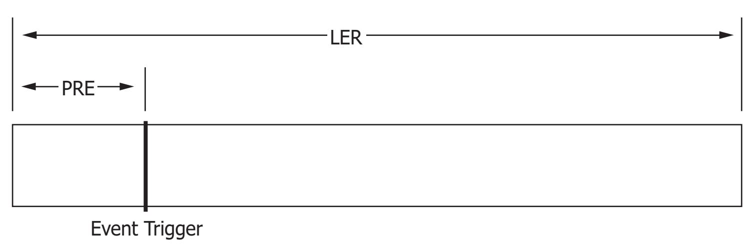


Figure 10.1 Data Capture/Event Report Times

Triggering

The SEL-787 triggers (generates) an event report when any of the following occur:

- ➤ Relay Word bit TRIP asserts
- ➤ Programmable SELOGIC control equation setting ER asserts (in Report settings)
- ➤ **TRI** (Trigger Event Reports) serial port command executes

Relay Word Bit TRIP

Refer to *Table 4.40*. If Relay Word bit TR1, TR2, TR3, or TR4 asserts to logical 1, an event report is automatically generated. Thus, any Relay Word bit that causes a trip does *not* have to be entered in SELOGIC control equation setting ER.

Programmable SELOGIC Control Equation Setting ER

The programmable SELOGIC control equation event report trigger setting ER is set to trigger event reports for conditions other than trip conditions (see **SET R** in *SET Command (Change Settings) on page 7.62*). When setting ER detects a logical 0 to logical 1 transition, it generates an event report (if the SEL-787 is not already generating a report that encompasses the new transition). The factory setting is shown in *Event Report Settings on page 4.157*.

TRI (Trigger Event Report) Command

The sole function of the **TRI** serial port command is to generate event reports, primarily for testing purposes. See *TRIGGER Command (Trigger Event Report) on page 7.73* for more information on the **TRI** (Trigger Event Report) command.

Event Summaries

IMPORTANT: Clearing the history report with the **HIS C** or **HIS CA** command also clears all event data within the SEL-787 event memory.

NOTE: The **HIS CA** command resets the unique event reference number to 10000.

For every triggered event, the relay generates and stores an event summary. The relay stores as many as 50 of the most recent event summaries (if event report length setting LER := 15), as many as 18 (if LER := 64), or as many as 5 (if LER := 180). When the relay stores a new event summary, it discards the oldest event and event summary if the event memory is full. Event summaries contain the following information:

- ➤ Relay and terminal identification (RID and TID)
- ➤ Event number, unique event reference number, date, time, event type (see *Table 10.2*), and frequency
- ➤ Primary magnitudes of winding phase, neutral (if optional neutral CT is available), and residual currents
- ➤ Primary magnitudes of the line to neutral voltage (if DELTA_Y := WYE) or phase-to-phase voltages (if DELTA_Y := DELTA) if optional voltage inputs are available
- ➤ Hottest RTD temperatures, SEL-2600 RTD Module or internal RTD card option required

The relay includes the event summary in the event report. The identifiers, date, and time information are at the top of the event report, and the remaining information follows at the end (See *Figure 10.4*). The example event summary in *Figure 10.2* corresponds to the standard 15-cycle event report in *Figure 10.4*. See *Table 10.1* for information on the **SUM** command.

```
=>SUM <Enter>

SEL-787-3S                                 Date: 03/23/2018   Time: 13:45:14.299
TRNSFRMR RELAY

Serial No = 000000000000000
FID = SEL-787-4-X345-V0-Z003002-D20180321               CID = FCB7
EVENT LOGS =  1             REF_NUM = 10000

Event:     Diff 87 Trip
Targets    11100000
Freq (Hz)  60.0

Winding One Current Mag
       IAW1          IBW1          ICW1          IGW1
(A)      99.7         101.5          99.4          3.61

Winding Two Current Mag
       IAW2          IBW2          ICW2          IGW2
(A)     993.2        1010.2         990.6         35.36

Winding Three Current Mag
       IAW3          IBW3          ICW3          IGW3
(A)    1200.5        1206.3        1195.2         18.03

Voltage Mag
       VAN    VBN    VCN    VG
(V)    7826   7828   8060    316

=>
```

Figure 10.2 Example Event Summary

Table 10.1 SUM Command

Command	Description
SUM	Return the most recent event summary.
SUM *n*	Return a particular *n* event summary.

The relay sends event summaries to all serial ports with setting AUTO := Y each time an event triggers.

Event Logs

The event logs field shows the number of events presently stored in the flash memory of the relay.

Event Reference Number

The event reference number is a unique event identification number assigned to the event. The unique event identification number of any event can be found by issuing the **HIS** command (see *Viewing the Event History on page 10.8* for details). The event reference number starts at 10000 and increments with each new event to a maximum of 42767. The event reference number rolls over to 10000 after reaching the next event after event 42767. The event reference number can be reset to 10000 by using the **HIS CA** command.

Event Type

The `Event` field displays the event type. Event types and the logic used to determine event types are shown in order of priority in *Table 10.2*.

Table 10.2 Event Types (Sheet 1 of 2)

Type	Condition
Diff 87 Trip	(87U OR 87R) AND TRIP
Diff 87Q Trip	87Q AND TRIP
REF Trip	(REF1F OR REF1P OR REF3AF OR REF3AP OR REF3BF OR REF3BP) AND TRIP
Wdg1 Ph 50 Trip	(50P11T OR 50P12T OR 50P13T OR 50P14T) AND TRIP
Wdg1 Gnd 50 Trip	(50G11T OR 50G12T) AND TRIP
Wdg1 50Q Trip	(50Q11T OR 50Q12T) AND TRIP
Wdg2 Ph 50 Trip	(50P21T OR 50P22T OR 50P23T OR 50P24T) AND TRIP
Wdg2 Gnd 50 Trip	(50G21T OR 50G22T) AND TRIP
Wdg2 50Q Trip	(50Q21T OR 50Q22T) AND TRIP
Wdg3 Ph A 50Trip	(50P31AT OR 50P32AT) AND TRIP
Wdg3 Ph B 50Trip	(50P31BT OR 50P32BT) AND TRIP
Wdg3 Ph C 50Trip	(50P31CT OR 50P32CT) AND TRIP
Wdg3 Ph 50 Trip	(50P31T OR 50P32T OR 50P33T OR 50P34T) AND TRIP
Wdg3 Gnd 50 Trip	(50G31T OR 50G32T) AND TRIP
Wdg3 50Q Trip	(50Q31T OR 50Q32T) AND TRIP
Wdg4 Ph 50 Trip	(50P41T OR 50P42T OR 50P43T OR 50P44T) AND TRIP
Wdg4 Gnd 50 Trip	(50G41T OR 50G42T) AND TRIP
Wdg4 50Q Trip	(50Q41T OR 50Q42T) AND TRIP
Wdg1&2 50P Trip	(50P121T OR 50P122T) AND TRIP
Wdg2&3 50P Trip	(50P231T OR 50P232T) AND TRIP
Wdg3&4 50P Trip	(50P341T OR 50P342T) AND TRIP
Wdg1&2 50G Trip	(50G121T OR 50G122T) AND TRIP
Wdg2&3 50G Trip	(50G231T OR 50G232T) AND TRIP
Wdg3&4 50G Trip	(50G341T OR 50G342T) AND TRIP
Neutral 50 Trip	(50N11T OR 50N12T) AND TRIP
Wdg1 Ph 51 Trip	51P1T AND TRIP
Wdg1 Gnd 51 Trip	51G1T AND TRIP
Wdg1 51Q Trip	51Q1T AND TRIP
Wdg2 Ph 51 Trip	51P2T AND TRIP
Wdg2 Gnd 51 Trip	51G2T AND TRIP
Wdg2 51Q Trip	51Q2T AND TRIP
Wdg3 Ph A 51Trip	51P3AT AND TRIP
Wdg3 Ph B 51Trip	51P3BT AND TRIP
Wdg3 Ph C 51Trip	51P3CT AND TRIP
Wdg3 Ph 51 Trip	51P3T AND TRIP
Wdg3 Gnd 51 Trip	51G3T AND TRIP
Wdg3 51Q Trip	51Q3T AND TRIP
Wdg4 Ph 51 Trip	51P4T AND TRIP

Table 10.2 Event Types (Sheet 2 of 2)

Type	Condition
`Wdg4 Gnd 51 Trip`	51G4T AND TRIP
`Wdg4 51Q Trip`	51Q4T AND TRIP
`Wdg1&2 51P Trip`	51PC12T AND TRIP
`Wdg2&3 51P Trip`	51PC23T AND TRIP
`Wdg3&4 51P Trip`	51PC34T AND TRIP
`Wdg1&2 51G Trip`	51GC12T AND TRIP
`Wdg2&3 51G Trip`	51GC23T AND TRIP
`Wdg3&4 51G Trip`	51GC34T AND TRIP
`Neutral 51 Trip`	51N1T AND TRIP
`PowerElemnt Trip`	(3PWR1T OR 3PWR2T) AND TRIP
`Undervolt Trip`	(27P1T OR 27P2T OR 27PP1T OR 27PP2T OR 27I1T OR 27I2T) AND NOT LOP AND TRIP
`Overvolt Trip`	(59P1T OR 59P2T OR 59PP1T OR 59PP2T OR 59Q1T OR 59Q2T OR 59G1T OR 59G2T OR 59I1T OR 59I2T OR 59I3T OR 59I4T) AND TRIP
`Volt/Hz 24 Trip`	(24D1T OR 24C2T) AND TRIP
`Frequency81 Trip`	(81D1T OR 81D2T OR 81D3T OR 81D4T) AND TRIP
`RTD Trip`	RTDT AND TRIP
`RTD Fail Trip`	RTDFLT AND TRIP
`Brk Failure Trip`	(BFT1 OR BFT2 OR BFT3 OR BFT4) AND TRIP
`Remote Trip`	REMTRIP AND TRIP
`CommIdleLossTrip`	(COMMIDLE OR COMMLOSS) AND TRIP
`Trigger`	Trigger command
`ER Trigger`	
`Trip`	TRIP with no known cause
`Trip*`	Upon cycling power on the relay if the **TRIP** LED is latched and no active TRIP exists

Currents, Voltages, and RTD Temperatures

The relay determines the maximum cosine-filtered phase current during an event. The instant the maximum cosine-filtered phase current occurs is marked by an asterisk (*) in the event report (see *Figure 10.4*). This row of data corresponds to the analogs shown in the summary report for the event. Further, the relay looks at DI_A*n*, DI_B*n*, and DI_C*n* (*n* = 1, 2, 3, or 4) Relay Word bits to determine if the peak detector is active at the trigger point (>) of the event. If the peak detector is active, it shows the peak detector output current in the summary report appended with “pk” string for the corresponding phase current instead of the maximum cosine-filtered phase current identified by the asterisk (*).

The `Current Mag` fields display the primary current magnitudes at the instant when the maximum phase current was measured. The currents displayed are listed below:

- Winding Currents (`IAWn`, `IBWn`, `ICWn, IGWn [n = 1, 2, 3, and 4]`)
- Neutral Current (`IN`)

NOTE: Frequency measurement is available in CEV reports only.

The `Voltage Mag` fields display the primary voltage magnitudes at the instant when the maximum phase current was measured. The voltages displayed are listed below (model dependent):

- DELTA_Y := WYE
  - Phase-to-Neutral Voltages (`VAN`, `VBN`, `VCN`)
  - Residual Voltage VG, calculated from `VA`, `VB`, `VC`
- DELTA_Y := DELTA
  - Phase-to-Phase Voltages (`VAB`, `VBC`, `VCA`)
- Synch-Check Voltage or Battery Voltage (`VS/VDC`)

If the RTDs are connected, the hottest RTD (°C) fields display the hottest RTD reading in each RTD group. The hottest RTD temperatures in degrees centigrade (°C) are listed below:

- Ambient
- Other

Event History

The event history report gives you a quick look at recent relay activity. The relay labels each new event in reverse chronological order with `1` as the most recent event. See *Figure 10.3* for a sample event history. Use this report to view the events that are presently stored in the SEL-787.

The event history contains the following:

- Standard report header
  - Relay and terminal identification
  - Date and time of report
  - Time source (if IRIG-B model)
- Event number, unique event reference number, date, time, event type (see *Table 10.2*)
- Maximum current
- Frequency (actual frequency if the voltage card is available, otherwise the nominal frequency)
- Target LED status

```
=>HIS <Enter>

SEL-787-3S                          Date: 03/23/2018   Time: 13:56:00.688
TRNSFRMR RELAY                      Time Source: Internal

FID=SEL-787-4-X345-V0-Z003002-D20180321

#     REF      DATE         TIME          EVENT         CURRENT    FREQ    TARGETS
1     10003    03/23/2018   13:46:46.146  ER Trigger    1210.0     60.0    11100000
2     10002    03/23/2018   13:46:43.812  Diff 87 Trip  1227.7     60.0    11100000
3     10001    03/23/2018   13:46:17.761  Trigger       1208.4     60.0    11100000
4     10000    03/23/2018   13:45:14.299  Diff 87 Trip  1206.3     60.0    11100000
```

Event Number | Reference Number | Event Type | Maximum Current | Frequency | User-Defined Target LEDs

Figure 10.3 Sample Event History

Viewing the Event History

Access the history report from the communications ports, using the **HIS** command or the analysis menu within ACSELERATOR QuickSet SEL-5030 Software. View and download history reports from Access Level 1 and higher.

Use the **HIS** command from a terminal to obtain the event history. You can specify the number of the most recent events that the relay returns.

Use the front-panel `MAIN > Events > Display Events` menu to display event history data on the SEL-787 front-panel display.

Use QuickSet to retrieve the relay event history. View the **Relay Event History** dialog box via the **Analysis > Get Event Files** menu.

Clearing

Use the **HIS C** command to clear or reset history data from Access Levels 1 and higher. Clear/reset history data at any communications port. This clears all event summaries, history records, and reports. The **HIS C** command does not reset the unique event reference number. This number continues to increment from the present value with each subsequent event. Use the **HIS CA** command to clear all event data and reset the unique event reference number to 10000.

Event Reports

The latest event reports are stored in nonvolatile memory. Each event report includes four sections:

- Analog values of current and voltage
- Digital states of the protection and control elements, including overcurrent, and voltage elements, plus status of digital output and input states
- Event summary (includes relay model number and serial number in Compressed ASCII event reports)
- Settings in service at the time of event triggering, consisting of Group, Logic, Global, and Report settings classes

Use the **EVE** command to retrieve the reports. There are several options to customize the report format (see *Table 10.3* and *Table 10.4*).

Table 10.3 EVE Command (Sheet 1 of 2)

Command	Description
EVE	Return the most recent event report (including settings and summary) at full length with 4 samples per cycle data for the analogs in Slot Z (Slot Z contains Windings 1 and 2).
EVE *n*	Return a particular *n* event report (including settings and summary) at full length with 4 samples per cycle data for the analogs in Slot Z (Slot Z contains Windings 1 and 2).
EVE R	Return a raw event report with 32 samples per cycle data for the analogs in Slot Z (Slot Z contains Windings 1 and 2).
EVE R *n*	Return a particular *n* event report (including settings and summary) with 32 samples per cycle data for the analogs in Slot Z (Slot Z contains Windings 1 and 2).

Table 10.3 EVE Command (Sheet 2 of 2)

Command	Description
EVE E *n*	Return the most recent event report (including settings and summary) at full length with 4 samples per cycle data for the analogs in Slot E (Slot E contains Windings 3 and 4 or the voltage channels).
EVE R E *n*	Return a particular *n* event report (including settings and summary) with 32 samples per cycle data for the analogs in Slot E (Slot E contains Windings 3 and 4 or the voltage channels).

Table 10.4 EVE Command Examples

Example	Description
EVE 5	For the fifth most recent event, return the event report with 4 samples per cycle data for the analogs in Slot Z (Slot Z contains Windings 1 and 2).
EVE R E 2	For the second most recent event, return the event report with 32 samples per cycle data for the analogs in Slot E (Slot E contains Windings 3 and 4 or the voltage channels).

Analog Event Reports (EVE Command)

The analog event report includes:

- Analog values of Windings 1, 2, 3, and 4 currents; IAW, IBW, ICW, IGW; neutral current IN (if available); voltages and frequency (if voltage card is used) (specific analog quantities depend on the SEL-787 model number)
- Digital states of the base model digital inputs (2) and digital outputs (3)
- Event summary (includes the serial number of the product)
- Setting in service at the time of event triggering, consisting of Group, Logic, Global, and Report settings classes

The relay displays currents and voltages in primary values as part of the report. If the winding phase CTs are wye connected, the relay can accurately derive the primary currents from the secondary values through multiplying them by the corresponding CT ratio. Delta-connected CTs, in general, remove zero-sequence current and introduce a phase shift. They also increase magnitude by $\sqrt{3}$ under balanced system conditions and as high as two times under unbalanced conditions. As a result, the relay cannot derive the primary currents/quantities accurately. The relay performs the following under all system conditions in the case of delta-connected CTs. The primary currents displayed are derived from the secondary values through multiplying them by the corresponding CT ratio and dividing them by $\sqrt{3}$. The phase angles are not compensated and reflect the same values as measured on the secondary.

Filtered and Unfiltered Analog Event Reports

The SEL-787 samples the power system measurands (ac voltage and ac current) 32 times per power system cycle. A digital filter extracts the fundamental frequency component of the measurands. The relay operates on the filtered values and reports these values in the standard, filtered event report (4 samples per cycle).

To view the raw inputs to the relay, select the unfiltered event report by using the **EVE R** command. Use the unfiltered event reports to observe power system conditions:

- ➤ Power system transients on current and voltage channels
- ➤ Decaying dc offset during fault conditions on current channels

Raw event reports display one extra cycle of data at the beginning of the report. Also, unlike the filtered report, the raw event report shows the actual relay terminal voltage inputs so if the external connections are for DELTA input, VA = Vab, VB = 0, VC = –Vbc (in primary volts).

Analog Event Report Column Definitions

NOTE: Active channels depend on the specific relay model.

Refer to the example analog event report in *Figure 10.4* to view event report columns. This example event report displays rows of information each 1/4 cycle. Retrieve this report with the **EVE** command.

The columns contain analog values, including ac current, ac voltage, and frequency, followed by base model input and output information. *Table 10.5* summarizes the analog event report columns.

Table 10.5 Analog Event Report Columns Definitions (Sheet 1 of 2)

Column Heading	Column Symbols	Description
IAW1		Current measured by channel IA, Winding 1 (primary A)
IBW1		Current measured by channel IB, Winding 1 (primary A)
ICW1		Current measured by channel IC, Winding 1 (primary A)
IGW1		Residual current (IAW1 + IBW1 + ICW1, primary A), displayed only when no voltages are shown
IAW2		Current measured by channel IA, Winding 2 (primary A)
IBW2		Current measured by channel IB, Winding 2 (primary A)
ICW2		Current measured by channel IC, Winding 2 (primary A)
IGW2		Residual current (IAW2 + IBW2 + ICW2, primary A), displayed only when no voltages are shown
IAW3		Current measured by channel IA, Winding 3 (primary A)
IBW3		Current measured by channel IB, Winding 3 (primary A)
ICW3		Current measured by channel IC, Winding 3 (primary A)
IGW3		Residual current (IAW3 + IBW3 + ICW3, primary A), displayed only when no voltages are shown
IAW4		Current measured by channel IA, Winding 4 (primary A)
IBW4		Current measured by channel IB, Winding 4 (primary A)
ICW4		Current measured by channel IC, Winding 4 (primary A)
IGW4		Residual current (IAW4 + IBW4 + ICW4, primary A), displayed only when no voltages are shown

Table 10.5 Analog Event Report Columns Definitions (Sheet 2 of 2)

Column Heading	Column Symbols	Description
IN		Current measured by channel IN (primary A) when neutral CT is present
VAN or VAB		Voltage measured by channel VAN or VAB (primary V), requires voltage input
VBN or VBC		Voltage measured by channel VBN or VBC (primary V), requires voltage input
VCN or VCA		Voltage measured by channel VCN or VCA calculated from VAB and VBC (primary V), requires voltage input
VS/VDC		Voltage measured by channel VS or VDC. The channel can be set as VS or VDC by the VS_BAT setting (see *Global Settings (SET G Command)*).
In 12	1	IN101 AND NOT IN102
	2	NOT IN101 AND IN102
	b	IN101 AND IN102
Out 12	1	OUT101 AND NOT OUT102
	2	NOT OUT101 AND OUT102
	b	OUT101 AND OUT102
Out 3	3	OUT103

Note that the ac values change from plus to minus (–) values in *Figure 10.4*, indicating the sinusoidal nature of the waveforms.

Other figures help in understanding the information available in the event report current columns:

- ➤ *Figure 10.5* shows how analog event report current column data relate to the actual sampled current waveform and rms current values.
- ➤ *Figure 10.6* shows how analog event report current column data can be converted to phasor rms current values.

Example 15-Cycle Event Report

Figure 10.4 is an example of a standard analog 15-cycle event report. Note that *Figure 10.4* shows the captures for both the Slot Z and Slot E analogs.

In *Figure 10.4*, an arrow (>) in the column following the VCA column would identify the "trigger" row. This is the row that corresponds to the Date and Time values at the top of the event report.

The asterisk (*) in the column following the IGW2 column identifies the row with the maximum phase current. The maximum phase current is calculated from the row identified with the asterisk and the row one quarter-cycle previous (see *Figure 10.5* and *Figure 10.6*). These currents are listed at the end of the event report in the event summary. If the trigger row (>) and the maximum phase current row (*) are the same row, the * symbol takes precedence.

```
=>EVE 13 <Enter>

SEL-787-3S                                Date: 03/23/2018   Time: 13:45:14.299
TRNSFRMR RELAY


Serial Number = 000000000000000
FID=SEL-787-4-X345-V0-Z003002-D20180321   CID=FCB7
```

Header and Firmware ID

```
                                                          O
                                                        I u
                                                        N t
                      Currents (Amps Pri)               1 13
   IAW1   IBW1   ICW1   IGW1   IAW2   IBW2   ICW2   IGW2 2 2
```

Analog and Digital Header

```
[1]
    0.0    0.0    0.5    0.5    5.0    0.0   -5.0    0.0 . ..
   -0.5    0.0    0.0   -0.5    0.0   -5.0   -5.0  -10.0 . ..
   -0.5   -1.0   -0.5   -2.0  -10.0    0.0    0.0  -10.0 . ..
   -0.5   -0.5   -0.5   -1.5   -5.0    0.0    0.0   -5.0 . ..
```

One Cycle of Data

```
[2]
    0.0    0.0    0.5    0.5    0.0   -5.0   -5.0  -10.0 . ..
    0.0    0.0    0.0    0.0    0.0   -5.0   -5.0  -10.0 . ..
   -1.0   -1.0   -1.0   -3.0  -10.0    0.0    0.0  -10.0 . ..
   -0.5   -0.5   -0.5   -1.5   -5.0    0.0    0.0   -5.0 . ..
[3]
    0.0    0.5    0.5    1.0    5.0   -5.0   -5.0   -5.0 . ..
    0.0    0.5    0.0    0.5    0.0    0.0    0.0    0.0 . ..
   15.5  -29.0   11.0   -2.5  155.0 -280.0  110.0  -15.0 . ..
   18.5   18.5  -38.5   -1.5  175.0  205.0 -390.0  -10.0 . ..

.
.
.

[15]
  -91.0   82.5   10.0    1.5 -920.0  805.0  120.0    5.0 . .*
  -42.0  -59.0   99.0   -2.0 -400.0 -610.0  990.0  -20.0 . .*
   90.5  -82.5  -10.5   -2.5  915.0 -805.0 -125.0  -15.0 . .*
   41.5   58.0  -99.5    0.0  395.0  600.0 -995.0    0.0 . .*

Serial No = 000000000000000
FID = SEL-787-4-X345-V0-Z003002-D20180321              CID = FCB7
EVENT LOGS = 13             REF_NUM = 10000

Event:     Diff 87 Trip
Targets    11100000
Freq (Hz)  60.0

Winding One Current Mag
       IAW1          IBW1          ICW1          IGW1
(A)      99.7         101.5          99.4          3.61

Winding Two Current Mag
       IAW2          IBW2          ICW2          IGW2
(A)     993.2        1010.2         990.6         35.36

Winding Three Current Mag
       IAW3          IBW3          ICW3          IGW3
(A)    1200.5        1206.3        1195.2         18.03

Voltage Mag
       VAN    VBN    VCN    VG
(V)    7826   7828   8060    316



SETTINGS CHANGED SINCE EVENT

Global Settings
PHROT   := ABC     FNOM    := 60      VS_VBAT := VS
DATE_F  := MDY     METHRES := Y
FAULT   := 51P1P OR 51P2P OR 51P3P OR 51G1P OR 51G2P OR 51G3P OR TRIP
EMP     := N       TGR     := 3
SS1     := 1
SS2     := 0
SS3     := 0
SS4     := 0
```

Figure 10.4 Example Standard 15-Cycle Analog Event Report 1/4-Cycle Resolution

```
EPMU    := N
IRIGC   := NONE    UTC_OFF := 0.00    DST_BEGM:= OFF
52ABF   := N       BFD1    := 0.50    BFI1    := R_TRIG TRIP1 OR R_TRIG TRIPXFMR
BFD2    := 0.50    BFI2    := R_TRIG TRIP2 OR R_TRIG TRIPXFMR
BFD3    := 0.50    BFI3    := R_TRIG TRIP3 OR R_TRIG TRIPXFMR

THFLTD  := OFF

IN101D  := 10      IN102D  := 10
EBMON1  := Y       COSP11  := 10000   COSP12  := 150     COSP13  := 12
KASP11  := 1.20    KASP12  := 8.00    KASP13  := 20.00   BKMON1  := TRIP1
EBMON2  := Y       COSP21  := 10000   COSP22  := 150     COSP23  := 12
KASP21  := 1.20    KASP22  := 8.00    KASP23  := 20.00   BKMON2  := TRIP2

EBMON3  := Y       COSP31  := 10000   COSP32  := 150     COSP33  := 12
KASP31  := 1.20    KASP32  := 8.00    KASP33  := 20.00   BKMON3  := TRIP3

RSTTRGT := 0
RSTENRGY:= 0
RSTMXMN := 0
RSTDEM  := 0
RSTPKDEM:= 0

DSABLSET:= 0

TIME_SRC:= IRIG1
89A2P1  := 0
89B2P1  := NOT 89A2P1
89A2P1D := 5.00    89A2P2  := 0
89B2P2  := NOT 89A2P2
89A2P2D := 5.00    89A2P3  := 0
89B2P3  := NOT 89A2P3
89A2P3D := 5.00    89A2P4  := 0
89B2P4  := NOT 89A2P4
89A2P4D := 5.00    89A2P5  := 0
89B2P5  := NOT 89A2P5
89A2P5D := 5.00    89A2P6  := 0
89B2P6  := NOT 89A2P6
89A2P6D := 5.00    89A2P7  := 0
89B2P7  := NOT 89A2P7
89A2P7D := 5.00    89A2P8  := 0
89B2P8  := NOT 89A2P8
89A2P8D := 5.00    89A2P9  := 0
89B2P9  := NOT 89A2P9
89A2P9D := 5.00    89A2P10 := 0
89B2P10 := NOT 89A2P10
89A2P10D:= 5.00    89A2P11 := 0
89B2P11 := NOT 89A2P11
89A2P11D:= 5.00    89A2P12 := 0
89B2P12 := NOT 89A2P12
89A2P12D:= 5.00    89A2P13 := 0
89B2P13 := NOT 89A2P13
89A2P13D:= 5.00    89A2P14 := 0
89B2P14 := NOT 89A2P14
89A2P14D:= 5.00    89A2P15 := 0
89B2P15 := NOT 89A2P15
89A2P15D:= 5.00    89A2P16 := 0
89B2P16 := NOT 89A2P16
89A2P16D:= 5.00
EN_LRC  := N       EN_LRC  := N

Group Settings

RID     := SEL-787-3S
TID     := TRNSFRMR RELAY
E87W1   := Y       E87W2   := Y       E87W3   := Y       W1CT    := WYE
W2CT    := WYE     W3CT    := WYE
CTR1    := 100     CTR2    := 1000    CTR3    := 1000    MVA     := 50.0
ICOM    := N       CCW12   := N       VWDG1   := 138.000 VWDG2   := 13.800
VWDG3   := 13.800
PTR     := 120.00  PTRS    := 120.00  VNOM    := 13.80   DELTA_Y := WYE
VIWDG   := 2       COMPANG := 0       SINGLEV := N
TAP1    := 2.09    TAP2    := 2.09    TAP3    := 2.09
O87P    := 0.30    87AP    := 0.15    87AD    := 5.00    SLP1    := 25
SLP2    := 70      IRS1    := 6.00
U87P    := 10.00   PCT2    := 15      PCT4    := 15      PCT5    := 35
TH5P    := OFF     HRSTR   := Y       HBLK    := N
```

Figure 10.4 Example Standard 15-Cycle Analog Event Report 1/4-Cycle Resolution (Continued)

```
50P11P  := OFF     50P12P  := OFF     50P13P  := OFF     50P14P  := OFF
50G11P  := OFF     50G12P  := OFF     50Q11P  := OFF     50Q12P  := OFF
51P1P   := OFF     51G1P   := OFF     51Q1P   := OFF
50P21P  := OFF     50P22P  := OFF     50P23P  := OFF     50P24P  := OFF
50G21P  := OFF     50G22P  := OFF     50Q21P  := OFF     50Q22P  := OFF
51P2P   := OFF
51G2P   := OFF     51Q2P   := OFF
50P31AP := OFF     50P31BP := OFF     50P31CP := OFF     50P32AP := OFF
50P32BP := OFF     50P32CP := OFF

51P3AP  := OFF

51P3BP  := OFF
51P3CP  := OFF
50P31P  := OFF     50P32P  := OFF     50P33P  := OFF     50P34P  := OFF
50G31P  := OFF     50G32P  := OFF     50Q31P  := OFF     50Q32P  := OFF
51P3P   := OFF     51G3P   := OFF     51Q3P   := OFF

E49RTD  := NONE
27P1P   := OFF     27P2P   := OFF

27PP1P  := OFF     27PP2P  := OFF

27S1P   := OFF     27S2P   := OFF


59P1P   := OFF     59P2P   := OFF
59PP1P  := OFF     59PP2P  := OFF     59G1P   := OFF     59G2P   := OFF
59Q1P   := OFF     59Q2P   := OFF

59S1P   := OFF     59S2P   := OFF


E27I1   := N       E27I2   := N

E59I1   := N       E59I2   := N       E59I3   := N       E59I4   := N
E24     := Y       24WDG   := WYE     24D1P   := 105
24D1D   := 1.00    24CCS   := ID      24IP    := 105     24IC    := 2.0
24ITD   := 0.1
24D2P2  := 176     24D2D2  := 3.00    24CR    := 240.00  24TC    := 1


LOPBLK  := 0


E25     := N       EPWR    := N

81D1TP  := OFF     81D2TP  := OFF
81D3TP  := OFF
81D4TP  := OFF
EDEM    := OFF

TDURD   := 0.50    CFD1    := 0.50    CFD2    := 0.50    CFD3    := 0.50
CFD4    := 0.50
TR1     := 50P11T OR 51P1T OR 51Q1T OR LT05 AND SV04T OR OC1
TR2     := 51P2T OR 51Q2T OR LT06 AND SV04T OR OC2
TR3     := 51P3T OR 51Q3T OR LT07 AND SV04T OR OC3

TR4     := 0
TRXFMR  := 87R OR 87U
REMTRIP := 0
ULTRIP1 := NOT (51P1P OR 51Q1P OR 52A1)
ULTRIP2 := NOT (51P2P OR 51Q2P OR 52A2)
ULTRIP3 := NOT (51P3P OR 51Q3P OR 52A3)
```

Figure 10.4 Example Standard 15-Cycle Analog Event Report 1/4-Cycle Resolution (Continued)

```
ULTRIP4 := 1
ULTRXFMR:= NOT (87R OR 87U)
52A1    := IN101
52B1    := NOT 52A1
CL1     := SV03T AND LT05 OR CC1
ULCL1   := TRIP1 OR TRIPXFMR
52A2    := IN102
52B2    := NOT 52A2
CL2     := SV03T AND LT06 OR CC2
ULCL2   := TRIP2 OR TRIPXFMR
52A3    := 0
52B3    := NOT 52A3
CL3     := SV03T AND LT07 OR CC3
ULCL3   := TRIP3 OR TRIPXFMR

52A4    := 0
52B4    := NOT 52A4
CL4     := 0
ULCL4   := TRIP4 OR TRIPXFMR


Report Settings

ESERDEL := N

SER1    := IN101 IN102 PB01 PB02 PB03 52A1 52A2 TRIP1 TRIP2 TRIP TRIPXFMR
SER2    := ORED51T ORED50T 87U 87R REF3AF REF3BF RTDT
SER3    := NA
SER4    := SALARM

EALIAS  := 3

ALIAS1  :=PB01 FP_LOCK PICKUP DROPOUT
ALIAS2  :=PB02 FP_CLOSE PICKUP DROPOUT
ALIAS3  :=PB03 FP_TRIP PICKUP DROPOUT


ER      := R_TRIG RB01
LER     := 15      PRE     := 5
FMR1NAM := FMR1
FMR1    :=NA
FMR2NAM := FMR2
FMR2    :=NA
FMR3NAM := FMR3
FMR3    :=NA
FMR4NAM := FMR4
FMR4    :=NA
RA01TYPE:= I
RA02TYPE:= I
RA03TYPE:= I
RA04TYPE:= I
RA05TYPE:= I
RA06TYPE:= I
RA07TYPE:= I
RA08TYPE:= I
RA09TYPE:= I
RA10TYPE:= I
RA11TYPE:= I
RA12TYPE:= I
RA13TYPE:= I
RA14TYPE:= I
RA15TYPE:= I
RA16TYPE:= I
RA17TYPE:= I
RA18TYPE:= I
RA19TYPE:= I
RA20TYPE:= I
RA21TYPE:= I
RA22TYPE:= I
RA23TYPE:= I
RA24TYPE:= I
RA25TYPE:= I
RA26TYPE:= I
RA27TYPE:= I
RA28TYPE:= I
RA29TYPE:= I
RA30TYPE:= I
RA31TYPE:= I
RA32TYPE:= I
```

Figure 10.4 Example Standard 15-Cycle Analog Event Report 1/4-Cycle Resolution (Continued)

```
LDLIST  := NA

LDAR    := 15


Logic Settings


ELAT    := N        ESV     := N        ESC     := N        EMV     := N


OUT101FS:= Y        OUT101  := HALARM OR SALARM
OUT102FS:= N        OUT102  := 0
OUT103FS:= N        OUT103  := TRIPXFMR


=>



=>EVE E 13 <Enter>

SEL-787-3S                              Date: 03/23/2018   Time: 13:45:14.299
TRNSFRMR RELAY


Serial Number = 000000000000000
FID=SEL-787-4-X345-V0-Z003002-D20180321   CID=FCB7



                                                                O
                                                              I u
                                                              N t
       Currents (Amps Pri)      Voltages (Volts Pri)          1 13
   IAW3   IBW3   ICW3   IGW3 VS/VDC     VA     VB     VC Freq 2 2
[1]
    0.0   -5.0   -5.0  -10.0  -1.2     -1      0      1 60.00 . ..
    0.0    0.0   -5.0   -5.0  -1.2      0      0      0 60.00 . ..
   -5.0    0.0    5.0    0.0   0.0     -1     -2     -1 60.00 . ..
   -5.0   -5.0    0.0  -10.0  -1.2      0     -2     -1 60.00 . ..
[2]
    0.0   -5.0  -10.0  -15.0  -1.2      0      1      0 60.00 . ..
    0.0   -5.0    0.0   -5.0  -1.2     -1      1      0 60.00 . ..
   -5.0    0.0    0.0   -5.0   0.0     -1     -4     -1 60.00 . ..
   -5.0   -5.0    0.0  -10.0   0.0     -1     -2     -1 60.00 . ..
[3]
    0.0   -5.0   -5.0  -10.0  -1.2     -1      1      0 60.00 . ..
    0.0    0.0   -5.0   -5.0  -2.4      0      0      1 60.00 . ..
  160.0 -320.0  150.0  -10.0   0.0   1129  -2102    991 60.00 . ..
  250.0  165.0 -425.0  -10.0   0.0   1625   1153  -2930 60.00 . ..
.
.
.
[15]
-1040.0 1035.0    0.0   -5.0  -1.2  -6863   6719    299 60.00 . .*
 -600.0 -605.0 1195.0  -10.0  -1.2  -3760  -4022   8056 60.00 . .*
 1030.0-1040.0   -5.0  -15.0   0.0   6865  -6715   -310 60.00 . .*
  595.0  600.0-1205.0  -10.0  -1.2   3750   4028  -8057 60.00 . .*

Serial No = 000000000000000
FID = SEL-787-4-X345-V0-Z003002-D20180321               CID = FCB7
EVENT LOGS = 13             REF_NUM = 10000

Event:     Diff 87 Trip
Targets    11100000
Freq (Hz)  60.0

Winding One Current Mag
       IAW1          IBW1          ICW1          IGW1
(A)      99.7         101.5          99.4          3.61

Winding Two Current Mag
       IAW2          IBW2          ICW2          IGW2
(A)     993.2        1010.2         990.6         35.36

Winding Three Current Mag
       IAW3          IBW3          ICW3          IGW3
(A)    1200.5        1206.3        1195.2         18.03

Voltage Mag
       VAN    VBN    VCN    VG
(V)    7826   7828   8060    316

=>
```

Figure 10.4 Example Standard 15-Cycle Analog Event Report 1/4-Cycle Resolution (Continued)

Figure 10.5 and *Figure 10.6* look in detail at an example of one cycle of A-phase current (Channel IAW1) data. *Figure 10.5* shows how the event report ac current column data relate to the actual sampled waveform and rms values. *Figure 10.6* shows how the event report current column data can be converted to phasor rms values. Voltages are processed similarly.

In *Figure 10.5*, note that any two rows of current data from the analog event report, 1/4 cycle apart, can be used to calculate rms current values.

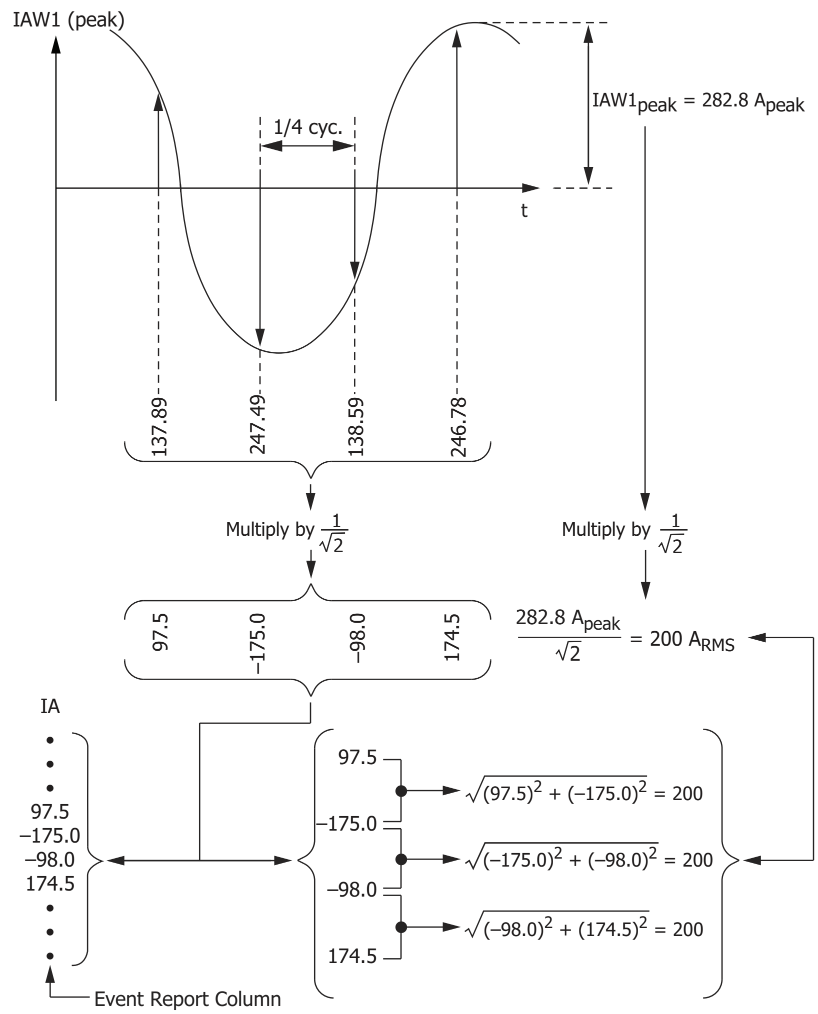


Figure 10.5 Derivation of Analog Event Report Current Values and RMS Current Values From Sampled Current Waveform

In *Figure 10.6*, note that two rows of current data from the analog event report, 1/4 cycle apart, can be used to calculate phasor rms current values. In *Figure 10.6*, at the present sample, the phasor rms current value is:

$$\mathrm{IAW1} = 200\ \mathrm{A}\ \angle{-29.3°} \qquad \textbf{Equation 10.1}$$

The present sample (IAW1 = 174.5 A) is a real rms current value that relates to the phasor rms current value:

$$200\ \mathrm{A} \bullet \cos(-29.3°) = 174.5\ \mathrm{A} \qquad \textbf{Equation 10.2}$$

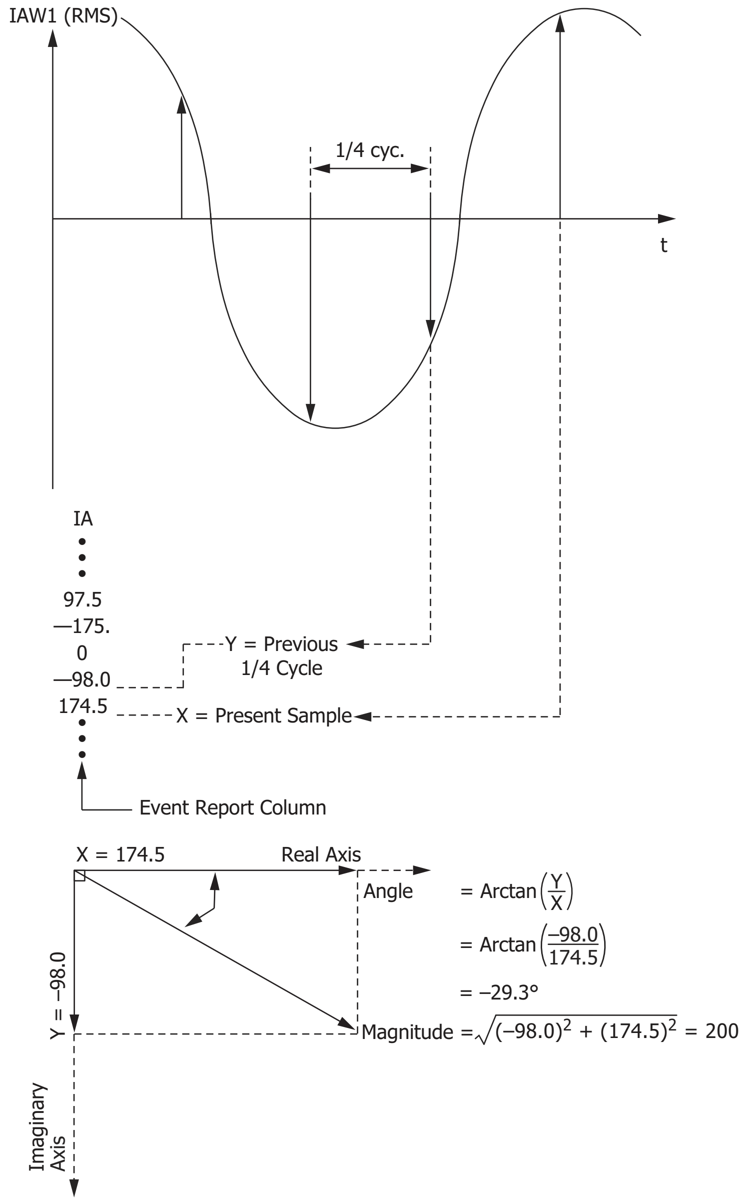


Figure 10.6 Derivation of Phasor RMS Current Values From Event Report Current Values

NOTE: The arctan function of many calculators and computing programs does not return the correct angle for the second and third quadrants (when X is negative). When in doubt, graph the X and Y quantities to confirm that the angle that your calculator reports is correct.

Digital Event Report (EVE D Command)

The digital event report includes:

- Digital states of control and protection elements, including overcurrent and voltage elements (if voltage inputs are available), plus status of digital inputs and outputs and RTD status
- Event summary (includes the serial number of the product)
- Settings in service at the time of event triggering, consisting of Group, Logic, Global, and Report settings classes

Use the **EVE D *n*** command to view the normal digital report for Slot Z protection elements with 4 samples/cycle for report *n* (if not listed, *n* is assumed to be 1). **EVE D R** gives the RAW report with 32 samples/cycle. Use the **EVE D E** command to view the digitals for Slot E protection elements.

Refer to the example event report in *Figure 10.7* to view the digital event report columns.

This example event report displays rows of information each 1/4 cycle. Retrieve this report with the **EVE D** command.

Table 10.6 gives the digital event report column definitions for the protection and control elements and the inputs and outputs.

NOTE: Active bits depend on the options included in the relay.

Table 10.6 Digital Event Report Column Definitions (Sheet 1 of 5)

Column Designation	Column Symbols	Column Symbol Relay Word Bits (RWB)
50P11	* t	50P11P picked up 50P11T picked up
50P12	* t	50P12P picked up 50P12T picked up
50P13	* t	50P13P picked up 50P13T picked up
50P14	* t	50P14P picked up 50P14T picked up
50G11	* t	50G11P picked up 50G11T picked up
50G12	* t	50G12P picked up 50G12T picked up
50Q11	* t	50Q11P picked up 50Q11T picked up
50Q12	* t	50Q12P picked up 50Q12T picked up
51P1	* t r	51P1P picked up 51P1T picked up 51P1R picked up
51G1	* t r	51G1P picked up 51G1T picked up 51G1R picked up
51Q1	* t r	51Q1P picked up 51Q1T picked up 51Q1R picked up
50P21	* t	50P21P picked up 50P21T picked up
50P22	* t	50P22P picked up 50P22T picked up
50P23	* t	50P23P picked up 50P23T picked up
50P24	* t	50P24P picked up 50P24T picked up
50G21	* t	50G21P picked up 50G21T picked up
50G22	* t	50G22P picked up 50G22T picked up
50Q21	* t	50Q21P picked up 50Q21T picked up
50Q22	* t	50Q22P picked up 50Q22T picked up

Table 10.6 Digital Event Report Column Definitions (Sheet 2 of 5)

Column Designation	Column Symbols	Column Symbol Relay Word Bits (RWB)
51P2	* t r	51P2P picked up 51P2T picked up 51P2R picked up
51G2	* t r	51G2P picked up 51G2T picked up 51G2R picked up
51Q2	* t r	51Q2P picked up 51Q2T picked up 51Q2R picked up
50P31	* t	50P31P picked up 50P31T picked up
50P32	* t	50P32P picked up 50P32T picked up
50P33	* t	50P33P picked up 50P33T picked up
50P34	* t	50P34P picked up 50P34T picked up
50G31	* t	50G31P picked up 50G31T picked up
50G32	* t	50G32P picked up 50G32T picked up
50Q31	* t	50Q31P picked up 50Q31T picked up
50Q32	* t	50Q32P picked up 50Q32T picked up
51P3	* t r	51P3P picked up 51P3T picked up 51P3R picked up
51G3	* t r	51G3P picked up 51G3T picked up 51G3R picked up
51Q3	* t r	51Q3P picked up 51Q3T picked up 51Q3R picked up
50P41	* t	50P41P picked up 50P41T picked up
50P42	* t	50P42P picked up 50P42T picked up
50P43	* t	50P43P picked up 50P43T picked up
50P44	* t	50P44P picked up 50P44T picked up
50G41	* t	50G41P picked up 50G41T picked up
50G42	* t	50G42P picked up 50G42T picked up
50Q41	* t	50Q41P picked up 50Q41T picked up

Table 10.6 Digital Event Report Column Definitions (Sheet 3 of 5)

Column Designation	Column Symbols	Column Symbol Relay Word Bits (RWB)
50Q42	* t	50Q42P picked up 50Q42T picked up
51P4	* t r	51P4P picked up 51P4T picked up 51P4R picked up
51G4	* t r	51G4P picked up 51G4T picked up 51G4R picked up
51Q4	* t r	51Q4P picked up 51Q2T picked up 51Q2R picked up
50N1	* t	50N1P picked up 50N1T picked up
50N2	* t	50N2P picked up 50N2T picked up
51N1	* t r	51N1P picked up 51N1T picked up 51N1R picked up
27P1	* t	27P1 picked up 27P1T picked up
27P2	* t	27P2 picked up 27P2T picked up
59P1	* t	59P1 picked up 59P1T picked up
59P2	* t	59P2 picked up 59P2T picked up
24D1	1 D	24D1 picked up 24D1T picked up
24C2	2 C r	24C2 picked up 24C2T picked up 24CR picked up
3PW1	* t	3PWR1P picked up 3PWR1T picked up
3PW2	* t	3PWR2P picked up 3PWR2T picked up
81D12	1 2 b	81D1T picked up 81D2T picked up Both 81D1T and 81D2T picked up
81D34	3 4 b	81D3T picked up 81D4T picked up Both 81D3T and 81D4T picked up
BFI1	* t	BFI1 picked up BFT1 picked up
BFI2	* t	BFI2 picked up BFT2 picked up
BFI3	* t	BFI3 picked up BFT3 picked up
BFI4	* t	BFI4 picked up BFT4 picked up

Table 10.6 **Digital Event Report Column Definitions** (Sheet 4 of 5)

Column Designation	Column Symbols	Column Symbol Relay Word Bits (RWB)
REF1	*	REF1P picked up
	f	REF1F picked up
	r	REF1R picked up
REF3A	*	REF3AP picked up
	f	REF3AF picked up
	r	REF3AR picked up
REF3B	*	REF3BP picked up
	f	REF3BF picked up
	r	REF3BR picked up
TRIP	*	Asserted
Inputs 3012	1	IN301 picked up
	2	IN302 picked up
	b	Both IN301 and IN302 picked up
Inputs 3034	3	IN303 picked up
	4	IN304 picked up
	b	Both IN303 and IN304 picked up
Inputs 3056	5	IN305 picked up
	6	IN306 picked up
	b	Both IN305 and IN306 picked up
Inputs 3078	7	IN307 picked up
	8	IN308 picked up
	b	Both IN307 and IN308 picked up
Inputs 4012	1	IN401 picked up
	2	IN402 picked up
	b	Both IN401 and IN402 picked up
Inputs 4034	3	IN403 picked up
	4	IN404 picked up
	b	Both IN403 and IN404 picked up
Inputs 4056	5	IN405 picked up
	6	IN406 picked up
	b	Both IN405 and IN406 picked up
Inputs 4078	7	IN407 picked up
	8	IN408 picked up
	b	Both IN407 and IN408 picked up
Outputs 3012	1	OUT301 picked up
	2	OUT302 picked up
	b	Both OUT301 and OUT302 picked up
Outputs 3034	3	OUT303 picked up
	4	OUT304 picked up
	b	Both OUT303 and OUT304 picked up
Outputs 3056	5	OUT305 picked up
	6	OUT306 picked up
	b	Both OUT305 and OUT306 picked up
Outputs 3078	7	OUT307 picked up
	8	OUT308 picked up
	b	Both OUT307 and OUT308 picked up
Outputs 4012	1	OUT401 picked up
	2	OUT402 picked up
	b	Both OUT401 and OUT402 picked up

Table 10.6 Digital Event Report Column Definitions (Sheet 5 of 5)

Column Designation	Column Symbols	Column Symbol Relay Word Bits (RWB)
Outputs 4034	3 4 b	OUT403 picked up OUT404 picked up Both OUT403 and OUT404 picked up
Outputs 4056	5 6 b	OUT405 picked up OUT406 picked up Both OUT405 and OUT406 picked up
Outputs 4078	7 8 b	OUT407 picked up OUT408 picked up Both OUT407 and OUT408 picked up
RTD Amb	a t	AMBALRM picked up AMBTRIP picked up
RTD Oth	a t	OTHALRM picked up OTHTRIP picked up
In12	1 2 b	IN101 picked up IN102 picked up Both IN101 and IN102 picked up
Out12	1 2 b	OUT101 picked up OUT102 picked up Both OUT101 and OUT102 picked up
Out3	*	OUT103 picked up

NOTE: The settings are not shown here because they are the same as the settings shown in Figure 10.4.

```
=>EVE D 13 <Enter>

SEL-787-3S                                 Date: 03/23/2018   Time: 13:45:14.299
TRNSFRMR RELAY


Serial Number = 000000000000000
FID=SEL-787-4-X345-V0-Z003002-D20180321   CID=FCB7

Winding1    Winding2                                 Optional I/O
                                                     Inputs       Outputs
                                               RRR                      RTD  O
50      51  50      51  555 2255 22 33 81 BBBB EEE T 33334444 33334444    I u
PPPPGGQQPGQ PPPPGGQQPGQ 001 7799 44 PP DD FFFF FFF R 00000000 00000000 AO n t
11111111111 22222222222 NNN PPPP DC WW 13 IIII 133 I 13571357 13571357 mt 1 13
12341212    12341212    121 1212 12 12 24 1234  AB P 24682468 24682468 bh 2 2
[1]
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..

[2]
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
[3]
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..

[4]
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
[5]
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..>
```

Figure 10.7 Example Standard 15-Cycle Digital Event Report (EVE D Command) 1/4-Cycle Resolution

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[6]
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. ***. ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .**
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
[7]
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
[8]
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
[9]
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
[10]
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*

[11]
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
[12]
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
[13]
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
[14]
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
[15]
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
Serial No = 000000000000000
FID = SEL-787-4-X345-V0-Z003002-D20180321             CID = FCB7
EVENT LOGS = 13             REF_NUM = 10000

Event:     Diff 87 Trip
Targets    11100000
Freq (Hz)  60.0


Winding One Current Mag
       IAW1          IBW1          ICW1          IGW1
(A)      99.7         101.5          99.4          3.61

Winding Two Current Mag
       IAW2          IBW2          ICW2          IGW2
(A)     993.2        1010.2         990.6         35.36


Winding Three Current Mag
       IAW3          IBW3          ICW3          IGW3
(A)    1200.5        1206.3        1195.2         18.03

Voltage Mag
       VAN    VBN    VCN    VG
(V)    7826   7828   8060    316

=>
```

Figure 10.7 Example Standard 15-Cycle Digital Event Report (EVE D Command) 1/4-Cycle Resolution (Continued)

```
=>EVE D E 13 <Enter>

SEL-787-3S                                  Date: 03/23/2018   Time: 13:45:14.299
TRNSFRMR RELAY


Serial Number = 000000000000000
FID=SEL-787-4-X345-V0-Z003002-D20180321   CID=FCB7


Winding3    Winding4                                   Optional I/O
                                              Inputs     Outputs
                                               RRR                     RTD  O
50      51  50      51  555 2255 22 33 81 BBBB EEE T 33334444 33334444    I u
PPPPGGQQPGQ PPPPGGQQPGQ 001 7799 44 PP DD FFFF FFF R 00000000 00000000 AO n t
33333333333 44444444444 NNN PPPP DC WW 13 IIII 133 I 13571357 13571357 mt 1 13
12341212    12341212    121 1212 12 12 24 1234  AB P 24682468 24682468 bh 2 2
[1]
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
[2]
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
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........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
[3]
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
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[4]
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
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[5]
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........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. .... ... . ........ ........ .. . ..>
[6]
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . ..
........rrr ........rrr ..r .... .r .. .. ***. ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .**
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
[7]
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
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........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
[8]
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
[9]
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*

[10]
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
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[11]
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[12]
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........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
[13]
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
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........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
```

Figure 10.7 Example Standard 15-Cycle Digital Event Report (EVE D Command) 1/4-Cycle Resolution (Continued)

```
[14]
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
[15]
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
........rrr ........rrr ..r .... .r .. .. .... ... * ........ ........ .. . .*
Serial No = 000000000000000
FID = SEL-787-4-X345-V0-Z003002-D20180321               CID = FCB7
EVENT LOGS = 13             REF_NUM = 10000

Event:     Diff 87 Trip
Targets    11100000
Freq (Hz)  60.0

Winding One Current Mag
       IAW1          IBW1          ICW1          IGW1
(A)      99.7         101.5          99.4          3.61

Winding Two Current Mag
       IAW2          IBW2          ICW2          IGW2
(A)     993.2        1010.2         990.6         35.36

Winding Three Current Mag
       IAW3          IBW3          ICW3          IGW3
(A)    1200.5        1206.3        1195.2         18.03

Voltage Mag
       VAN    VBN    VCN    VG
(V)    7826   7828   8060    316

=>
```

Figure 10.7 Example Standard 15-Cycle Digital Event Report (EVE D Command) 1/4-Cycle Resolution (Continued)

Differential Event Report (EVE DIFz Command)

The differential event report includes:

- ➤ Differential analog quantities for 87-1, 87-2, and 87-3 differential elements
- ➤ Digital states of differential and harmonic protection elements, plus status of base model digital inputs and outputs
- ➤ Event summary (includes the serial number of the product)
- ➤ Settings in service at the time of event triggering, consisting of Group, Logic, Global, and Report settings classes)

Use the **EVE DIF*z n*** command to view the normal Differential Report (*z* = 1 for 87-1 element, *z* = 2 for 87-2 element, and *z* = 3 for 87-3 element) with 4 samples/cycle for report *n* (if not listed, *n* is assumed to be 1).

Refer to the example event report in *Figure 10.8* to view the differential event report columns. This example event report displays rows of information each 1/4 cycle. Retrieve this report with the **EVE DIF1** command.

Table 10.7 gives the Differential event report column definitions for the Analog Quantities IOP*z*, IRT*z*, I*z*F2, and I*z*F5 for *z* = 1, 2, and 3. *Table 10.8* gives the Differential event report digital column definitions for the Protection and Control elements and the base model inputs and outputs.

Table 10.7 Differential Event Report Column Definitions for Analog Quantities

Column Heading	Description
IOP1	Operate Current for Differential Element 87-1 (multiples of TAP)
IRT1	Restraint Current for Differential Element 87-1 (multiples of TAP)
I1F2	Second-Harmonic Current for Differential Element 87-1 (multiples of TAP)
I1F5	Fifth-Harmonic Current for Differential Element 87-1 (multiples of TAP)
IOP2	Operate Current for Differential Element 87-2 (multiples of TAP)
IRT2	Restraint Current for Differential Element 87-2 (multiples of TAP)
I2F2	Second-Harmonic Current for Differential Element 87-2 (multiples of TAP)
I2F5	Fifth-Harmonic Current for Differential Element 87-2 (multiples of TAP)
IOP3	Operate Current for Differential Element 87-3 (multiples of TAP)
IRT3	Restraint Current for Differential Element 87-3 (multiples of TAP)
I3F2	Second-Harmonic current for Differential Element 87-3 (multiples of TAP)
I3F5	Fifth-Harmonic current for Differential Element 87-3 (multiples of TAP)

Table 10.8 Differential Event Report Digital Column Definitions for Protection, Control, and I/O Elements

Column Designation	Column Symbols	Column Symbol Relay Word Bits (RWB)
87R	*	87R picked up
87R12	1 2 b	87R1 picked up 87R2 picked up Both 87R1 and 87R2 picked up
87R3	*	87R3 Picked up
87U12	1 2 b	87U1 picked up 87U2 picked up Both 87U1 and 87U2 picked up
87U3	*	87U3 Picked up
87B12	1 2 b	87BL1 picked up 87BL2 picked up Both 87BL1 and 87BL2 picked up
87B3	*	87BL3 picked up
87HR12	1 2 b	87HR1 picked up 87HR2 picked up Both 87HR1 and 87HR2 picked up
87HR3	*	87HR3 Picked up
HB1	2 5 b	2_4HB1 picked up 5HB1 picked up Both 2_4HB1 and 5HB1 picked up
HB2	2 5 b	2_4HB2 picked up 5HB2 picked up Both 2_4HB2 and 5HB2 picked up
HB3	2 5 b	2_4HB3 picked up 5HB3 picked up Both 2_4HB3 and 5HB3 picked up
TH5	a t	TH5 picked up TH5T picked up

NOTE: The settings are not shown here because they are the same as the settings shown in Figure 10.4.

```
=>EVE DIF 13 <Enter>

SEL-787-3S                               Date: 03/23/2018   Time: 13:45:14.299
TRNSFRMR RELAY


Serial Number = 000000000000000
FID=SEL-787-4-X345-V0-Z003002-D20180321   CID=FCB7

                                     Differential         O
        Differential Quantities      8 87 87 87 87       I u
           Multiples of TAP          7 R  U  B  HR HB  T n t
                                     R 13 13 13 13     H 1 13
   IOP1   IRT1   I1F2   I1F4   I1F5    2  2  2  2  123 5 2 2
[1]
  0.003  0.005  0.009  0.172  0.012  . .. .. .. .. ... . . ..
  0.010  0.011  0.003  0.171  0.010  . .. .. .. .. ... . . ..
  0.012  0.012  0.007  0.168  0.002  . .. .. .. .. ... . . ..
  0.007  0.007  0.005  0.168  0.007  . .. .. .. .. ... . . ..
[2]
  0.000  0.000  0.003  0.168  0.012  . .. .. .. .. ... . . ..
  0.012  0.012  0.002  0.169  0.010  . .. .. .. .. ... . . ..
  0.014  0.014  0.007  0.168  0.002  . .. .. .. .. ... . . ..
  0.008  0.008  0.003  0.168  0.008  . .. .. .. .. ... . . ..
[3]
  0.002  0.002  0.007  0.169  0.012  . .. .. .. .. ... . . ..
  0.225  0.225  0.002  0.169  0.010  . .. .. .. .. ... . . ..
  0.368  0.369  0.166  0.147  0.036  . .. .. b* .. 225 . . ..
  0.953  0.953  0.251  0.305  0.037  . .. .. b* .. 222 . . ..
[4]
  1.123  1.125  0.295  0.355  0.030  . .. .. b* .. .22 . . ..
  1.497  1.498  0.183  0.210  0.029  . .. .. b* .. 222 . . ..
  1.519  1.521  0.002  0.180  0.005  . 2. .. .. .. ... . . ..
  1.529  1.531  0.009  0.169  0.010  . b* .. .. .. ... . . ..
[5]
  1.531  1.533  0.003  0.166  0.012  . b* .. .. .. ... . . ..
  1.525  1.527  0.005  0.172  0.008  . b* .. .. .. ... . . ..
  1.519  1.521  0.008  0.172  0.002  . b* .. .. .. ... . . ..
  1.526  1.528  0.005  0.172  0.012> * b* .. .. b* ... . . ..
[6]
  1.529  1.531  0.007  0.172  0.015  * b* .. .. b* ... . . .*
  1.525  1.527  0.008  0.172  0.010  * b* .. .. b* ... . . .*
  1.523  1.525  0.005  0.172  0.003* * b* .. .. b* ... . . .*
  1.531  1.533  0.007  0.172  0.012  * b* .. .. b* ... . . .*
[7]
  1.533  1.535  0.005  0.172  0.012  * b* .. .. b* ... . . .*
  1.527  1.529  0.003  0.172  0.002  * b* .. .. b* ... . . .*
  1.523  1.524  0.007  0.172  0.000  * b* .. .. b* ... . . .*
  1.529  1.531  0.005  0.172  0.007  * b* .. .. b* ... . . .*
[8]
  1.530  1.532  0.005  0.169  0.012  * b* .. .. b* ... . . .*
  1.524  1.526  0.002  0.175  0.010  * b* .. .. b* ... . . .*
  1.522  1.524  0.005  0.175  0.002  * b* .. .. b* ... . . .*
  1.530  1.532  0.003  0.175  0.008  * b* .. .. b* ... . . .*
[9]
  1.533  1.535  0.007  0.176  0.012  * b* .. .. b* ... . . .*
  1.529  1.531  0.005  0.175  0.010  * b* .. .. b* ... . . .*
  1.524  1.525  0.008  0.175  0.000  * b* .. .. b* ... . . .*
  1.528  1.530  0.007  0.177  0.007  * b* .. .. b* ... . . .*
[10]
  1.531  1.533  0.005  0.176  0.012  * b* .. .. b* ... . . .*
  1.527  1.529  0.005  0.178  0.011  * b* .. .. b* ... . . .*
  1.522  1.524  0.005  0.175  0.005  * b* .. .. b* ... . . .*
  1.531  1.533  0.008  0.178  0.010  * b* .. .. b* ... . . .*

[11]
  1.534  1.536  0.002  0.173  0.011  * b* .. .. b* ... . . .*
  1.528  1.530  0.007  0.171  0.005  * b* .. .. b* ... . . .*
  1.525  1.527  0.002  0.174  0.000  * b* .. .. b* ... . . .*
  1.531  1.533  0.005  0.172  0.007  * b* .. .. b* ... . . .*
[12]
  1.532  1.534  0.002  0.174  0.010  * b* .. .. b* ... . . .*
  1.526  1.528  0.009  0.170  0.008  * b* .. .. b* ... . . .*
  1.520  1.522  0.005  0.172  0.002  * b* .. .. b* ... . . .*
  1.527  1.529  0.009  0.173  0.010  * b* .. .. b* ... . . .*
[13]
  1.530  1.532  0.003  0.172  0.012  * b* .. .. b* ... . . .*
  1.526  1.527  0.009  0.172  0.007  * b* .. .. b* ... . . .*
  1.522  1.524  0.002  0.174  0.002  * b* .. .. b* ... . . .*
  1.531  1.533  0.007  0.176  0.008  * b* .. .. b* ... . . .*
```

Figure 10.8 Example Standard 15-Cycle Differential Event Report (EVE DIF1 Command) 1/4-Cycle Resolution

```
[14]
  1.533  1.535  0.003  0.176  0.010  * b* .. .. b* ... . . .*
  1.527  1.529  0.007  0.175  0.008  * b* .. .. b* ... . . .*
  1.522  1.524  0.009  0.177  0.002  * b* .. .. b* ... . . .*
  1.531  1.533  0.007  0.172  0.007  * b* .. .. b* ... . . .*
[15]
  1.532  1.534  0.002  0.172  0.010  * b* .. .. b* ... . . .*
  1.524  1.526  0.007  0.168  0.008  * b* .. .. b* ... . . .*
  1.520  1.522  0.003  0.171  0.002  * b* .. .. b* ... . . .*
  1.527  1.529  0.007  0.170  0.005  * b* .. .. b* ... . . .*
Serial No = 000000000000000
FID = SEL-787-4-X345-V0-Z003002-D20180321              CID = FCB7
EVENT LOGS = 13             REF_NUM = 10000

Event:     Diff 87 Trip
Targets    11100000
Freq (Hz)  60.0

Winding One Current Mag
       IAW1          IBW1          ICW1          IGW1
(A)      99.7         101.5          99.4          3.61

Winding Two Current Mag
       IAW2          IBW2          ICW2          IGW2
(A)     993.2        1010.2         990.6         35.36

Winding Three Current Mag
       IAW3          IBW3          ICW3          IGW3
(A)    1200.5        1206.3        1195.2         18.03

Voltage Mag
       VAN    VBN    VCN    VG
(V)    7826   7828   8060    316

=>
```

Figure 10.8 Example Standard 15-Cycle Differential Event Report (EVE DIF1 Command) 1/4-Cycle Resolution (Continued)

Retrieving Event Reports Via Ethernet File Transfer

Selected event reports are available as read-only files that can be retrieved through the use of Ethernet File Transfer Protocol (FTP) or Manufacturing Message Specification (MMS). MMS is only available in models that support IEC 61850 and only when IEC 61850 and MMS File transfer are enabled (E61850 := Y, EMMSFS := Y). See *File Transfer Protocol (FTP) and MMS File Transfer on page 7.15*, *Virtual File Interface on page 7.73*, and *MMS on page G.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, 32 sample/cycle, unfiltered event, equivalent to issuing a **CEV R** 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** command) and the compressed event history (equivalent to the **CHIS** command). See *HISTORY Command on page 7.52*. The Event files can also be retrieved with the **FIL** command. See *FILE Command on page 7.48* and *Compressed Event Reports on page 10.2* for additional information.

CEVENT

The relay provides a Compressed ASCII event report for SCADA and other automation applications. QuickSet uses Compressed ASCII commands to gather event report data. If you want to view the Compressed ASCII event report data, use a terminal to issue ASCII command **CEV**. A sample of the report appears in *Figure 10.9*; this is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of the line in the Compressed ASCII report.

NOTE: The CEV DIF report includes the operate and restraint currents IOPQ and IRTQ (associated with the 87Q element) that are not included in the EVE DIF report.

Items included in the Compressed ASCII event report are similar to the event report, although the relay reports the items in a special order. CEV files (and COMTRADE files) include all Relay Word bits (see *Appendix L: Relay Word Bits*). See *SEL Compressed ASCII Commands on page C.1* for more information on the Compressed ASCII command set.

Report Header

```
=>CEV 13 <Enter>
"FID","CEV_VER","PART_NUM","SER_NUM","097C"
"FID=SEL-787-4-X345-V0-Z003002-D20180321","2.0.1","07873SE1B0X0X7585A87X","000000000000000","132E"
"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0ACA"
3,23,2018,13,45,14,299,"046D"
```

Summary Labels

```
"REC_NUM","REF_NUM","NUM_CH_A","NUM_CH_D","FREQ","NFREQ","SAM/CYC_A","SAM/
 CYC_D","NUM_OF_CYC","PRIM_VAL","CTR_IAW1","CTR_IBW1","CTR_ICW1","CTR_IGW1","CTR_IAW2","CTR_IBW2","C
 TR_ICW2","CTR_IGW2","CTR_IAW3","CTR_IBW3","CTR_ICW3","CTR_IGW3","*","*","*","*","*","PTR_VS","*","P
 TR_VA","PTR_VB","PTR_VC","EVENT","GROUP","IAW1(A)","IBW1(A)","ICW1(A)","IGW1(A)","IAW2(A)","IBW2(A)
 ","ICW2(A)","IGW2(A)","IAW3(A)","IBW3(A)","ICW3(A)","IGW3(A)","*","*","*","*","*","VS(V)","*","VA(V
 )","VB(V)","VC(V)","VG(V)","AMB(C)","OTH(C)","76B9"
```

Summary Data

```
13,10000,22,1312,60.0,60,4,4,15,"YES",100.00,100.00,100.00,100.00,1000.00,1000.00,1000.00,1000.00,10
 00.00,1000.00,1000.00,1000.00,1.0,1.0,1.0,1.0,1.0,120.00,1.0,120.00,120.00,120.00,"Diff 87
 Trip",1,99.7,101.5,99.4,3.61,993.2,1010.2,990.6,35.36,1200.5,1206.3,1195.2,18.03,0,0,0,0,0,0.000,0.
 000,7826.578,7828.628,8060.361,316.911,"NA","NA","41A8"
```

Column Labels

```
"IAW1(A)","IBW1(A)","ICW1(A)","IGW1(A)","IAW2(A)","IBW2(A)","ICW2(A)","IGW2(A)","IAW3(A)","IBW3(A)",
 "ICW3(A)","IGW3(A)","*","*","*","*","*","VS(V)","*","VA(V)","VB(V)","VC(V)","TRIG","50P11T 50P12T
 50P13T 50P14T 50P21T 50P22T 50P23T 50P24T 50P31T 50P32T 50P33T 50P34T 50P41T 50P42T 50P43T 50P44T
 50G11T 50G12T 50G21T 50G22T 50G31T 50G32T 50G41T 50G42T 50Q11T 50Q12T 50Q21T 50Q22T 50Q31T 50Q32T
 50Q41T 50Q42T 51P1T 51P2T 51P3T 51P4T 51Q1T 51Q2T 51Q3T 51Q4T 51G1T 51G2T 51G3T 51G4T * * * * REMTRIP
 * * * * * ORED50T ORED51T 50P11P 50P12P 50P13P 50P14P 50P21P 50P22P 50P23P 50P24P 50P31P 50P32P
 50P33P 50P34P 50P41P 50P42P 50P43P 50P44P 50G11P 50G12P 50G21P 50G22P 50G31P 50G32P 50G41P 50G42P
 50Q11P 50Q12P 50Q21P 50Q22P 50Q31P 50Q32P 50Q41P 50Q42P 51P1P 51P2P 51P3P 51P4P 51Q1P 51Q2P 51Q3P
 51Q4P 51G1P 51G2P 51G3P 51G4P * * * * 51P1R 51P2R 51P3R 51P4R 51Q1R 51Q2R 51Q3R 51Q4R 51G1R 51G2R
 51G3R 51G4R * * * * 50N11P 50N12P 50N11T 50N12T 51N1T * 51N1P 51N1R 50P31AP 50P31AT 50P31BP 50P31BT
 50P31CP 50P31CT * * 50P32AP 50P32AT 50P32BP 50P32BT 50P32CP 50P32CT * * 51P3AP 51P3AT 51P3BP 51P3BT
 51P3CP 51P3CT * * 51P3AR 51P3BR 51P3CR * 51PC12R 51PC34R 51GC12R 51GC34R 51PC12P 51PC34P 51GC12P
 51GC34P 51PC12T 51PC34T 51GC12T 51GC34T TH5 87AP TH5T 87AT 52A1 52A2 52A3 52A4 87U1 87U2 87U3 87U
 87R1 87R2 87R3 87R 2_4HB1 2_4HB2 2_4HB3 2_4HBL 5HB1 5HB2 5HB3 5HBL 87BL1 87BL2 87BL3 87HB 87HR1 87HR2
 87HR3 87HR REF1E REF1BY REF1F REF1R REF1FP REF1RP 50NREF1 50GREF1 REF3AE REF3ABY REF3AF REF3AR
 REF3AFP REF3ARP 50NREF3A 50GREF3A REF3BE REF3BBY REF3BF REF3BR REF3BFP REF3BRP 50NREF3B 50GREF3B
 24D1 24D1T 24C2 24C2T 24CR * * * 3PWR1P 3PWR2P 3PWR1T 3PWR2T * * DCHI DCLO 59P1 59P2 59P1T 59P2T
 59PP1 59PP2 59PP1T 59PP2T 59G1 59G2 59G1T 59G2T 59Q1 59Q2 59Q1T 59Q2T 59S1 59S2 59S1T 59S2T * * 3P59
 * 27P1 27P2 27P1T 27P2T 27PP1 27PP2 27PP1T 27PP2T 27S1 27S2 27S1T 27S2T 3P27 * * * TRIP OUT101 OUT102
 OUT103 * * * * * * * * * * * * * * * * * * * * REF1PP REF1P REF3APP REF3AP REF3BPP REF3BP * * REF1PR
 REF3APR REF3BPR * * * * * IN101 IN102 * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * BFI1
 BFI2 BFI3 BFI4 BFT1 BFT2 BFT3 BFT4 RTDT AMBALRM AMBTRIP OTHALRM OTHTRIP * * * LINKA LINKB PMDOK
 SALARM WARNING TSOK IRIGOK FAULT COMMIDLE COMMLOSS COMMFLT CFGFLT LINKFAIL PASEL PBSEL LOP 81D1T
 81D2T 81D3T 81D4T LINK1 * * * FREQTRK ER FREQFZ * RSTENRGY RSTMXMN RSTDEM RSTPKDEM RTDFLT RTDIN TRGTR
 RTDA * DSABLSET RSTTRGT HALARM RTD1A RTD1T RTD2A RTD2T RTD3A RTD3T RTD4A RTD4T RTD5A RTD5T RTD6A
 RTD6T RTD7A RTD7T RTD8A RTD8T RTD9A RTD9T RTD10A RTD10T RTD11A RTD11T RTD12A RTD12T CLOSE1 CLOSE2
 CLOSE3 CLOSE4 * * * * SG1 SG2 SG3 SG4 TREA1 TREA2 TREA3 TREA4 TR1 TR2 TR3 TR4 TRIP1 TRIP2 TRIP3 TRIP4
 ULTRIP1 ULTRIP2 ULTRIP3 ULTRIP4 ULCL1 ULCL2 ULCL3 ULCL4 OC1 OC2 OC3 OC4 CL1 CL2 CL3 CL4 CC1 CC2 CC3
 CC4 CF1 CF2 CF3 CF4 PMTRIG ULTRXFMR TRXFMR TRIPXFMR * * * * PB01 PB02 PB03 PB04 PB05 PB06 PB07 PB08
 PB01_PUL PB02_PUL PB03_PUL PB04_PUL PB05_PUL PB06_PUL PB07_PUL PB08_PUL PB1A_LED PB1B_LED PB2A_LED
 PB2B_LED PB3A_LED PB3B_LED PB4A_LED PB4B_LED PB5A_LED PB5B_LED PB6A_LED PB6B_LED PB7A_LED PB7B_LED
 PB8A_LED PB8B_LED * * T01_LED T02_LED T03_LED T04_LED T05_LED T06_LED DNAUX1 DNAUX2 DNAUX3 DNAUX4
 DNAUX5 DNAUX6 DNAUX7 DNAUX8 DNAUX9 DNAUX10 DNAUX11 RELAY_EN * INR1 INR2 INR3 PHDEM 3I2DEM GNDEM * *
 TFLTALA TFLTALB TFLTALC LB01 LB02 LB03 LB04 LB05 LB06 LB07 LB08 LB09 LB10 LB11 LB12 LB13 LB14 LB15
 LB16 LB17 LB18 LB19 LB20 LB21 LB22 LB23 LB24 LB25 LB26 LB27 LB28 LB29 LB30 LB31 LB32 RB01 RB02 RB03
 RB04 RB05 RB06 RB07 RB08 RB09 RB10 RB11 RB12 RB13 RB14 RB15 RB16 RB17 RB18 RB19 RB20 RB21 RB22 RB23
 RB24 RB25 RB26 RB27 RB28 RB29 RB30
```

Figure 10.9 Sample Compressed ASCII Event Report

```
 RB31 RB32 SV01 SV02 SV03 SV04 SV05 SV06 SV07 SV08 SV01T SV02T SV03T SV04T SV05T SV06T SV07T SV08T
 SV09 SV10 SV11 SV12 SV13 SV14 SV15 SV16 SV09T SV10T SV11T SV12T SV13T SV14T SV15T SV16T SV17 SV18
 SV19 SV20 SV21 SV22 SV23 SV24 SV17T SV18T SV19T SV20T SV21T SV22T SV23T SV24T SV25 SV26 SV27 SV28
 SV29 SV30 SV31 SV32 SV25T SV26T SV27T SV28T SV29T SV30T SV31T SV32T LT01 LT02 LT03 LT04 LT05 LT06
 LT07 LT08 LT09 LT10 LT11 LT12 LT13 LT14 LT15 LT16 LT17 LT18 LT19 LT20 LT21 LT22 LT23 LT24 LT25 LT26
 LT27 LT28 LT29 LT30 LT31 LT32 SC01QU SC02QU SC03QU SC04QU SC05QU SC06QU SC07QU SC08QU SC01QD SC02QD
 SC03QD SC04QD SC05QD SC06QD SC07QD SC08QD SC09QU SC10QU SC11QU SC12QU SC13QU SC14QU SC15QU SC16QU
 SC09QD SC10QD SC11QD SC12QD SC13QD SC14QD SC15QD SC16QD SC17QU SC18QU SC19QU SC20QU SC21QU SC22QU
 SC23QU SC24QU SC17QD SC18QD SC19QD SC20QD SC21QD SC22QD SC23QD SC24QD SC25QU SC26QU SC27QU SC28QU
 SC29QU SC30QU SC31QU SC32QU SC25QD SC26QD SC27QD SC28QD SC29QD SC30QD SC31QD SC32QD 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 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 * * * * * * * * * * * * * *
 * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 * * * * * * * * DI_A1 DI_B1 DI_C1 DI_A2 DI_B2 DI_C2 TESTDB MATHERR DI_A3 DI_B3 DI_C3 DI_A4 DI_B4
 DI_C4 * * TQUAL1 TQUAL2 TQUAL4 TQUAL8 DST DSTP LPSEC LPSECP TSNTPB TSNTPP TUTCS TUTC1 TUTC2 TUTC4
 TUTC8 TUTCH BCW1A BCW1B BCW1C BCW1 BCW2A BCW2B BCW2C BCW2 BCW3A BCW3B BCW3C BCW3 BCW4A BCW4B BCW4C B
CW4 59VP 59VS SF 25A1 25A2 * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * 89A2P1
 89B2P1 89CL2P1 89OP2P1 89A2P2 89B2P2 89CL2P2 89OP2P2 89A2P3 89B2P3 89CL2P3 89OP2P3 89A2P4 89B2P4
 89CL2P4 89OP2P4 89A2P5 89B2P5 89CL2P5 89OP2P5 89A2P6 89B2P6 89CL2P6 89OP2P6 89A2P7 89B2P7 89CL2P7
 89OP2P7 89A2P8 89B2P8 89CL2P8 89OP2P8 89A2P9 89B2P9 89CL2P9 89OP2P9 89A2P10 89B2P10 89CL2P10
 89OP2P10 89A2P11 89B2P11 89CL2P11 89OP2P11 89A2P12 89B2P12 89CL2P12 89OP2P12 89A2P13 89B2P13
 89CL2P13 89OP2P13 89A2P14 89B2P14 89CL2P14 89OP2P14 89A2P15 89B2P15 89CL2P15 89OP2P15 89A2P16
 89B2P16 89CL2P16 89OP2P16 89AL2P1 89AL2P2 89AL2P3 89AL2P4 89AL2P5 89AL2P6 89AL2P7 89AL2P8 89AL2P9
 89AL2P10 89AL2P11 89AL2P12 89AL2P13 89AL2P14 89AL2P15 89AL2P16 52B1 52B2 52B3 52B4 ENLRC LOCAL BKJMP
 * 27I1 27I1T 27I1RS 27I1TC 27I2 27I2T 27I2RS 27I2TC 59I1 59I1T 59I1RS 59I1TC 59I2 59I2T 59I2RS 59I2TC
 59I3 59I3T 59I3RS 59I3TC 59I4 59I4T 59I4RS 59I4TC * * * * * * * * * * * * * * * * * * * * * * * * *
 * * * * * * * * * * * * * * * * * * * * * * *","4D23"
```

Column Label

```
0.0,0.5,0.0,0.5,0.0,0.0,0.0,0.0,0.0,0.0,-5.0,-5.0,0.0,0.0,0.0,0.0,0.0,-2.4,0.0,0,0,1,
 ,"00000000000000000000000000FFF001000000EF00000000000000000800000000000000000000E0000000000000000C0
 00000000000008000F000040000000000001700000000000000000000000000000000000000000000000000000000000000
 00000000000000000000000000000000000000000000000000000000000000F000000000000000000000000000005555555
 5555555550000F2111111000000000000","4F0C"
15.5,-29.0,11.0,-2.5,155.0,-280.0,110.0,-15.0,160.0,-320.0,150.0,
 -10.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,1129,-2102,991,
 ,"00000000000000000000000000FFF001000000EF004000D3E00000000800000000000000000000E0000000000000000C0
 00000000000008000F000040000000000001700000000000000000000000000000000000000000000000000000000000000
 00000000000000000000000000000000000000000000000000000000000000F000000000000000000000000000005555555
 5555555550000F2111111000000000000","54F9"
18.5,18.5,-38.5,-1.5,175.0,205.0,-390.0,-10.0,250.0,165.0,-425.0,
 -10.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,1625,1153,-2930,
 ,"00000000000000000000000000FFF001000000EF004000F0E00000000800000000000000000000E0000000000000000C0
 00000000000008000F000040000000000001700000000000000000000000000000000000000000000000000000000000000
 00000000000000000000000000000000000000000000000000000000000000F000000000000000000000000000005555555
 5555555550000F2111111000000000000","554C"
-60.5,70.0,-7.5,2.0,-615.0,690.0,-70.0,5.0,-675.0,840.0,-170.0,-5.0,0.0,0.0,0.0,0.0,0.0,-1.2,0.0,-
 4512,5509,-946,
 ,"00000000000000000000000000FFF001000000EF00400070E00000000800000000000000000000E0000000000000000C0
 00000000000008000F000040000000000001700000000000000000000000000000000000000000000000000000000000000
 00000000000000000000000000000000000000000000000000000000000000F000000000000000000000000000005555555
 5555555550000F2111111000000000000","54E3"
```

Event Data (Cycle 1)

The clock shown represents four quarter cycles of data.

.
.
.

```
89.5,-84.0,-8.0,-2.5,900.0,-820.0,-105.0,-25.0,1020.0,-1055.0,25.0,
 -10.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,6774,-6808,-120,
 ,"00000000000000000000000000FFF001000000EF00400E00000000000800000000000000000000E0000000000000000C0
 00000000000008000F000040000000000001700000000000000000000000000000000000000000000000000000000000000
 00000000000000000000000000000000000000000000000000000000000000F000000000000000000000000000005555555
 5555555550000F2111111000000000000","558D"
43.5,56.0,-99.5,0.0,415.0,585.0,-995.0,5.0,620.0,575.0,-1200.0,
 -5.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,3911,3869,-
 8063,">","00000000000000000000000000FFF001000000EF00400F000F0000000800000000000008000000E0000000000
 000000C00000000000008000F000030000000002000170000000000000000000000000000000000000000000000000000
 0000000000000000000000000000000000000000000000000000000000000000000000F0000000000000000000000000000
 055555555555555550000F2111111000000000000","5556"
-90.0,83.5,8.0,1.5,-905.0,815.0,100.0,10.0,-1025.0,1050.0,-30.0,-5.0,0.0,0.0,0.0,0.0,0.0,-1.2,0.0,
 -6780,6804,127,
 ,"00000000000000000000000000FFF001000000EF00400F000F0000000800000000000009000000E000000000E000010C0
 00000000000008800FF0000B000000000200017000000000000000000000000000000000000000000000000000000000000
 00000000000000000000000000000000000000000000000000000000000000F000000000000000000000000000005555555
 5555555550000F2111111000000000000","5531"
```

Event Data

The quarter cycle with the ">" symbol represents the trigger row for the event.

Figure 10.9 Sample Compressed ASCII Event Report (Continued)

```
.
.
.
-44.0,-57.0,99.0,-2.0,-420.0,-590.0,985.0,-25.0,-625.0,-585.0,1195.0,
 -15.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,-3904,-3878,8059,
 ,"00000000000000000000000000FFF001000000EF00400F000F0000000800000000000090000000E0000000000000010C0
 0000000000000008800FF0000B000000000200017000000000000000000000000000000000000000000000000000000000
 00000000000000000000000000000000000000000000000000000000000000F000000000000000000000000000005555555
 555555555550000F2111111000000000000","569F"
89.5,-84.0,-8.5,-3.0,900.0,-820.0,-105.0,-25.0,1025.0,-1055.0,20.0,-
 10.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,6784,-6800,-
 137,"*","00000000000000000000000000FFF001000000EF00400F000F0000000800000000000090000000E00000000000
 00010C0000000000000008800FF0000B000000000200017000000000000000000000000000000000000000000000000000
 0000000000000000000000000000000000000000000000000000000000000000000000F0000000000000000000000000000
 5555555555555550000F2111111000000000000","562C"
43.5,56.5,-100.0,0.0,420.0,585.0,-995.0,10.0,620.0,575.0,-1200.0,-5.0,0.0,0.0,0.0,0.0,0.0,-
 1.2,0.0,3895,3886,-8060,
 ,"00000000000000000000000000FFF001000000EF00400F000F0000000800000000000090000000E0000000000000010C0
 0800000000000008800FF0000B000000000200017000000000000000000000000000000000000000000000000000000000
 00000000000000000000000000000000000000000000000000000000000000F000000000000000000000000000005555555
 555555555550000F2111111000000000000","55A9"
```

Event Data

The quarter cycle with the "*" symbol represents the row with the largest measured current for the event. This is the row used for the summary data.

```
Global Settings
PHROT   := ABC     FNOM    := 60      VS_VBAT := VS
DATE_F  := MDY     METHRES := Y
FAULT   := 51P1P OR 51P2P OR 51P3P OR 51G1P OR 51G2P OR 51G3P OR TRIP
EMP     := N       TGR     := 3
.
.
.
```

Global Settings

```
Group Settings

RID     := SEL-787-3S
TID     := TRNSFRMR RELAY
E87W1   := Y       E87W2   := Y       E87W3   := Y       W1CT    := WYE
W2CT    := WYE     W3CT    := WYE
CTR1    := 100     CTR2    := 1000    CTR3    := 1000    MVA     := 50.0
ICOM    := N       CCW12   := N       VWDG1   := 138.000 VWDG2   := 13.800
VWDG3   := 13.800
PTR     := 120.00  PTRS    := 120.00  VNOM    := 13.80   DELTA_Y := WYE
VIWDG   := 2       COMPANG := 0       SINGLEV := N
TAP1    := 2.09    TAP2    := 2.09    TAP3    := 2.09
O87P    := 0.30    87AP    := 0.15    87AD    := 5.00    SLP1    := 25
SLP2    := 70      IRS1    := 6.00
U87P    := 10.00   PCT2    := 15      PCT4    := 15      PCT5    := 35
TH5P    := OFF     HRSTR   := Y       HBLK    := N
.
.
.
```

Group Settings

```
Report Settings

ESERDEL := N

SER1    := IN101 IN102 PB01 PB02 PB03 52A1 52A2 TRIP1 TRIP2 TRIP TRIPXFMR
SER2    := ORED51T ORED50T 87U 87R REF3AF REF3BF RTDT
SER3    := NA
SER4    := SALARM

EALIAS  := 3
.
.
.
```

Report Settings

```
Logic Settings


ELAT    := N       ESV     := N       ESC     := N       EMV     := N
.
.
.
```

Logic Settings

```
=>
```

Figure 10.9 Sample Compressed ASCII Event Report (Continued)

The order of the labels in the digital portion of the Column Labels field matches the order of the HEX-ASCII Relay Word. Each numeral in the

HEX-ASCII Relay Word reflects the status of four Relay Word bits from the Digital Column Labels field of the Compressed ASCII event report. The HEX-ASCII Relay Word from the trigger cycle from *Figure 10.9* follows.

```
00000000000000000000000000FFF001000000EF004
00F000F0000000800000000000080000000E0000000000000000C000000000000008000F00000300
00000002000170000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000F000000000000000000000000
0000055555555555555550000F2111111000000000000
```

In this HEX-ASCII Relay Word, the first numeral in the HEX-ASCII Relay Word is an 0. In binary, this is 0000. Mapping the labels to the digital Column Labels yields the following:

```
50P11T        50P12T        50P13T        50P14T
  0             0             0             0
```

Viewing Compressed Event (CEV) Reports

The CEV can be viewed in the following ways:

- ➤ SYNCHROWAVE Event (SEL-5601-2)
- ➤ ACSELERATOR QuickSet SEL-5030 Software via SYNCHROWAVE Event (SEL-5601-2)

Using QuickSet, navigate to the **Options** menu under **Tools** and select SYNCHROWAVE Event (SEL-5601-2) as the event viewer.

NOTE: If CTCONX or CTCONY is set to DELTA for any given winding, then the corresponding channel currents reported in the CEV reports are compensated in magnitude (i.e., divided by square root 3). The phase angles are not compensated and reflect the same values as measured on the secondary. Refer to Delta-Connected CTs in Section 5: Metering and Monitoring.

To view the saved events using the SEL-5601 or SEL-5030 Software, click on the **View Event Files** function from the **Tools** > **Events** menu to select the event you want to view (QuickSet remembers the location where you stored the previous event record). Use **View Combined Event Files** to simultaneously view as many as three separate events. To view the saved events using SYNCHROWAVE Event software, click on the **Load Event** function on the right side of the screen.

As shown in *Figure 10.10*, all the analog and digital data can be viewed with SYNCHROWAVE Event or QuickSet via SYNCHROWAVE Event. The Export Event feature allows you to export the CEV report in COMTRADE format. Similarly, the Export Data feature allows you to export the CEV report in comma separated values (CSV) format.

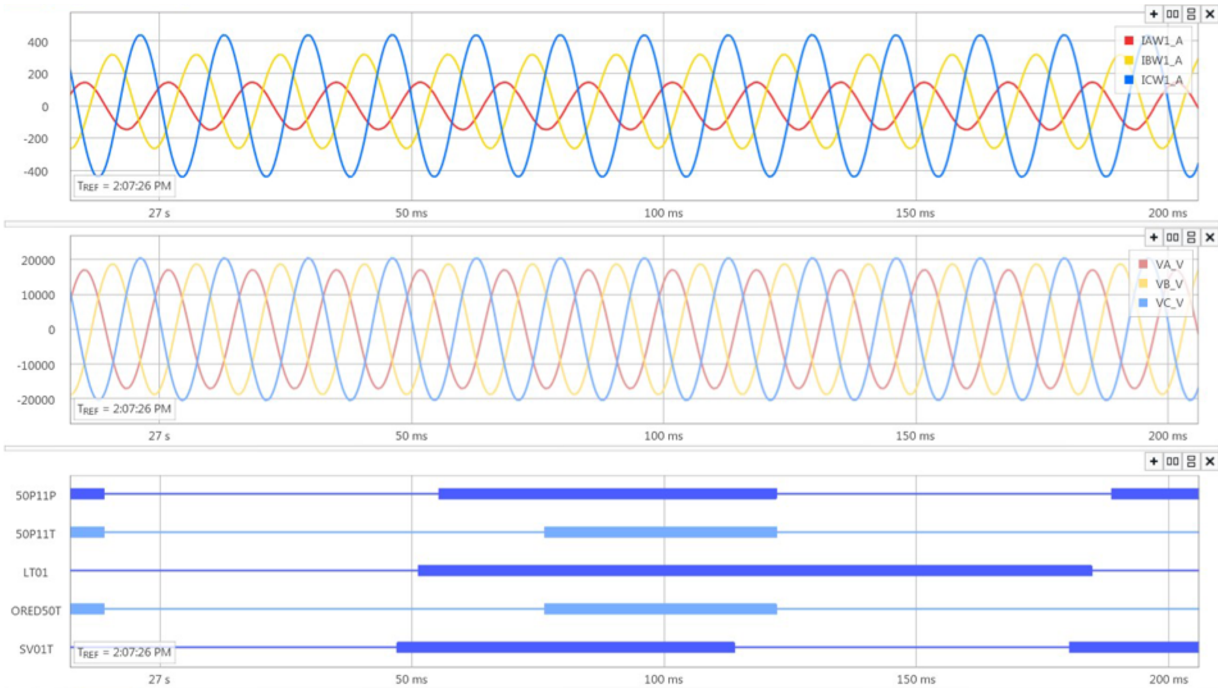


Figure 10.10 Sample CEV Report Viewed With SYNCHROWAVE Event

With SYNCHROWAVE Event, you have six options for converting CEV reports to COMTRADE.

- COMTRADE 1999 ASCII
- COMTRADE 1999 Binary
- COMTRADE 2013 ASCII
- COMTRADE 2013 Binary
- COMTRADE 2013 Binary32
- COMTRADE 2013 Float32

COMTRADE File Format Event Reports

NOTE: COMTRADE event reports are sampled at 32 samples per cycle, which are equivalent to CEV R event reports.

NOTE: COMTRADE events can be extracted using the **FILE** command (see Section 7: Communications), Ethernet File Transfer Protocol (FTP), or IEC 61850 Manufacturing Message Specification (MMS). To transfer files using MMS, set EMMSFS to Y.

The SEL-787 stores high-resolution raw oscillography data in binary format and uses COMTRADE file types to output these data:

- .HDR—header file
- .CFG—configuration file
- .DAT—high-resolution raw data file

The .HDR file contains summary information about the event in ASCII format. The .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 10.11*.

FID,"SEL-787-4-X339-V0-Z003002-D20180206" Event_Report_Type,"UVR" Part_Number,"07874XE1A1X0XA585023X" Serial_Number,"000000000000000" [Summary] Time_Source,"Internal" Event_Logs,"1" Event_Number,"10021" Event_Date,"09/02/2018" Event_Time,"14:34:11.104000" Event,"ER Trigger" Freq,"50.00" Targets,"10000000" IAW1(A),"42601.0547" IBW1(A),"47480.2070" ICW1(A),"54100.0938" IGW1(A),"8602.3252" IAW2(A),"25211.3887" IBW2(A),"35237.6328" ICW2(A),"37502.1758" IGW2(A),"0.0000" IAW3(A),"29002.2559" IBW3(A),"34577.4961" ICW3(A),"39630.0508" IGW3(A),"0.0000" IAW4(A),"68183.8906" IBW4(A),"54912.6563" ICW4(A),"77725.7500" IGW4(A),"17195.4941"	Event Summary Information

Figure 10.11 Sample COMTRADE .HDR Header File

```
Global Settings
PHROT   := ABC     FNOM    := 50      DATE_F  := MDY     METHRES := Y
FAULT   := 51P1P OR 51P2P OR 51P3P OR 51G1P OR 51G2P OR 51G3P OR TRIP
EMP     := N       TGR     := 3
SS1     := 1
SS2     := 0
SS3     := 0
SS4     := 0

EPMU    := N
IRIGC   := NONE    UTC_OFF := 0.00    DST_BEGM:= OFF
52ABF   := N       BFD1    := 0.50    BFI1    := R_TRIG TRIP1 OR R_TRIG TRIPXFMR
BFD2    := 0.50    BFI2    := R_TRIG TRIP2 OR R_TRIG TRIPXFMR
BFD3    := 0.50    BFI3    := R_TRIG TRIP3 OR R_TRIG TRIPXFMR
BFD4    := 0.50    BFI4    := R_TRIG TRIP4 OR R_TRIG TRIPXFMR

THFLTD  := OFF

IN101D  := 10      IN102D  := 10
IN301D  := 10      IN302D  := 10      IN303D  := 10      IN304D  := 10
EBMON1  := Y       COSP11  := 10000   COSP12  := 150     COSP13  := 12
KASP11  := 1.20    KASP12  := 8.00    KASP13  := 20.00   BKMON1  := TRIP1
EBMON2  := Y       COSP21  := 10000   COSP22  := 150     COSP23  := 12
KASP21  := 1.20    KASP22  := 8.00    KASP23  := 20.00   BKMON2  := TRIP2

EBMON3  := Y       COSP31  := 10000   COSP32  := 150     COSP33  := 12
KASP31  := 1.20    KASP32  := 8.00    KASP33  := 20.00   BKMON3  := TRIP3

EBMON4  := Y       COSP41  := 10000   COSP42  := 150     COSP43  := 12
KASP41  := 1.20    KASP42  := 8.00    KASP43  := 20.00   BKMON4  := TRIP4

RSTTRGT := 0
RSTENRGY:= 0
RSTMXMN := 0
RSTDEM  := 0
RSTPKDEM:= 0

DSABLSET:= 0

TIME_SRC:= IRIG1
89A2P1  := 0
89B2P1  := NOT 89A2P1
89A2P1D := 5.00    89A2P2  := 0
89B2P2  := NOT 89A2P2
89A2P2D := 5.00    89A2P3  := 0
89B2P3  := NOT 89A2P3
89A2P3D := 5.00    89A2P4  := 0
89B2P4  := NOT 89A2P4
89A2P4D := 5.00    89A2P5  := 0
89B2P5  := NOT 89A2P5
89A2P5D := 5.00    89A2P6  := 0
89B2P6  := NOT 89A2P6
89A2P6D := 5.00    89A2P7  := 0
89B2P7  := NOT 89A2P7
89A2P7D := 5.00    89A2P8  := 0
89B2P8  := NOT 89A2P8
89A2P8D := 5.00    89A2P9  := 0
89B2P9  := NOT 89A2P9
89A2P9D := 5.00    89A2P10 := 0
89B2P10 := NOT 89A2P10
89A2P10D:= 5.00    89A2P11 := 0
89B2P11 := NOT 89A2P11
89A2P11D:= 5.00    89A2P12 := 0
89B2P12 := NOT 89A2P12
89A2P12D:= 5.00    89A2P13 := 0
89B2P13 := NOT 89A2P13
89A2P13D:= 5.00    89A2P14 := 0
89B2P14 := NOT 89A2P14
89A2P14D:= 5.00    89A2P15 := 0
89B2P15 := NOT 89A2P15
89A2P15D:= 5.00    89A2P16 := 0
89B2P16 := NOT 89A2P16
89A2P16D:= 5.00
EN_LRC  := N       EN_LRC  := N
```

Global Settings

Figure 10.11 Sample COMTRADE .HDR Header File (Continued)

```
Group Settings

RID     := SEL-787-4X
TID     := TRNSFRMR RELAY
E87W1   := Y       E87W2   := Y       E87W3   := Y       E87W4   := Y
W1CT    := WYE     W2CT    := DELTA   W3CT    := DELTA   W4CT    := WYE
CTR1    := 10000   CTR2    := 10000   CTR3    := 10000   CTR4    := 10000
MVA     := 200.0   ICOM    := N       CCW12   := N       CCW34   := N
VWDG1   := 10.000  VWDG2   := 10.000  VWDG3   := 10.000  VWDG4   := 10.000

TAP1    := 1.15    TAP2    := 2.00    TAP3    := 2.00    TAP4    := 1.15
O87P    := 0.60    87AP    := 0.60    87AD    := 5.00    SLP1    := 25
SLP2    := 70      IRS1    := 6.00
U87P    := 10.00   PCT2    := 15      PCT4    := 15      PCT5    := 35
TH5P    := OFF     HRSTR   := Y       HBLK    := N


50P11P  := OFF     50P12P  := OFF     50P13P  := OFF     50P14P  := OFF
50G11P  := OFF     50G12P  := OFF     50Q11P  := OFF     50Q12P  := OFF
51P1P   := OFF     51G1P   := OFF     51Q1P   := OFF
50P21P  := OFF     50P22P  := OFF     50P23P  := OFF     50P24P  := OFF
50Q21P  := OFF     50Q22P  := OFF
51P2P   := OFF     51Q2P   := OFF
50P31AP := OFF     50P31BP := OFF     50P31CP := OFF     50P32AP := OFF
50P32BP := OFF     50P32CP := OFF

51P3AP  := OFF

51P3BP  := OFF
51P3CP  := OFF
50P31P  := OFF     50P32P  := OFF     50P33P  := OFF     50P34P  := OFF
50Q31P  := OFF     50Q32P  := OFF
51P3P   := OFF     51Q3P   := OFF
50P41P  := OFF     50P42P  := OFF     50P43P  := OFF     50P44P  := OFF
50G41P  := OFF     50G42P  := OFF     50Q41P  := OFF     50Q42P  := OFF
51P4P   := OFF     51G4P   := OFF     51Q4P   := OFF

E49RTD  := NONE
EDEM    := OFF

TDURD   := 0.50    CFD1    := 0.50    CFD2    := 0.50    CFD3    := 0.50
CFD4    := 0.50
TR1     := 0
TR2     := 0
TR3     := 0

TR4     := 0
TRXFMR  := 0
REMTRIP := 0
ULTRIP1 := NOT (51P1P OR 51Q1P OR 52A1)
ULTRIP2 := NOT (51P2P OR 51Q2P OR 52A2)
ULTRIP3 := NOT (51P3P OR 51Q3P OR 52A3)

ULTRIP4 := NOT (51P4P OR 51Q4P OR 52A4)
ULTRXFMR:= NOT (87R OR 87U)
52A1    := IN101
52B1    := NOT 52A1
CL1     := SV03T AND LT05 OR CC1
ULCL1   := TRIP1 OR TRIPXFMR
52A2    := IN102
52B2    := NOT 52A2
CL2     := SV03T AND LT06 OR CC2
ULCL2   := TRIP2 OR TRIPXFMR
52A3    := 0
52B3    := NOT 52A3
CL3     := SV03T AND LT07 OR CC3
ULCL3   := TRIP3 OR TRIPXFMR

52A4    := 0
52B4    := NOT 52A4
CL4     := SV03T AND LT08 OR CC4
ULCL4   := TRIP4 OR TRIPXFMR
```

Group Settings

Figure 10.11 Sample COMTRADE .HDR Header File (Continued)

```
Report Settings

ESERDEL := N

SER1    := IN101 IN102 IN301 IN302
SER2    := ORED51T ORED50T 87U 87R REF3AF REF3BF RTDT
SER3    := NA
SER4    := SALARM

EALIAS  := 3

ALIAS1  :=PB01 FP_LOCK PICKUP DROPOUT
ALIAS2  :=PB02 FP_CLOSE PICKUP DROPOUT
ALIAS3  :=PB03 FP_TRIP PICKUP DROPOUT

ER      := R_TRIG IN101
LER     := 180     PRE     := 3
FMR1NAM := FMR1
FMR1    :=NA
FMR2NAM := FMR2
FMR2    :=NA
FMR3NAM := FMR3
FMR3    :=NA
FMR4NAM := FMR4
FMR4    :=NA

RA01TYPE:= I
RA02TYPE:= I
RA03TYPE:= I
RA04TYPE:= I
RA05TYPE:= I
RA06TYPE:= I
RA07TYPE:= I
RA08TYPE:= I
RA09TYPE:= I
RA10TYPE:= I
RA11TYPE:= I
RA12TYPE:= I
RA13TYPE:= I
RA14TYPE:= I
RA15TYPE:= I
RA16TYPE:= I
RA17TYPE:= I
RA18TYPE:= I
RA19TYPE:= I
RA20TYPE:= I
RA21TYPE:= I
RA22TYPE:= I
RA23TYPE:= I
RA24TYPE:= I
RA25TYPE:= I
RA26TYPE:= I
RA27TYPE:= I
RA28TYPE:= I
RA29TYPE:= I
RA30TYPE:= I
RA31TYPE:= I
RA32TYPE:= I

LDLIST  := NA

LDAR    := 15
```

Report Settings

Figure 10.11 Sample COMTRADE .HDR Header File (Continued)

<pre>Logic Settings
 	
ELAT   := 8   ESV   := 5   ESC   := N   EMV   := N
 	
SET01   := R_TRIG SV01T AND NOT LT01
RST01   := R_TRIG SV01T AND LT01
SET02   := (PB02 AND R_TRIG SV02T) AND LT01 AND NOT ((52A1 AND LT05) OR (52A2 AND LT06)
 OR (52A3 AND LT07) OR (52A4 AND LT08)) AND (LT05 OR LT06 OR LT07 OR LT08)
RST02   := (SV03T OR R_TRIG SV02T) AND LT02
SET03   := (PB03 AND R_TRIG SV02T) AND ((52A1 AND LT05) OR (52A2 AND LT06) OR (52A3 AND
 LT07) OR (52A4 AND LT08)) AND (LT05 OR LT06 OR LT07 OR LT08)
RST03   := (SV04T OR R_TRIG SV02T) AND LT03
SET04   := NA
RST04   := NA
SET05   := PB05 AND R_TRIG SV02T AND NOT LT05
RST05   := (PB05 OR PB06 OR PB07 OR PB08) AND R_TRIG SV02T AND LT05
SET06   := PB06 AND R_TRIG SV02T AND NOT LT06
RST06   := (PB05 OR PB06 OR PB07 OR PB08) AND R_TRIG SV02T AND LT06
SET07   := PB07 AND R_TRIG SV02T AND NOT LT07
RST07   := (PB05 OR PB06 OR PB07 OR PB08) AND R_TRIG SV02T AND LT07
SET08   := PB08 AND R_TRIG SV02T AND NOT LT08
RST08   := (PB05 OR PB06 OR PB07 OR PB08) AND R_TRIG SV02T AND LT08
 	
SV01PU := 3.00   SV01DO := 0.00
SV01   := PB01
SV02PU := 0.25   SV02DO := 0.00
SV02   := PB01 OR PB02 OR PB03 OR PB05 OR PB06 OR PB07 OR PB08
SV03PU := 2.00   SV03DO := 0.00
SV03   := LT02
SV04PU := 0.00   SV04DO := 0.00
SV04   := LT03
SV05PU := 0.25   SV05DO := 0.25
SV05   := (PB01 OR PB02 OR LT02 OR LT03) AND NOT SV05T
 	
OUT101FS:= Y   OUT101 := HALARM OR SALARM
OUT102FS:= N   OUT102 := 0
OUT103FS:= N   OUT103 := TRIPXFMR
OUT301FS:= N   OUT301 := 0
OUT302FS:= N   OUT302 := 0
OUT303FS:= N   OUT303 := 0
OUT304FS:= N   OUT304 := 0</pre>
	Logic Settings

<pre>SAM/CYC_A = 32
SAM/CYC_D = 4</pre>
	Analog, Digital, and Input Samples per Cycle Data

Figure 10.11 Sample COMTRADE .HDR Header File (Continued)

.CFG File

The .CFG file contains data that is used to reconstruct the input signals to the relay and the status of Relay Word bits during the event report (see *Figure 10.12*). A <CR><LF> follows each line. If control inputs or control outputs are unavailable 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-787-Rxxx-V0-Zxxxxxx-Dyyyymmdd,1999`	COMTRADE Standard
`#T,#A,#D`	Total Channels, Analog, Digital

Figure 10.12 Sample COMTRADE .CFG Configuration File Data

`1,IAW1,A,,A,7.071068,0.0,0,-32767,32767,1000.0,1.0,P`
`2,IBW1,B,,A,7.071068,0.0,0,-32767,32767,1000.0,1.0,P`
`3,ICW1,C,,A,7.071068,0.0,0,-32767,32767,1000.0,1.0,P`
`4,IGW1,,,A,7.071068,0.0,0,-32767,32767,1000.0,1.0,P`
`5,IAW2,A,,A,7.071068,0.0,0,-32767,32767,1000.0,1.0,P`
`6,IBW2,B,,A,7.071068,0.0,0,-32767,32767,1000.0,1.0,P`
`7,ICW2,C,,A,7.071068,0.0,0,-32767,32767,1000.0,1.0,P`
`8,IGW2,,,A,7.071068,0.0,0,-32767,32767,1000.0,1.0,P`
`9,IAW3,A,,A,7.071068,0.0,0,-32767,32767,1000.0,1.0,P`
`10,IBW3,B,,A,7.071068,0.0,0,-32767,32767,1000.0,1.0,P`
`11,ICW3,C,,A,7.071068,0.0,0,-32767,32767,1000.0,1.0,P`
`12,IGW3,,,A,7.071068,0.0,0,-32767,32767,1000.0,1.0,P`
`13,IAW4,A,,A,7.071068,0.0,0,-32767,32767,1000.0,1.0,P`
`14,IBW4,B,,A,7.071068,0.0,0,-32767,32767,1000.0,1.0,P`
`15,ICW4,C,,A,7.071068,0.0,0,-32767,32767,1000.0,1.0,P`
`16,IGW4,,,A,7.071068,0.0,0,-32767,32767,1000.0,1.0,P`
	Analog Channel 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)

`1,rwb_label`[b,c]`,,,0`
`2,rwb_label`[b,c]`,,,0`
.
.
.
`nnnn`[d]`,rwb_label`[b,c]`,,,0`
	Digital (Status) Channel Data
	[b]rwb_label is replaced with Relay Word bit labels as seen in Table L.1
	[c]Place holders denoted by asterisk (*), are labeled as UNUSEDxxx (where xxx is the number of the associated label)
	[d]nnnn = number of the last Relay Word bit

`<FNOM>`
`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 10.12 Sample COMTRADE .CFG Configuration File Data (Continued)

The configuration file has the following format:

- Relay ID, firmware ID, 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

NOTE: In COMTRADE event reports, currents and voltages are reported in primary amps and volts, respectively. The data for delta-connected CTs (CTCONn = DELTA) and PTs (DELTAY_n = DELTA) are not compensated for, unlike in a CEV report (n = X or Y). The currents and voltages reported in COMTRADE reports are simply the secondary values seen by the relay at its terminals multiplied by the corresponding CT and PT ratios.

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 software applications can read binary COMTRADE files, including SYNCHROWAVE Event and QuickSet.

Retrieving COMTRADE Event Files

COMTRADE files are available as read-only files that can be retrieved through the use of the **FILE** command and Ymodem file transfer, Ethernet File Transfer Protocol (FTP), web server (EHTTP := Y), or Manufacturing Message Specification (MMS). MMS file transfer is only available in models that support IEC 61850 and only when IEC 61850 is enabled (E61850 := Y) and MMS file services is enabled (EMMSFS := Y). See *FILE Command on page 7.48*, *File Transfer Protocol (FTP) and MMS File Transfer on page 7.15*, and *MMS on page G.5* for additional information. You can also retrieve COMTRADE files via QuickSet. Refer to *View Event History on page 3.20* for details.

Sequential Events Recorder (SER) Report

The SER report captures relay element state changes over an extended period. SER report data are useful in commissioning tests and root-cause analysis studies. SER information is stored when state changes occur. The report records the most recent 1024 state changes if a relay element is listed in the SER trigger equations.

SER Triggering

NOTE: A file containing an SER report can be extracted using the **FILE** command (see Section 7: Communications), the Ethernet File Transfer Protocol (FTP), or the IEC 61850 Manufacturing Message Specification (MMS). To transfer files using MMS, set EMMSFS to Y.

Settings SER1 through SER4 are used to select entries in the SER report. To capture relay element state changes in the SER report, the relay element name must be programmed into one of the four SER trigger equations. Each of the four programmable trigger equations allows entry of as many as 24 relay elements; the SER report can monitor a total of 96 relay elements.

The relay adds a message to the SER to indicate power up or settings change conditions:

```
Relay Powered Up
.
.
.
Relay Settings Changed
```

Each entry in the SER includes the SER row number, date, time, element name, and element state.

SER Aliases

You may rename as many as 32 of the SER trigger conditions using the ALIAS settings. For instance, the factory-default alias setting 2 renames Relay Word bit PB02 for reporting in the SER:

```
ALIAS2:= PB02 FP_LOCK PICKUP DROPOUT
```

When Relay Word bit PB02 is asserted, the SER report shows the date and time of FP_LOCK PICKUP. When Relay Word bit PB02 is deasserted, the SER report shows the date and time of FP_LOCK DROPOUT. With this and other alias assignments, the SER record is easier for the operator to review. See *Relay Word Bit Aliases on page 4.157* for additional details.

Retrieving and Clearing SER Reports

The SER report is available as a read-only file that can be retrieved through the use of Ethernet FTP or MMS. MMS is only available in models that support IEC 61850 and only when IEC 61850 and MMS file transfer are enabled (E61850 = Y, EMMSFS := Y). See *File Transfer Protocol (FTP) and MMS File Transfer on page 7.15*, *Virtual File Interface on page 7.73*, and

MMS on page G.5 for additional information. See *SER Command (Sequential Events Recorder Report) on page 7.61* for details on the **SER** command.

Example SER Report

Figure 10.4 shows an example SER report.

```
=>SER <Enter>

SEL-787-3S                                  Date: 09/09/2013   Time: 16:39:21.949
TRNSFRMR RELAY                              Time Source: External

Serial No = 000000000000000
FID = SEL-787-4-X197-V0-Z001001-D20130906               CID = AADA

#     DATE         TIME              ELEMENT              STATE
6  09/09/2013  16:20:26.686   87R                      Asserted
5  09/09/2013  16:20:26.686   TRIP                     Asserted
4  09/09/2013  16:20:26.686   TRIPXFMR                 Asserted
3  09/09/2013  16:20:27.277   87R                      Deasserted
2  09/09/2013  16:20:27.277   TRIP                     Deasserted
1  09/09/2013  16:20:27.277   TRIPXFMR                 Deasserted

=>
```

Figure 10.13 Example Sequential Events Recorder (SER) Event Report

Section 11
Testing and Troubleshooting

Overview

Relay testing is typically divided into two categories:

- Tests performed at the time the relay is installed or commissioned
- Tests performed periodically once the relay is in service

This section provides information on both types of testing for the SEL-787 Transformer Protection Relay. Because the SEL-787 is equipped with extensive self-tests, traditional periodic test procedures may be eliminated or greatly reduced.

Should a problem arise during either commissioning or periodic tests, the section on *Troubleshooting on page 11.20* provides a guide to isolating and correcting the problem.

Testing Tools

Serial Port Commands

The following serial port commands assist you during relay testing.

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. Compare these quantities against other devices of known accuracy. The **METER** command is available at the serial ports and front-panel display. See *Section 7: Communications* and *Section 8: Front-Panel Operations*.

The relay generates a 15-, 64-, or 180-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 10: Analyzing Events*.

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 10: Analyzing Events*.

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 7: Communications* and *Section 8: Front-Panel Operations*. Similar results can be achieved using the web server. See *Section 3: PC Interface*.

Low-Level Test Interface

NOTE: The SEL-RTS Relay Test System consists of the SEL-AMS Adaptive Multichannel Source and SEL-5401 Test System Software.

NOTE: The SEL-787 with the LEA option is not supported by the SEL-RTS Low-Level Relay Test System.

The SEL-787 has a low-level test interface on the 6 ACI current card (Slot Z) and on the 6 ACI current card, 3 ACI/4 AVI current/voltage card, 4 ACI/3 AVI current/voltage card, 1 ACI/3 AVI current/voltage card, or 1 ACI current card (Slot E). You can test the relay in either of two ways: conventionally by applying ac signals to the relay inputs or by applying low magnitude ac voltage signals to the test interface on the printed circuit boards.

The SEL-RTS Low-Level Relay Test System can be used to provide signals to test the relay. *Figure 11.1* shows the Test Interface connectors.

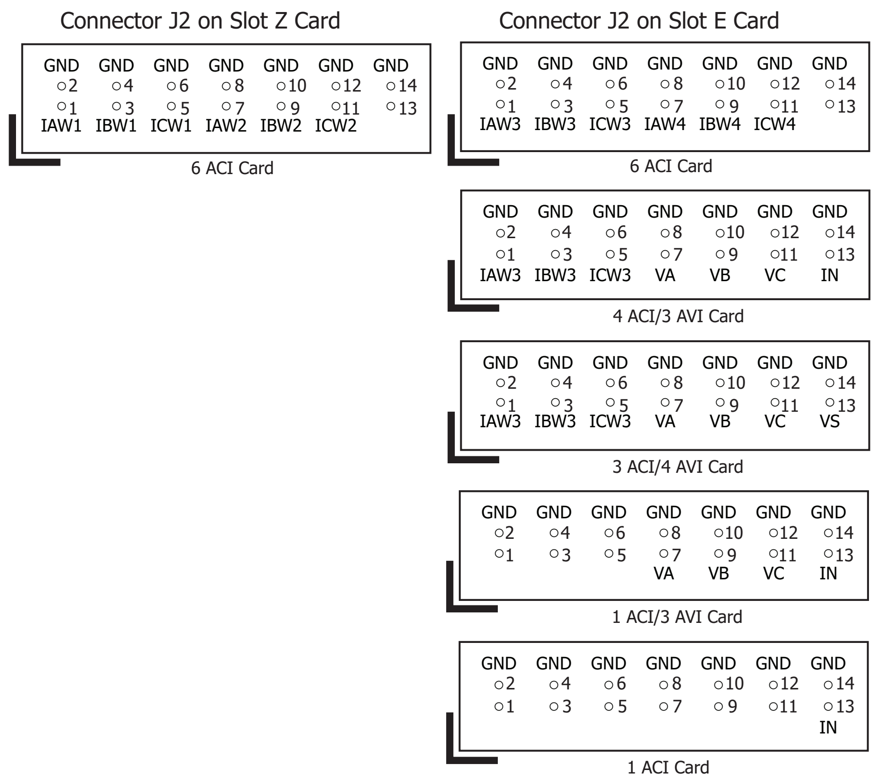


Figure 11.1 Low-Level Test Interface (J2 and J3)

Note that there are five options for the Slot E for low level interface:

- The 6 ACI card supports line current inputs for Windings 3 and 4.
- The 4 ACI/3 AVI card supports the neutral current input IN and three-phase ac voltage inputs VA, VB, and VC, along with the line current inputs for Winding 3.
- The 3 ACI/4 AVI card supports the VS/VBat input and three-phase ac voltage inputs VA, VB, and VC, along with the line current inputs for Winding 3.
- The 1 ACI/3 AVI card supports the neutral current input IN and three-phase ac voltage inputs VA, VB, and VC.
- The 1 ACI card supports the neutral current input IN.

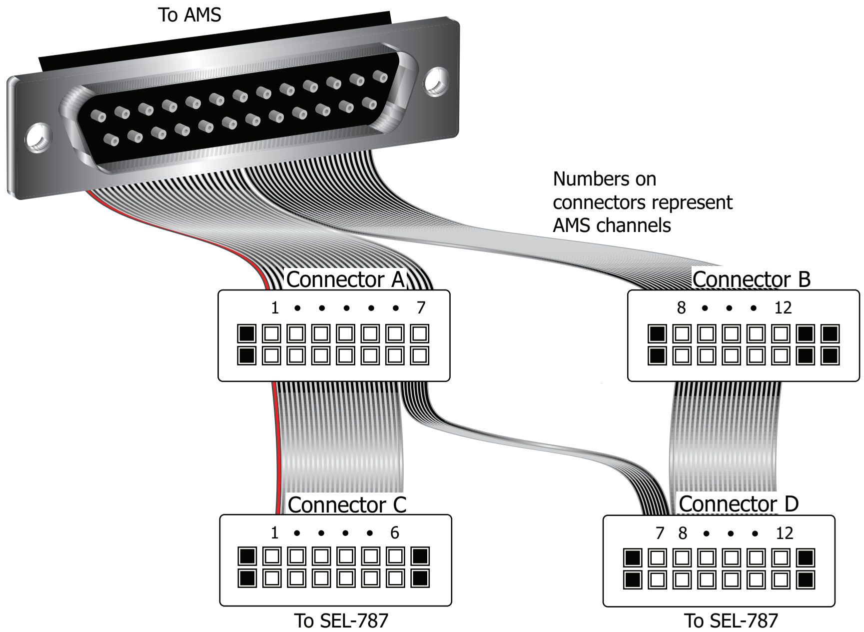


Figure 11.2 SEL-C700G Ribbon Cable Connector Diagram

Table 11.1 shows the signal scale factor information used by the AMS Relay Test System SEL-5401 Software for the calibrated inputs.

The SEL-787 Relay can have as many as 13 analog input channels while the SEL-AMS has only 12 analog output channels. As a result, in the models SEL-787-3E and SEL-787-3S, one analog input channel always gets left out. *Table 11.5* and *Table 11.6* provide options for achieving different channel connections.

Table 11.1 Resultant Scale Factors for Inputs (Sheet 1 of 2)

Channel Label	Circuit Board & Connector	Nominal Input	Scale Factor (A/V or V/V)
IAW1	J2 on Slot Z card	5 A/1 A	106.14/21.23
IBW1	J2 on Slot Z card	5 A/1 A	106.14/21.23
ICW1	J2 on Slot Z card	5 A/1 A	106.14/21.23
IAW2	J2 on Slot Z card	5 A/1 A	106.14/21.23
IBW2	J2 on Slot Z card	5 A/1 A	106.14/21.23
ICW2	J2 on Slot Z card	5 A/1 A	106.14/21.23
VA	J2 on Slot E card	250 V	218.4
VB	J2 on Slot E card	250 V	218.4
VC	J2 on Slot E card	250 V	218.4
IN	J2 on Slot E card	5 A/1 A	106.14/21.23
IAW3	J2 on Slot E card	5 A/1 A	106.14/21.23
IBW3	J2 on Slot E card	5 A/1 A	106.14/21.23
ICW3	J2 on Slot E card	5 A/1 A	106.14/21.23
IAW4	J2 on Slot E card	5 A/1 A	106.14/21.23

Table 11.1 Resultant Scale Factors for Inputs (Sheet 2 of 2)

Channel Label	Circuit Board & Connector	Nominal Input	Scale Factor (A/V or V/V)
IBW4	J2 on Slot E card	5 A/1 A	106.14/21.23
ICW4	J2 on Slot E card	5 A/1 A	106.14/21.23
Vs	J2 on Slot E card	250 V	218.4

Table 11.2 SEL-C700G Cable Connection Options for SEL-787-2X

Slot	Card Connector (J2) Signals	SEL-C700G Cable Connection Options[a]	
		SEL-787-4X	
		SEL-C700G Connector	AMS CH#
Z	IAW1 IBW1 ICW1 IAW2 IBW2 ICW2	C	1 2 3 4 5 6

[a] Only the commonly used connection options are shown; additional connections are possible.

Table 11.3 SEL-C700G Cable Connection Options for SEL-787-21

Slot	Card Connector (J2) Signals	SEL-C700G Cable Connection Options[a]	
		SEL-787-21	
		SEL-C700G Connector	AMS CH#
Z	IAW1 IBW1 ICW1 IAW2 IBW2 ICW2	C	1 2 3 4 5 6
E	– – – – – – IN	D	– – – – – – 12

[a] Only the commonly used connection options are shown; additional connections are possible.

Table 11.4 SEL-C700G Cable Connection Options for SEL-787-2E

Slot	Card Connector (J2) Signals	SEL-C700G Cable Connection Options[a] SEL-787-2E SEL-C700G Connector	AMS CH#
Z	IAW1	C	1
	IBW1		2
	ICW1		3
	IAW2		4
	IBW2		5
	ICW2		6
E	–	D	–
	–		–
	–		–
	VA		9
	VB		10
	VC		11
	IN		12

[a] Only the commonly used connection options are shown; additional connections are possible.

Table 11.5 SEL-C700G Cable Connection Options for SEL-787-3E

Slot	Card Connector (J2) Signals	SEL-C700G Cable Connection Options[a]							
		SEL-787-3E							
		SEL-C700G Connector	AMS CH#	SEL-C700G Connector	AMS CH#	SEL-C700G Connector	AMS CH#	SEL-C700G Connector	AMS CH#
Z	IAW1	C	1	C	1	B	8	B	–
	IBW1		2		2		9		8
	ICW1		3		3		10		9
	IAW2		4		4		11		10
	IBW2		5		5		12		11
	ICW2		6		6		–		12
E	IAW3	D	7	D	–	A	1	A	1
	IBW3		8		7		2		2
	ICW3		9		8		3		3
	VA		10		9		4		4
	VB		11		10		5		5
	VC		12		11		6		6
	IN		–		12		7		7

[a] Only the commonly used connection options are shown; additional connections are possible.

Table 11.6 SEL-C700G Cable Connection Options for SEL-787-3S

Slot	Card Connector (J2) Signals	SEL-C700G Cable Connection Options[a]							
		SEL-787-3S							
		SEL-C700G Connector	AMS CH#	SEL-C700G Connector	AMS CH#	SEL-C700G Connector	AMS CH#	SEL-C700G Connector	AMS CH#
Z	IAW1	C	1	C	1	B	8	B	–
	IBW1		2		2		9		8
	ICW1		3		3		10		9
	IAW2		4		4		11		10
	IBW2		5		5		12		11
	ICW2		6		6		–		12
E	IAW3	D	7	D	–	A	1	A	1
	IBW3		8		7		2		2
	ICW3		9		8		3		3
	VA		10		9		4		4
	VB		11		10		5		5
	VC		12		11		6		6
	VS		–		12		7		7

[a] Only the commonly used connection options are shown; additional connections are possible.

Table 11.7 SEL-C700G Cable Connection Options for SEL-787-4X

Slot	Card Connector (J2) Signals	SEL-C700G Cable Connection Options[a]	
		SEL-787-4X	
		SEL-C700G Connector	AMS CH#
Z	IAW1	C	1
	IBW1		2
	ICW1		3
	IAW2		4
	IBW2		5
	ICW2		6
E	IAW3	D	7
	IBW3		8
	ICW3		9
	IAW4		10
	IBW4		11
	ICW4		12

[a] Only the commonly used connection options are shown; additional connections are possible.

Access the low-level test interface connectors by using the following procedure.

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

Step 1. Loosen the mounting screws and the ground screw on the back and remove the back cover.

Step 2. Remove the 6 ACI board from Slot Z.

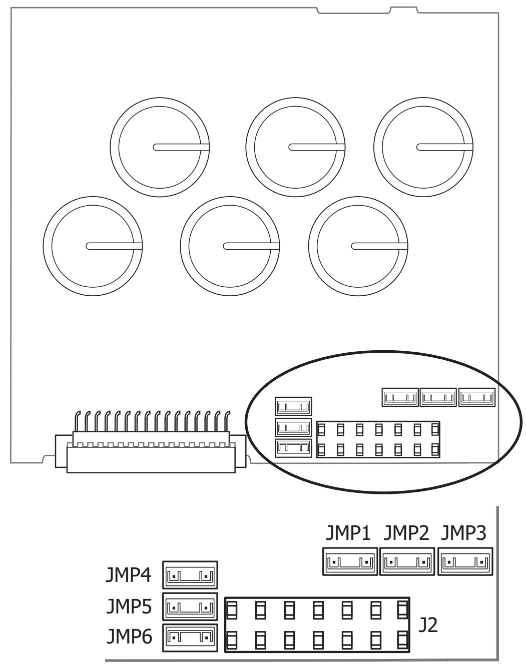
Step 3. Locate jumpers JMP1–JMP6 and change them from Pin 1–2 (normal position) to Pin 2–3 (low-level test position).

Step 4. Locate connector J2 and connect low-level signal connector C of the SEL-C700G cable, using *Figure 11.1* and *Figure 11.2* (e.g., ribbon cable connector of SEL-RTS Test System).

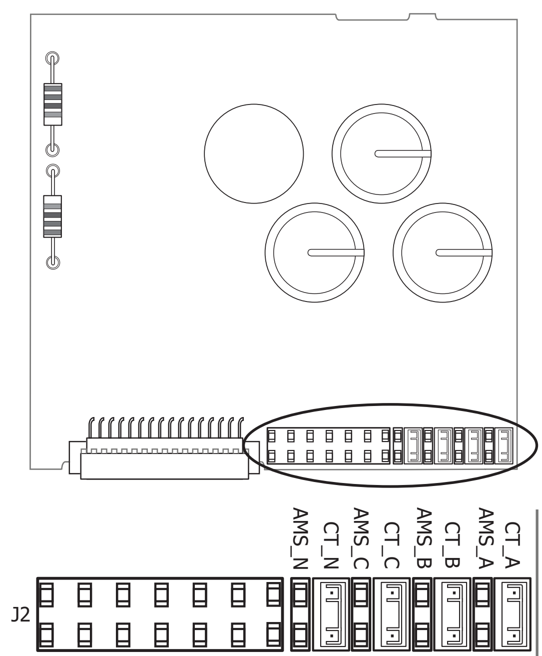
Step 5. Insert the 6 ACI board back in its Slot Z.

Step 6. Remove the 6 ACI board from Slot **E**.

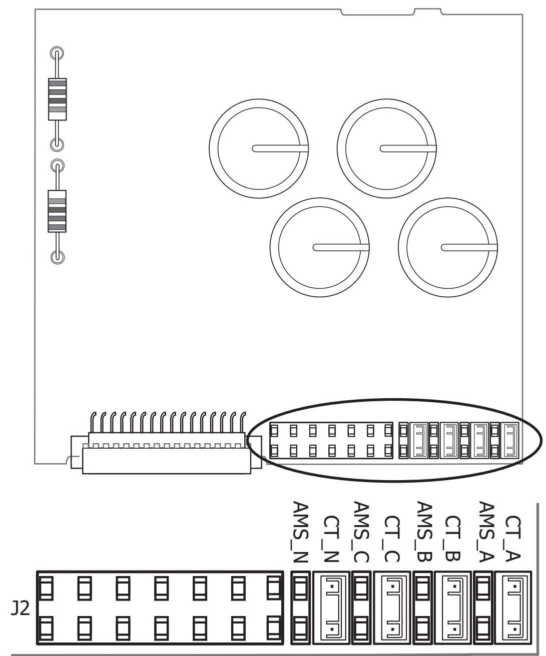
Locate jumpers JMP1–JMP6 and change them from Pin 1–2 (normal position) to Pin 2–3 (low-level test position).



If Slot E has a 3 ACI/4 AVI or 4 ACI/3 AVI card instead of a 6 ACI card, then remove the board and locate J3 and move the pins from CT_A to AMS_A, CT_B to AMS_B, and CT_C to AMS_C positions.



Also, move the CT_N pin to the AMS_N pin for the 4 ACI/3 AVI card. If Slot E has a 1 ACI/3 AVI or 1 ACI board, move the CT_N pin to the AMS_N pin. Voltage inputs do not have jumpers.



Step 7. Locate connector J2 on the board and connect low-level signal connector D of the C700G cable, using *Figure 11.1* and *Figure 11.2* (e.g., ribbon cable connector of SEL-RTS Test System).

Step 8. Insert the board back into Slot **E**.

Refer to the SEL-*RTS Instruction Manual* for additional detail.

When simulating a delta PT connection, DELTA_Y := DELTA, with the low-level test interface referenced in *Figure 11.1*, apply the following signals:

➤ Apply low-level test signal VAB to Pin VA.

➤ Apply low-level test signal –VBC (equivalent to VCB) to Pin VC.

➤ Do not apply any signal to Pin VB.

Commissioning Tests

SEL performs a complete functional check and calibration of each SEL-787 before it is shipped. This helps to ensure that you receive a relay that operates correctly and accurately. Commissioning tests confirm that the relay is properly connected including the control signal inputs and outputs.

The following connection tests help you enter settings into the SEL-787 and verify that the relay is properly connected. Brief functional tests ensure that the relay settings are correct. It is unnecessary to test every element, timer, and function in these tests. Modify the procedure as necessary to conform to your standard practices. Use the procedure at initial relay installation; you should not need to repeat it unless major changes are made to the relay electrical connections.

Required Equipment

- The SEL-787, installed and connected according to your protection design
- A PC with serial port, terminal emulation software, and serial communications cable
- *SEL-787-2, -3, -4 Settings Sheets* with settings appropriate to your application and protection design
- The ac and dc elementary schematics and wiring diagrams for this relay installation
- A continuity tester
- A protective relay ac test source
  - Minimum: single-phase voltage and current with phase angle control
  - Preferred: three-phase voltage and current with phase angle control

Connection Tests

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

Step 1. Remove control voltage and ac signals from the SEL-787 by opening the appropriate breaker(s) or removing fuses.

Step 2. Isolate the relay contact assigned to be the **TRIP** output.

Step 3. Verify correct ac and dc connections by performing point-to-point continuity checks on the associated circuits.

Step 4. Apply ac or dc control voltage to the relay.

After the relay is energized, the front-panel green **ENABLED** LED should illuminate.

Step 5. Use the appropriate serial cable (SEL-C234A cable or equivalent) to connect a PC to the relay.

Step 6. Start the PC terminal emulation software and establish communication with the relay.

Refer to *Section 7: Communications* for more information on serial port communications.

Step 7. Set the correct relay time and date by using either the front-panel or serial port commands (**TIME *hh:mm:ss*** and **DATE *mm/dd/yy*** commands).

Step 8. Using the **SET**, **SET P**, **SET G**, **SET L**, and **SET R** serial port commands, enter the relay settings from the settings sheets for your application.

Step 9. If you are connecting an external SEL-2600 RTD Module, follow the substeps below; otherwise continue with the next step.

a. Connect the fiber-optic cable to the RTD Module fiber-optic output.

b. Plug the relay end of the fiber-optic cable into the relay fiber-optic Rx input (Port 2).

Step 10. Verify the relay ac connections.

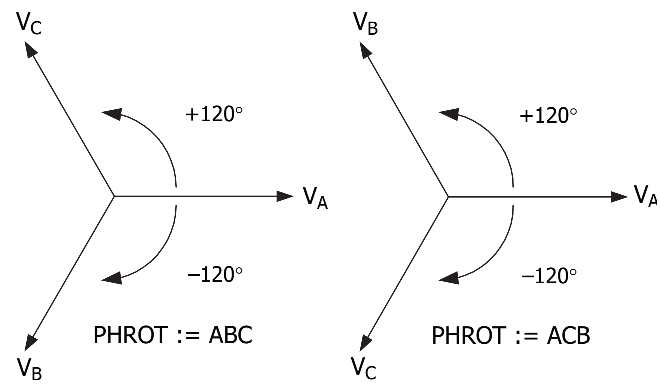
Step 11. Connect the ac test source current or voltage to the appropriate relay terminals.

NOTE: Make sure the current transformer secondary windings are shorted before they are disconnected from the relay.

a. Disconnect the current transformer and voltage transformer (if present) secondaries from the relay prior to applying test source quantities.

b. If you set the relay to accept phase-to-ground voltages (DELTA_Y := WYE), set the current and/or voltage phase angles as shown in *Figure 11.3*.

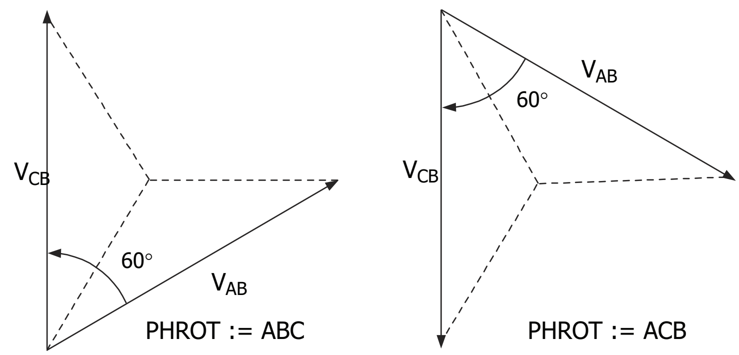
c. If you set the relay to accept delta voltages (DELTA_Y := DELTA), set the current and/or voltage phase angles as shown in *Figure 11.4*.



When setting PHROT := ABC, set angle V_A = angle I_A = 0°
set angle V_B = angle I_B = –120°
set angle V_C = angle I_C = 120°

When setting PHROT := ACB, set angle V_A = angle I_A = 0°
set angle V_B = angle I_B = 120°
set angle V_C = angle I_C = –120°

Figure 11.3 Three-Phase Wye AC Connections



When setting PHROT := ABC, set angle I_A = 0°
set angle I_B = –120°
set angle I_C = 120°
set angle V_{AB} = +30°
set angle V_{CB} = +90°

When setting PHROT := ACB, set angle I_A = 0°
set angle I_B = 120°
set angle I_C = –120°
set angle V_{AB} = –30°
set angle V_{CB} = –90°

Figure 11.4 Three-Phase Open-Delta AC Connections

Step 12. Apply rated current (1 A or 5 A).

Step 13. If the relay is equipped with voltage inputs, apply rated voltage for your application.

Step 14. Use the front-panel `METER > Fundamental` function or serial port **METER** command to verify that the relay is measuring the magnitude and phase angle of both voltage and current correctly, taking into account the relay PTR and CTR*n* settings and the fact that the quantities are displayed in primary units.

Step 15. If you are using a current transformer for the neutral, apply a single-phase current to the IN terminals. Do not apply voltage.

Step 16. Verify that the relay is measuring the magnitude and phase angle correctly.

The expected magnitude is (applied current) • (CTRN1). The expected phase angle is zero (0).

Step 17. Verify control input connections. Using the front-panel `MAIN > Targets > Row 41` function, check the control input status in the relay (IN101 or IN102).

As you apply rated voltage to each input, the position in Row 41 corresponding to that input should change from zero (0) to one (1).

Step 18. Verify output contact operation:

a. For each output contact, set the input to logical 1. This causes the output contact to close. For example, setting OUT101 = 1 causes the output OUT101 contact to close.

b. Repeat the process for all contact outputs.

Make sure that each contact closure does what you want it to do in the annunciation, control, or trip circuit associated with that contact closure.

Step 19. Perform any desired protection element tests. Perform only enough tests to prove that the relay operates as intended; exhaustive element performance testing is not necessary for commissioning.

Step 20. Connect the relay for tripping duty.

Step 21. Verify that any settings changed during the tests performed in *Step 18* and *Step 19* are changed back to the correct values for your application.

Step 22. Use the serial port commands in *Table 11.8* to clear the relay data buffers and prepare the relay for operation.

This prevents data generated during commissioning testing from being confused with operational data collected later.

Table 11.8 Serial Port Commands That Clear Relay Data Buffers

Serial Port Command	Task Performed
LDP C	Clears Load Profile Data
SER R	Resets Sequential Events Record buffer
SUM R	Resets Event Report and Summary Command buffers

Step 23. When it is safe to do so, energize the transformer.

Step 24. Verify the following ac quantities by using the front-panel `METER > Fundamental` or serial port **METER** command.

- ➢ Phase current magnitudes should be nearly equal.
- ➢ Phase current angles should be balanced, have proper phase rotation, and have the appropriate phase relationship to the phase voltages.

Step 25. If your relay is equipped with voltage inputs, check the following:

- ➢ Phase voltage magnitudes should be nearly equal.
- ➢ Phase voltage phase angles should be balanced and have proper phase rotation.

The SEL-787 is now ready for continuous service.

Functional Tests

Measuring Phase Current Accuracy for Current Inputs on Slots Z and E

Step 1. Connect the current source to the relay, as shown in *Figure 11.5*.

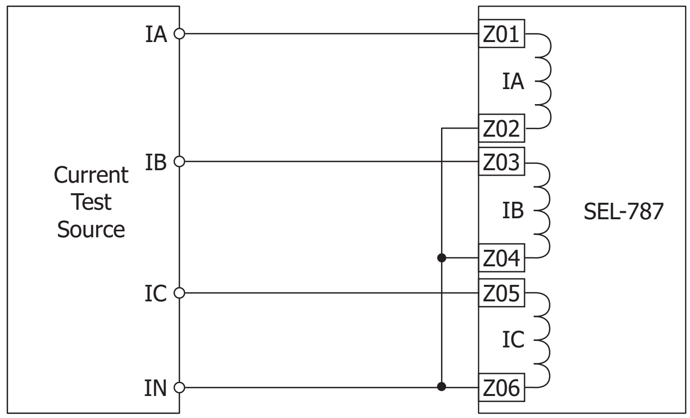


Figure 11.5 Winding 1 CTR1 Current Source Connections On Slot Z Example

Step 2. Using the front-panel `SET/SHOW` or the serial port **SHO** command, record the CTR*n* (where *n* = 1, 2, 3, or 4), and PHROT setting values.

Step 3. Set the phase current angles to apply balanced three-phase currents in accordance with the PHROT setting. Refer to *Figure 11.3*.

Step 4. Set each phase current magnitude equal to the values listed in Column 1 of *Table 11.9*. Use the front-panel to view the phase current values. The relay should display the applied current magnitude times the CTR*n* setting.

Table 11.9 Phase Current Measuring Accuracy

|I| Applied (A secondary)[a]	Expected Reading CTRn x |I|	A-Phase Reading (A primary)	B-Phase Reading (A primary)	C-Phase Reading (A primary)
0.2 x I_{NOM}				
0.9 x I_{NOM}				
1.6 x I_{NOM}				

[a] I_{NOM} = rated secondary amperes (1 or 5).

Step 5. Repeat *Step 1* through *Step 4* for Windings 2, 3, and 4 using *Figure 11.5* and *Table 11.8*.

Power and Power Factor Measuring Accuracy for SEL-787 Models With Voltage Option

Wye-Connected Voltages

Perform the following steps to test wye-connected voltages in the SEL-787-3E or SEL-787-3S Relay:

Step 1. Connect the current source to the relay, using the example shown in *Figure 11.5*.

Step 2. Connect the voltage source to the relay, as shown in *Figure 11.6*. Make sure that DELTA_Y := WYE.

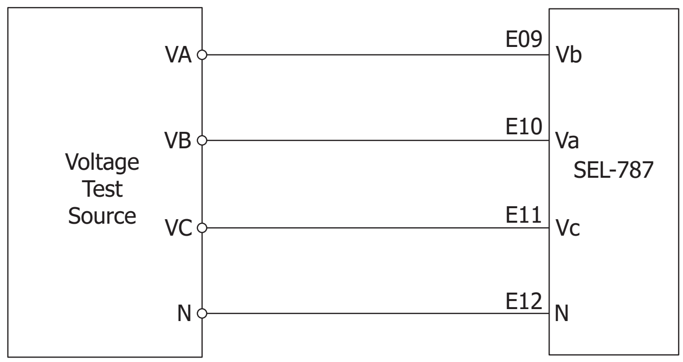


Figure 11.6 Wye Voltage Source Connections

Step 3. Using the front-panel `SET/SHOW` or the serial port **SHOW** command, record the CTR*n* (where *n* = 1, 2, or 3), PTR, and PHROT setting values.

Step 4. Apply the current and voltage quantities shown in Column 1 of *Table 11.10*.

Values are given for PHROT := ABC and PHROT := ACB.

Step 5. Use the front-panel `METER` function or the serial port **MET** command to verify the results.

Table 11.10 Power Quantity Accuracy—Wye Voltages[a]

Applied Currents and Voltages	Real Power (kW)	Reactive Power (kVAR)	Power Factor (pf)
PHROT := ABC IAW*n* = 2.5 ∠–26° IBW*n* = 2.5 ∠–146° ICW*n* = 2.5 ∠+94°	**Expected:** P = 0.898 • CTR*n* • PTR	**Expected:** Q = 0.438 • CTR*n* • PTR	**Expected:** pf = 0.90 lag
VA = 67 ∠0° VB = 67 ∠–120° VC = 67 ∠+120°	**Measured:**	**Measured:**	**Measured:**
PHROT := ACB IAW*n* = 2.5 ∠–26° IBW*n* = 2.5 ∠+94° ICW*n* = 2.5 ∠–146°	**Expected:** P = 0.898 • CTR*n* • PTR	**Expected:** Q = 0.438 • CTR*n* • PTR	**Expected:** pf = 0.90 lag
VA = 67 ∠0° VB = 67 ∠+120° VC = 67 ∠–120°	**Measured:**	**Measured:**	**Measured:**

[a] n = VIWDG setting.

Delta-Connected Voltages

Perform the following steps to test delta-connected voltages:

Step 1. Connect the current source to the relay, using the example shown in *Figure 11.5*.

Step 2. Connect the voltage source to the relay, as shown in *Figure 11.7*. Make sure that DELTA_Y := DELTA.

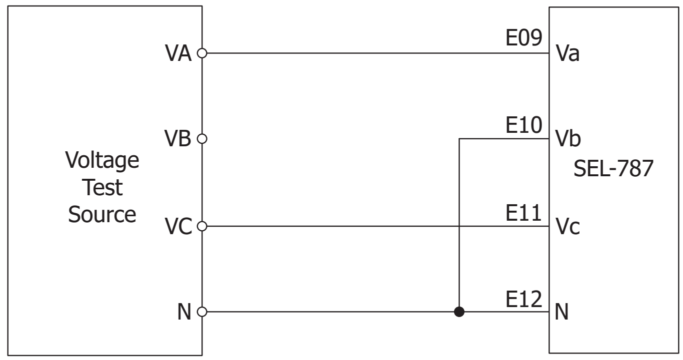


Figure 11.7 Delta Voltage Source Connections

Step 3. Using the front-panel `SET/SHOW` or the serial port **SHOW** command, record the CTR*n* (where *n* = 1, 2, or 3), PTR, and PHROT setting values.

Step 4. Apply the current and voltage quantities shown in Column 1 of *Table 11.11*.

Values are given for PHROT := ABC and PHROT := ACB.

Step 5. Use the front-panel `METER` or the serial port **MET** command to verify the results.

Table 11.11 Power Quantity Accuracy—Delta Voltages[a]

Applied Currents and Voltages	Real Power (kW)	Reactive Power (kVAR)	Power Factor (pf)
PHROT := ABC IAW*n* = 2.5 ∠–26° IBW*n* = 2.5 ∠–146° ICW*n* = 2.5 ∠+94°	**Expected:** P = 0.4677 • CTR*n* • PTR	**Expected:** Q = 0.2286 • CTR*n* • PTR	**Expected** pf = 0.90 lag
VA (Vab) = 120 ∠+30° VC (Vcb) = 120 ∠+90°	**Measured:**	**Measured:**	**Measured:**
PHROT := ACB IAW*n* = 2.5 ∠–26° IBW*n* = 2.5 ∠+94° ICW*n* = 2.5 ∠–146°	**Expected:** P = 0.4677 • CTR*n* • PTR	**Expected:** Q = 0.2286 • CTR*n* • PTR	**Expected:** pf = 0.90 lag
VA (Vab) = 120 ∠–30° VC (Vcb) = 120 ∠–90°	**Measured:**	**Measured:**	**Measured:**

[a] n = VIWDG setting.

Application Guides for Field Testing and Commissioning

Please refer to the following application guides on selinc.com for help with field testing and commissioning.

- Application Guide AG2011-09, *Single-Phase Testing of the* SEL-787 *Differential Element*
- Application Guide AG2011-10, *Single-Phase Testing of the SEL-787 Harmonic Blocking and Restraint Functions*
- Application Guide AG2011-11, *Single-Phase Testing of the* SEL-787*,* SEL-787-*3, and* SEL-787-*4 REF Elements*
- Application Guide AG2013-25, *Three-Phase Restrained Differential Element Testing for the SEL-387 and SEL-787*

Periodic Tests (Routine Maintenance)

Because the SEL-787 is equipped with extensive self-tests, the most effective maintenance task is to monitor the front-panel messages after a self-test failure. In addition, each relay event report generated by a fault should be reviewed. Such reviews frequently reveal problems with equipment external to the relay, such as instrument transformers and control wiring.

The SEL-787 does not require specific routine tests, but your operation standards may require some degree of periodic relay verification. If you need or want to perform periodic relay verification, the following checks are recommended.

Table 11.12 Periodic Relay Checks

Test	Description
Relay Status	Use the front-panel `STATUS` or serial port **STATUS** command to verify that the relay self-tests have not detected any WARN or FAIL conditions.
Meter	Verify that the relay is correctly measuring current and voltage (if included) by comparing the relay meter readings to separate external meters.
Control Input	Using the front-panel `MAIN > Targets > Row 21` function, check the control input status in the relay. As you apply rated voltage to each input, the position in Row 21 corresponding to that input should change from zero (0) to one (1).
Contact Output	For each output contact, set the input to Logic 1. This causes the output contact to close. For example, setting OUT101 := 1 causes the output **OUT101** contact to close. Repeat the process for all contact outputs. Make sure that each contact closure does what you want it to do in the annunciation, control, or trip circuit associated with that contact closure.

Self-Test

The SEL-787 runs a variety of self-tests. The relay takes the following corrective actions for out-of-tolerance conditions (see *Table 11.13*):

- Protection Disabled: The relay disables protection and control elements and trip/close logic. All output contacts are de-energized. The ENABLED front-panel LED is extinguished.
- ALARM Output: Two Relay Word bits, HALARM and SALARM, signal self-test problems. SALARM is pulsed for software programmed conditions, such as settings changes, firmware upgrade attempts via Ethernet, access level changes, unsuccessful password entry attempts, active group change, copy command, and password change. HALARM is pulsed for hardware self-test warnings. HALARM is continuously asserted (set to logical 1) for hardware self-test failures. A diagnostic alarm may be configured as explained in *Section 4: Protection and Logic Functions*. In the Alarm Status column of *Table 11.13*, Latched indicates that HALARM is continuously asserted, Not Latched indicates that HALARM is pulsed for five seconds, and NA indicates that HALARM is not asserted.
- 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 for failures.
- For certain failures, the relay automatically restarts as many as three times. In many instances, this corrects the failure. The failure message might not be fully displayed before automatic restart occurs. Indication that the relay restarted is recorded in the Sequential Events Recorder (SER).

NOTE: Refer to Access Commands (ACCESS, 2ACCESS, and CAL) for more information on when SALARM is pulsed for access level changes and unsuccessful password entry attempts.

NOTE: "W" in the STA response indicates a warning for the corresponding quantity.

Use the serial port **STATUS** command or front-panel 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.

Table 11.13 Relay Self-Tests (Sheet 1 of 4)

Self-Test	Description	Normal Range	Protection Disabled on Failure	Alarm Status	Auto Message on Failure	Front-Panel Message on Failure	Corrective Action
Watchdog Timer Periodic Resetting	(1/32 cycle)		Yes	De-energized	No	No	
Main Board FPGA (power up)	Fail if main board field-programmable gate array does not accept program or the version number is incorrect		Yes	Latched	Yes	Status Fail FPGA Failure	Automatic restart. Contact SEL if failure returns.
Main Board FPGA (run time)	Fail on lack of data acquisition interrupts or on detection of a CRC error in the FPGA code		Yes	Latched	Yes	Status Fail FPGA Failure	Automatic restart. Contact SEL if failure returns.
GPSB (back-plane) Communications	Fail if GPSB is busy on entry to processing interval		Yes	Latched	Yes	Status Fail GPSB Failure	Automatic restart. Contact SEL if failure returns.

Table 11.13 Relay Self-Tests (Sheet 2 of 4)

Self-Test	Description	Normal Range	Protection Disabled on Failure	Alarm Status	Auto Message on Failure	Front-Panel Message on Failure	Corrective Action
Front-Panel HMI (power up)	Two-line display: Fails if ID registers do not match or if the FPGA programming is unsuccessful Touchscreen display: Automatic diagnostics identify an issue		No	Not Latched	Yes	NA	STA C, to clear the warning in the status report. Contact SEL if failure returns.
External RAM (power up)	Performs a read/write test on system RAM		Yes	Latched	No	No	
External RAM (run time)	Performs a read/write test on system RAM		Yes	Latched	Yes	Status Fail RAM Failure	Automatic restart. Contact SEL if failure returns.
Internal RAM (power up)	Performs a read/write test on system CPU RAM		Yes	Latched	No	No	
Internal RAM (run time)	Performs a read/write test on system CPU RAM		Yes	Latched	Yes	Status Fail RAM Failure	Automatic restart. Contact SEL if failure returns.
Code Flash (power up)	SELBOOT qualifies code with a checksum		NA	NA	NA	NA	
Data Flash (power up)	Checksum is computed on critical data		Yes	Latched	Yes	Status Fail Non_Vol Failure	
Data Flash (run time)	Checksum is computed on critical data		Yes	Latched	Yes	Status Fail Non_Vol Failure	
Critical RAM (settings)	Performs a checksum test on the active copy of settings		Yes	Latched	Yes	Status Fail CR_RAM Failure	Automatic restart. Contact SEL if failure returns.
Critical RAM (run time)	Verify instruction matches FLASH image		Yes	Latched	Yes	Status Fail CR_RAM Failure	Automatic restart. Contact SEL if failure returns.
I/O Board Failure	Check if ID register matches part number		Yes	Latched	Yes	Status Fail Card [C|D|E] Failure	
DeviceNet Board Failure	DeviceNet card does not respond in three consecutive 300 ms time out periods		NA	NA	NA	COMMFLT Warning	
Card Z (power up)	Fail if ID register does not match part number		Yes	Latched	Yes	Status Fail Card Z Fail	
Card Z A/D Offset Warn	Measure dc offset at each input channel	–50 mV to +50 mV	No	Not Latched	No	NA	STA C, to clear the warning in the status report. Contact SEL if failure returns.
ADCCHK (Slot Z)	A/D reference channel check	2.375 or >2.625 V	Yes	Latched	Yes	Status Fail Card Z Fail	Automatic restart. Contact SEL if failure returns.
Card E (power up)	Fail if ID register does not match part number		Yes	Latched	Yes	Status Fail Card E Fail	

Table 11.13 Relay Self-Tests (Sheet 3 of 4)

Self-Test / Description	Normal Range	Protection Disabled on Failure	Alarm Status	Auto Message on Failure	Front-Panel Message on Failure	Corrective Action
Card E A/D Offset Warn Measure dc offset at each input channel	–50 to +50 mV	No	Not Latched	No	NA	STA C, to clear the warning in the status report. Contact SEL if failure returns.
ADCCHK (Slot E) A/D reference channel check	2.375 V or >2.625 V	Yes	Latched	Yes	Status Fail Card E Fail	Automatic restart. Contact SEL if failure returns.
+0.9 V Fail Monitor +0.9 V power supply	0.855 to 0.945 V	Yes	Latched	Yes	Status Fail +0.9 V Failure	
+1.2 V Fail Monitor +1.2 V power supply	1.152 to 1.248 V	Yes	Latched	Yes	Status Fail +1.2 V Failure	
+1.5 V Fail Monitor +1.5 V power supply	1.35 to 1.65 V	Yes	Latched	Yes	Status Fail +1.5 V Failure	
+1.8 V Fail Monitor +1.8 V power supply	1.71 to 1.89 V	Yes	Latched	Yes	Status Fail +1.8 V Failure	
+3.3 V Fail Monitor +3.3 V power supply	3.07 to 3.53 V	Yes	Latched	Yes	Status Fail +3.3 V Failure	
+5 V Fail Monitor +5 V power supply	4.65 to 5.35 V	Yes	Latched	Yes	Status Fail +5 V Failure	
+2.5 V Fail Monitor +2.5 V power supply	2.32 to 2.68 V	Yes	Latched	Yes	Status Fail +2.5 V Failure	
+3.75 V Fail Monitor +3.75 V power supply	3.48 to 4.02 V	Yes	Latched	Yes	Status Fail +3.75 V Failure	
–1.25 V Fail Monitor -1.25 V power supply	–1.16 to –1.34 V	Yes	Latched	Yes	Status Fail –1.25 V Failure	
–5 V Fail Monitor -5 V power supply	–4.65 to –5.35 V	Yes	Latched	Yes	Status Fail –5 V Failure	
Clock Battery Monitor clock battery	2.3 to 3.5 V	No	Not Latched	Yes	NA	STA C, to clear the warning in the status report. Contact SEL if failure returns.
Clock Chip Unable to communicate with clock or fails time keeping test		No	Not Latched	Yes	NA	STA C, to clear the warning in the status report. Contact SEL if failure returns.
Clock Chip RAM Clock chip static RAM fails		No	Not Latched	Yes	NA	STA C, to clear the warning in the status report. Contact SEL if failure returns.
External/Internal RTD Fails if the internal RTD card or the external RTD reports that at least one enabled RTD input is open or shorted, if there is no communication, or if there is a power supply failure for the external RTD module		NA	NA	No	RTD Failure	STA C, to clear the warning in the status report. Contact SEL if failure returns.

Table 11.13 Relay Self-Tests (Sheet 4 of 4)

Self-Test	Description	Normal Range	Protection Disabled on Failure	Alarm Status	Auto Message on Failure	Front-Panel Message on Failure	Corrective Action
CID (configured IED description) File (access)	Failure to access/read CID file		No	NA	No	Status Fail CID File Failure	
Exception Vector	CPU error		Yes	Latched	NA	Vector nn Relay Disabled	Automatic restart. Contact SEL if failure returns.

Troubleshooting

Table 11.14 Troubleshooting

Symptom/Possible Cause	Diagnosis/Solution
The relay ENABLED front-panel LED is dark.	
Input power is not present or a fuse is blown.	Verify that input power is present. Check fuse continuity.
Self-test failure	View the self-test failure message on the front-panel display.
The relay front-panel display does not show characters.	
The relay front-panel has timed out.	Press the **ESC/HOME** pushbutton to activate the display.
The relay is de-energized.	Verify input power and fuse continuity.
The relay does not accurately measure voltages or currents.	
Wiring error	Verify input wiring.
Incorrect CTR1, CTR2, CTR3, CTR4, CTRN, or PTR setting	Verify instrument transformer ratios, connections, and associated settings.
Voltage neutral terminal (N) is not properly grounded.	Verify wiring and connections.
The relay does not respond to commands from a device connected to the serial port.	
Cable is not connected.	Verify the cable connections.
Cable is not the correct type.	Verify the cable pinout.
The relay or device is at an incorrect data rate or has another parameter mismatch.	Verify device software setup.
The relay serial port has received an XOFF, halting communications.	Type **<Ctrl+Q>** to send the relay XON and restart communications.
The relay does not respond to faults.	
The relay is improperly set.	Verify the relay settings.
Improper test source settings	Verify the test source settings.
Current or voltage input wiring error	Verify input wiring.
Failed relay self-test	Use the front-panel RELAY STATUS function to view self-test results.

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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Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.338.3838
Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com

SEL-787-2, -3, -4 Relay Commissioning Test Worksheet

System Information

System Settings

RID (Relay identification) =	
TID (Terminal identification) =	
MVA (Maximum transformer Rating) =	

	Winding 1	Winding 2	Winding 3	Winding 4
Current transformer connection:	W1CT =	W2CT =	W3CT =	W4CT =
Current transformer ratio:	CTR1 =	CTR2 =	CTR3 =	CTR4 =
Connection compensation:	W1CTC =	W2CTC =	W3CTC =	W4CTC =
Nominal line-to-line voltage (kV):	VWDG1 =	VWDG2 =	VWDG3 =	VWDG4 =
TAP calculation:	TAP1 =	TAP2 =	TAP3 =	TAP4 =

Differential Settings

087P =	SLP1 =	SLP2 =	IRS1 =	U87P =

Metered Load (Data taken from substation panel meters, not the SEL-787-2, -3, -4)

± Readings from meters	Winding 1	Winding 2	Winding 3	Winding 4
Megawatts:	MW1 =	MW2 =	MW3 =	MW4 =
Megavars:	MVAR1 =	MVAR2 =	MVAR3 =	MVAR4 =
MVA calculation:	MVA1 =	MVA2 =	MVA3 =	MVA4 =

MVA calculation:

$$\mathrm{MVAn} = \sqrt{\mathrm{MWn}^2 + \mathrm{MVARn}^2}$$

Calculated Relay Load

	Winding 1	Winding 2	Winding 3	Winding 4
Primary Amperes calculation:	I1pri =	I2pri =	I3pri =	I4pri =
Secondary Amperes calculation:	I1sec =	I2sec =	I3sec =	I4sec =

Primary Amperes calculation:

$$\text{Inpri} = \frac{\text{MVAn} \bullet 1000}{\sqrt{3} \bullet \text{VWDGn}}$$

Secondary Amperes calculation:

$$\text{WnCT} = \text{Y, In sec} = \frac{\text{Inpri}}{\text{CTRn}}$$

$$\text{WnCT} = \text{D, In sec} = \frac{\text{Inpri} \bullet \sqrt{3}}{\text{CTRn}}$$

Settings Check

The following check assures zero-sequence current filtering is applied to all necessary transformer windings.

It is essential to use a non-zero Winding CT Connection Compensation (W*n*CTC) setting for all grounded-WYE connected transformer windings with WYE connected CTs.

Verify that no grounded-WYE transformer windings with WYE connected CTs has setting W*n*CTC = 0. Refer to *Appendix O: Protection Application Examples* for the guidelines in determining correct compensation settings.

Note the following commissioning checks will not detect the failure to properly filter zero-sequence current. Failure to adhere to this check will result in a differential operation for external faults involving ground.

Proper zero-sequence filtering verified?

____

Connection Check

System load conditions should be higher than 0.1 A secondary. 0.5 A secondary is recommended for the best results.

Differential Connection (issue MET DIF <Enter> to serial port or front panel)

Operate Current:	IOP1 =	IOP2 =	IOP3 =
Restraint Current:	IRT1 =	IRT2 =	IRT3 =
Mismatch Calculation:	MM1 =	MM2 =	MM3 =
Check individual current magnitudes, phase angles, and operate and restraint currents in an event report if mismatch is not less than 0.10.			

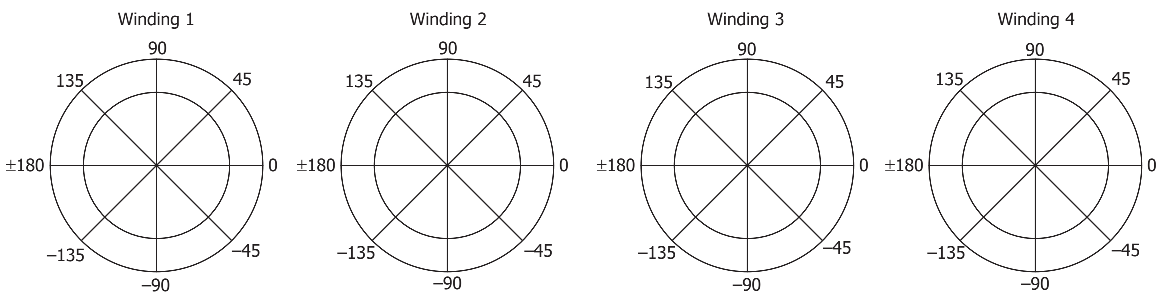
Mismatch Calculation:

$$\text{MMn} = \frac{\text{IOPn}}{\text{IRTn}}$$

Magnitude, Angle, and Phase Rotation Check

Issue **MET <Enter>** to the serial port or front panel. If wye-connected CTs are used, then magnitudes of the currents in the MET response correspond to secondary currents seen by the relay multiplied by the corresponding CT ratio. The angles of the currents in the MET response correspond to the angles of secondary currents as seen by the relay. Refer to the *Delta-Connected CTs* for information on how the currents are reported when delta-connected CTs are used. Under balanced load conditions, the secondary amperes can be calculated by dividing the primary amperes in the MET report with the corresponding CT ratio. The secondary angles are the same as the primary angles in the MET report.

	Winding 1	Winding 2	Winding 3	Winding 4
A-Phase Secondary Amperes:	IAW1 = ________	IAW2 = ________	IAW3 = ________	IAW4 = ________
A-Phase Angle:	________	________	________	________
B-Phase Secondary Amperes:	IBW1 = ________	IBW2 = ________	IBW3 = ________	IBW4 = ________
B-Phase Angle:	________	________	________	________
C-Phase Secondary Amperes:	ICW1 = ________	ICW2 = ________	ICW3 = ________	ICW4 = ________
C-Phase Angle:				



1. Calculated relay amperes match MET amperes?

2. Phase rotation is as expected for each winding?

3. Do angular relationships among windings correspond to expected results? (Remember that secondary current values for load current flowing out of a winding will be 180° out-of-phase with the reference phase position for that winding in the case of standard CT connections. Refer to *Figure O.11* for an example of standard CT connections.)

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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. The status report displays the firmware identification (FID) string.

NOTE: Firmware SEL-787-4-Rxxx is for all models of the SEL-787.

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 string.

Existing firmware:

FID=SEL-787-4-**R100**-V0-Z001001-D*xxxxxxxx*

Standard release firmware:

FID=SEL-787-4-**R101**-V0-Z001001-D*xxxxxxxx*

A point release is identified by a change in the V-number of the device FID string.

Existing firmware:

FID=SEL-787-4-R100-**V0**-Z001001-D*xxxxxxxx*

Standard release firmware:

FID=SEL-787-4-R100-**V1**-Z001001-D*xxxxxxxx*

The date code is after the D. For example, the following is firmware version R100, date code December 03, 2014.

FID=SEL-787-4-R100-V0-Z001001-**D20141203**

NOTE: R1xx series firmware can be upgraded to any of the latest firmware versions.

Table A.1, *Table A.2*, and *Table A.3* list the firmware versions, a description of modifications, and the instruction manual date code that corresponds to the firmware versions of each series of firmware. The most recent firmware version is listed first.

Starting with revisions published after March 1, 2022, changes that address security vulnerabilities are marked with “[Cybersecurity]”. Other improvements to cybersecurity functionality that should be evaluated for potential cybersecurity importance are marked with “[Cybersecurity Enhancement]”.

Table A.1 R300 Series Firmware Revision History (Sheet 1 of 5)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
SEL-787-4-R303-V1-Z005003-D20241121	Includes all the functions of SEL-787-4-R303-V0-Z005003-D20240826 with the following addition: ➤ Improved the performance of the relay under high burden conditions.	20241121
SEL-787-4-R303-V0-Z005003-D20240826	➤ [Cybersecurity] Resolved an issue where the SALARM Relay Word bit did not pulse for an incorrect password entered via the touchscreen. ➤ [Cybersecurity] Resolved an issue where a Bridge Protocol Data Unit (BPDU) packet of an invalid size could cause the relay to perform a diagnostic restart. ➤ Added ordering options for low-energy analog (LEA) cards in Slot E and Slot Z. ➤ Enhanced the breaker failure logic by adding re-trip logic, separate breaker failure trip logic, a settable breaker failure seal-in delay setting, BFISID*n* (*n* = 1–4), and the residual current (3I0) supervision setting. ➤ Extended the combined winding overcurrent elements to support combined Winding 2 and Winding 3 currents. ➤ Added the negative-sequence percentage-restrained differential element (87Q) to provide protection for sensitive, low-magnitude faults, such as turn-to-turn faults. ➤ Added SELogic settings SCBK*m*BO and SCBK*m*BC (*m* = 1–4) for the IEC 61850 breaker control interlocking (CILO) logical node. ➤ Enhanced the REF element internal fault coverage for applications using neutral grounding resistors. ➤ Added the PFLEAD Relay Word bit to indicate power factor lead or lag. ➤ Added support to download filtered differential event reports from the web server. ➤ REF*n*POL (*n* = 1, 3A or 3B) setting range is made independent of CCW*m* (*m* = 12, 23, 34) settings. ➤ Modified the TEST DB functionality to override Relay Word bits that are in the Sequential Events Recorder (SER). ➤ Improved performance of relay in Switched mode during a network storm. ➤ Resolved an issue where the GOOSE messages did not use the correct MAC address after the MAC address was updated. ➤ Resolved an issue where synchrophasor data frames could be dropped when used in a UDP_S transport scheme. ➤ Lowered the minimum pickup value for definite-time overcurrent elements from 0.5 A to 0.25 A for 5 A relays and from 0.1 A to 0.05 A for 1 A relays. ➤ Resolved an issue where entering a special character for a settings value during an SEL ASCII session could cause the relay to interpret the setting as 0. ➤ Resolved an issue where Port 1B became occasionally unresponsive after changing the NETMODE setting value from SWITCHED to PRP. ➤ Resolved an issue where changing the DELTAY_X setting did not retain the SYNCPX setting.	20240826

Table A.1 R300 Series Firmware Revision History (Sheet 2 of 5)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
	➤ Modified the usage rule for VNOM setting to support secondary VNOM voltages of up to 480 V (L-L) when DELTA_Y is set to WYE. ➤ Resolved a reporting issue where the I*n*F4 quantities (*n* = 1–3) in the CEV DIF report were incorrect. ➤ Resolved an issue where the power elements could operate when phase-to-phase secondary voltage is below 20 V. ➤ Improved the accuracy of data time stamp in the COMTRADE event report. ➤ Resolved an issue where the relay could experience a NON VOL failure under certain conditions.	
SEL-787-4-R302-V2-Z005003-D20240826	Includes all the functions of SEL-787-4-R302-V1-Z005003-D20240329 with the following additions: ➤ [Cybersecurity] Resolved an issue where the SALARM Relay Word bit did not pulse for an incorrect password entered via the touch-screen. ➤ [Cybersecurity] Resolved an issue where a Bridge Protocol Data Unit (BPDU) packet of an invalid size could cause the relay to perform a diagnostic restart. ➤ Modified the TEST DB functionality to override Relay Word bits that are in the Sequential Events Recorder (SER). ➤ Improved performance of relay in Switched mode during a network storm. ➤ Resolved an issue where the GOOSE messages did not use the correct MAC address after the MAC address was updated. ➤ Resolved an issue where synchrophasor data frames could be dropped when used in a UDP_S transport scheme. ➤ Resolved an issue where entering a special character for a settings value during an SEL ASCII session could cause the relay to interpret the setting as 0. ➤ Resolved an issue where Port 1B became occasionally unresponsive after changing the NETMODE setting value from SWITCHED to PRP. ➤ Resolved a reporting issue where the I*n*F4 quantities (*n* =1–3) in the CEV DIF report were incorrect. ➤ Resolved an issue where the power elements could operate when phase-to-phase secondary voltage is below 20 V. ➤ Improved the accuracy of data time stamp in the COMTRADE event report. ➤ Resolved an issue where the relay could experience a NON VOL failure under certain conditions. **NOTE:** We recommend that you save all the events stored in the relay before upgrading to firmware version R302-V2. Clear the event history buffer after the firmware upgrade.	20240826
SEL-787-4-R302-V1-Z005003-D20240329	Includes all the functions of SEL-787-4-R302-V0-Z005003-D20220826 with the following additions: ➤ [Cybersecurity] Removed advanced diagnostic commands from Access Level C. ➤ Improved the resolution of the frequency measurement in the COMTRADE event report.	20240329

Table A.1 R300 Series Firmware Revision History (Sheet 3 of 5)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
	➤ Resolved an issue where the Precision Time Protocol (PTP) was not able to synchronize the time if the PTP transport mechanism setting PTPTR was set equal to LAYER2. This issue affects firmware version R302-V0 only. ➤ Resolved an issue where the relay failed to synchronize with the SNTP server when Rapid Spanning Tree Protocol (RSTP) was enabled. This issue impacts firmware version R302-V0 only. ➤ Resolved an issue where energy quantities that were mapped to math variables were reported as zero. ➤ Resolved an issue with the through-fault event (TFE) report update. ➤ Resolved an issue with the rms voltage analog quantities not being reported according to the DELTA_Y setting. ➤ Resolved an issue where an event with a duplicate event record number, caused by a defective event record, could not be retrieved. ➤ Resolved an issue with the processing of the math variables.	
SEL-787-4-R302-V0-Z005003-D20220826	➤ [Cybersecurity] Resolved a rare, low-risk issue where deliberately crafted Ethernet traffic could cause the relay to perform a diagnostic restart. ➤ [Cybersecurity] Updated a third-party networking software component that removes low-risk security vulnerabilities that could result in temporary loss of Ethernet communications. ➤ Added firmware support for new hardware component suppliers. ➤ Added support for IEEE 802.1Q-2014 Rapid Spanning Tree Protocol (RSTP) for models with the dual Ethernet port option. ➤ Added support for the IEC 61850 Local/Remote control feature defined in the IEC 61850-7-4 standard. ➤ Added support for the IEC 61850 functional naming feature. ➤ Added SELOGIC variable SC850SM for IEC 61850 simulation mode. ➤ Increased the number of Relay Word bit aliases to 32. ➤ Improved performance to allow touchscreen operation after a firmware downgrade. ➤ Expanded the setting range for the VIWDG setting to include Windings 1 and 2 when CCW12 = Y. ➤ Added analog quantities for the operate and restraint currents used in the differential element. ➤ Enhanced the relay firmware to retain the configuration settings for the IP address, subnet mask, and default router for Port 1 during a firmware upgrade from any previous 3*xx* firmware version. ➤ Resolved an issue when the relay failed to evaluate analog quantity I850MOD when mapped to a SELOGIC control equation. ➤ Resolved an issue where the relay always remained in IEC 61850 ON mode after issuing the **R_S** command independent of the selected IEC 61850 mode/behavior. ➤ Resolved an issue that caused the touchscreen to incorrectly display "Resend the Touchscreen settings." ➤ Resolved an issue where the relay did not accept OC*n* (*n* = 1–4) bits in the DNP3 binary output map.	20220826

Table A.1 R300 Series Firmware Revision History (Sheet 4 of 5)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
SEL-787-4-R301-V0	Note: SEL-787-4 R301-V0 was not production released. R302-V0 follows R300-V7.	—
SEL-787-4-R300-V7-Z004003-D20220826	Includes all the functions of SEL-787-4-R300-V6-Z004003-D20220225 with the following additions: ➤ Added firmware support for new hardware component suppliers. ➤ Improved performance to allow touchscreen operation after a firmware downgrade. ➤ Resolved an issue where the relay always remained in IEC 61850 ON mode after issuing the **R_S** command independent of the selected IEC 61850 mode/behavior. ➤ Resolved an issue where the relay did not accept OC*n* (*n* = 1–4) bits in the DNP3 binary output map.	20220826
SEL-787-4-R300-V6-Z004003-D20220225	Includes all the functions of SEL-787-4-R300-V5-Z004003-D20211213 with the following addition: ➤ [Cybersecurity] Resolved an issue where GOOSE receive messages would no longer be processed during or after a GOOSE data storm on the network.	20220225
SEL-787-4-R300-V5-Z004003-D20211213	Includes all the functions of SEL-787-4-R300-V4-Z004003-D20210910 with the following addition: ➤ Revised the firmware to allow replacement of the field-programmable gate array (FPGA) part.	20211213
SEL-787-4-R300-V4-Z004003-D20210910	Includes all the functions of SEL-787-4-R300-V3-Z004003-D20210104 with the following additions: ➤ Added the IEC 61850 blocked-by-interlocking control error response. ➤ Resolved an issue where a large number of file read operations could lead to a data retrieval error. ➤ Resolved an issue where EtherNet/IP communication stopped after approximately 25 days.	20210910
SEL-787-4-R300-V3-Z004003-D20210104	Includes all the functions of SEL-787-4-R300-V2-Z004003-D20200921 with the following additions: ➤ Resolved a rare issue where Telnet traffic could cause a diagnostic restart of the relay. ➤ Resolved an issue in touchscreen relay models where repeated triggering of the TRIP/WARN messages resulted in the relay becoming disabled. ➤ Resolved an issue where all winding currents were reported via the synchrophasor protocol regardless of the PHCURR setting.	20210104
SEL-787-4-R300-V2-Z004003-D20200921	Includes all the functions of SEL-787-4-R300-V1-Z004003-D20200331 with the following additions: ➤ Resolved an issue with the EPORT setting for the Ethernet port. ➤ Resolved an issue in the relay where Modbus Register addresses did not match the Modbus Register Map.	20200921
SEL-787-4-R300-V1-Z004003-D20200331	Includes all the functions of SEL-787-4-R300-V0-Z004003-D20200331 with the following additions: ➤ Added support for zipped and digitally signed (.zds) firmware files. These .zds firmware files require the SELBOOT firmware version to be upgraded to R600 first. Firmware files with the .s19 and .z19 extensions cannot be sent to relays with SELBOOT firmware R600. ➤ Added the ability to upgrade relay firmware remotely over an Ethernet network.	20200331

Table A.1 R300 Series Firmware Revision History (Sheet 5 of 5)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
	➤ Added web server capability to relays equipped with Ethernet. ➤ Added control support to the two-position disconnects. ➤ Added two three-position disconnects with control support. ➤ Added support for IEEE 1588-2008 firmware-based Precision Time Protocol (PTP) for time synchronization. ➤ Added IEC 61850 Test Mode with standard operating modes, including On, Blocked, Test, Test/Blocked, and Off. ➤ Added the EtherNet/IP communications option for relays equipped with Ethernet. ➤ Improved Sequential Events Recorder (SER) time-stamp accuracy for digital inputs to 1 ms. ➤ Improved event reports to include settings at the time of the event. ➤ Added the ability to trigger event reports from the Event History application on the touchscreen display. ➤ Improved the security of the resistance temperature detector (RTD) FAULT, ALARM, and TRIP indicators by adding an approximately 12-second delay to filter RTD measurements distorted by electrical noise. ➤ Updated the TCP keep-alive settings so they can be turned off or configured as desired. This update applies to all TCP protocols, including Telnet, File Transfer Protocol (FTP), MMS, and C37.118 phasor measurement unit (PMU). ➤ Increased the upper limit of the frequency trip delay setting 81D*n*TD (*n* = 1 to 4) from 240.00 to 400.00 seconds. ➤ Resolved an issue in which the relay continued to send Fast Sequential Events Recorder (SER) data to the real-time automation controller (RTAC) after the relay acknowledged an RTAC disable command. ➤ Addressed an issue with event type mismatch between the CHI and CEV commands that resulted in real-time automation controllers (RTACs) being unable to collect events with event type strings longer than 14 characters. ➤ Resolved an issue where the state of Target LED (TLED) data points was not correctly reported in GOOSE messages. ➤ Resolved an issue where the TAP setting values were rounded differently between the firmware and PC software. ➤ Resolved an issue where the DISPLAY option was missing from the EVENTS menu in the two-line display. Only firmware versions R200-V0 and R200-V1 are affected. ➤ Resolved an issue where the Global access control setting DSABLSET did not disable editing settings via the touchscreen interface when DSABLSET := Y. ➤ Resolved an issue in the touchscreen models where editing the DNP3 setting, TIMERQ, resulted in an unresponsive screen until the Home pushbutton was pressed. ➤ Resolved an issue where the COMTRADE events included event data four times. Firmware versions R200-V0 and higher are affected by this issue. ➤ Modified firmware to increment the state number (stNum) in GOOSE messages for any change of the quality attribute.	
SEL-787-4-R300-V0-Z004003-D20200331	➤ SEL-787-4-R300-V0 was not released.	20200331

Table A.2 R200 Series Firmware Revision History (Sheet 1 of 3)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
SEL-787-4-R201-V5-Z003002-D20220826	Includes all the functions of SEL-787-4-R201-V4-Z003002-D20220225 with the following addition: ➤ Added firmware support for new hardware component suppliers.	20220826
SEL-787-4-R201-V4-Z003002-D20220225	Includes all the functions of SEL-787-4-R201-V3-Z003002-D20211213 with the following addition: ➤ [Cybersecurity] Resolved an issue where GOOSE receive messages would no longer be processed during or after a GOOSE data storm on the network.	20220225
SEL-787-4-R201-V3-Z003002-D20211213	Includes all the functions of SEL-787-4-R201-V2-Z003002-D20210910 with the following addition: ➤ Revised the firmware to allow replacement of the field-programmable gate array (FPGA) part.	20211213
SEL-787-4-R201-V2-Z003002-D20210910	Includes all the functions of SEL-787-4-R201-V1-Z003002-D20210104 with the following addition: ➤ Resolved an issue where a large number of file read operations could lead to a data retrieval error.	20210910
SEL-787-4-R201-V1-Z003002-D20210104	Includes all the functions of SEL-787-4-R201-V0-Z003002-D20200331 with the following additions: ➤ Resolved a rare issue where Telnet traffic could cause a diagnostic restart of the relay. ➤ Resolved an issue in touchscreen relay models where repeated triggering of the TRIP/WARN messages resulted in the relay becoming disabled. ➤ Resolved an issue where all winding currents were reported via the synchrophasor protocol regardless of the PHCURR setting.	20210104
SEL-787-4-R201-V0-Z003002-D20200331	➤ Resolved an issue in which the relay continued to send Fast SER data to the RTAC after the relay acknowledged an RTAC disable command. ➤ Resolved an issue where the state of Target LED (TLED) data points was not correctly reported in GOOSE messages. ➤ Resolved an issue where the DISPLAY option was missing from the EVENTS menu in the two-line display. Only firmware versions R200-V0 and R200-V1 are affected. ➤ Resolved an issue in the touchscreen models where editing the DNP3 setting, TIMERQ, resulted in an unresponsive screen until the Home pushbutton was pressed. ➤ Resolved an issue where the relay enabled 1/2 cycle before the front-end analogs settled down, leading to nuisance events on relay turn on. This issue affects firmware versions R200-V0 and R200-V1 only.	20200331
SEL-787-4-R200-V1-Z003002-D20200117	Includes all the functions of SEL-787-4-R200-V0-Z003002-D20180629 with the following addition: ➤ Resolved a communications issue that could occasionally result in increased latency of a relay response to Ethernet requests. Only firmware version R200-V0 is affected.	20200117
SEL-787-4-R200-V0-Z003002-D20180629	➤ Added three new model options (SEL-787-2E, 21, 2X) with two-winding capabilities. ➤ Added the touchscreen display front-panel option.	20180629

Table A.2 R200 Series Firmware Revision History (Sheet 2 of 3)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
	➤ Enhanced the CPU card design, including the addition of a GOOSE port with a dedicated MAC address to improve GOOSE performance. (**Note:** Relays with older CPU cards can be upgraded to firmware version R200 or higher, but the relay will not have the GOOSE performance improvements.) ➤ Updated IEC 61850 protocol implementation to IEC 61850 Edition 2. ➤ Added file transfer support in IEC 61850 for CEV and COMTRADE events; SER, LDP, BRE, TFE, and HIS reports; and CID and settings files. ➤ Increased the maximum number of GOOSE subscriptions to 64. ➤ Added password authentication and session timeout for MMS services. ➤ Added IEC 62439 Parallel Redundancy Protocol (PRP) for models with the dual Ethernet port option. ➤ Increased the number of DNP sessions from 3 to 5. ➤ Added Modbus Master IP settings. ➤ Added the enable port setting EPORT to all of the communications ports to enhance port security. Added Telnet access setting ETELNET and FTP access setting EFTPSERV to Ethernet Port 1. ➤ Added the MAXACC setting to all of the communication ports, including the front panel, to control limited or full access. Note that front panel MAXACC setting is not supported in relays with the touchscreen option. ➤ Added an ordering option for a 14 digital input card in Slots C, D, and E. ➤ Added COMTRADE support for events in the relay. ➤ Added a unique reference numbering system for HIS, CHIS, SUM, CSUM, EVE, and CEV reports. ➤ Added OFF to all of the 50 elements delay settings ranges. ➤ Added the inverse-time over- and undervoltage elements. ➤ Added disconnect status logic with double point indication to monitor the status of as many as 16 disconnect switches. ➤ Enhanced the firmware to allow for control of as many as 4 breakers for all models. ➤ Added individual phase power measurements for all models. ➤ Added a setting, METHRES, in the Global settings category, that allows for turning off the squelching of currents and voltages below a certain level. ➤ Added torque-control settings for the frequency (81) elements, with the default value set to 1. ➤ Modified GPSB diagnostics logic to show failure only if the GPSB diagnostics fail three consecutive times within 24 hours. ➤ Enhanced the SELOGIC processing capacity in the relay. ➤ Resolved an issue with changing phase angles even though the magnitude/angles of the analog channels were squelched.	

Table A.2 R200 Series Firmware Revision History (Sheet 3 of 3)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
	➤ Increased the resolution of VWDG*n* (*n* = 1, 2, 3, or 4) setting from 2 to 3 decimal places. ➤ Resolved a relay disabling issue that occurred when the setting EPMU was set to Y and there was a corrupt IRIG signal. ➤ Resolved a relay disabling issue that occurred when setting EBMON*n* = N and the breaker monitor set point values were set to zero. ➤ Resolved an incorrect reporting issue of Winding 3 and Winding 4 peak detector current in the event summary (SUM) report. ➤ Resolved an issue where the relay may incorrectly accept and use user-entered TAP values while in auto-calculate mode (setting MVA ≠ OFF). Incorrect values could cause a misoperation. ➤ Resolved an issue where the analog quantity for frequency got reset to 0 after a settings change. ➤ Resolved an issue with the Modbus registers for phase and phase-to-phase max/min voltages that retained a previous value when the DELTA_Y setting was changed. ➤ Corrected an issue with resetting the breaker monitor data via Modbus using registers 261 or 2001H. ➤ Corrected an issue with the firmware where the IRS1 setting was rounded off to one decimal place (instead of two). ➤ Added the **TEST DB** command to support relay testing. ➤ Improved Ethernet operation for the synchrophasor protocol by addressing the issue of loss of packets.	

Table A.3 R100 Series Firmware Revision History (Sheet 1 of 2)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
SEL-787-4-R101-V0-Z002001-D20160630	➤ Removed option D from the NETPORT setting. ➤ Modified the prompt for the DNP Master IP Address, DNPIP*n*, to distinguish them from the device IP address. ➤ Revised the setting range for the TAP*n* settings (*n* = 1, 2, 3, 4) from 0.10 • $I_{NOM}n$–6.20 • $I_{NOM}n$ to 0.10 • $I_{NOM}n$–31.00 • $I_{NOM}n$, where $I_{NOM}n$ is 1 A or 5 A. Also revised the allowed ratio of the maximum (TAP*n*/$I_{NOM}n$) to the minimum (TAP*n*/$I_{NOM}n$) from 7.50 to 32.00. ➤ Resolved an issue related to harmonic blocking function of the differential element (87). The harmonic blocking function fails to block the 87 element under certain setting combinations. This issue is applicable to the SEL-787-3E and SEL-787-3S models and does not affect the SEL-787-4X model. ➤ Added the LOPBLK SELOGIC control equation setting with the default value set to 0 to allow for blocking of the LOP logic under user-defined conditions. Also raised the minimum threshold for positive-sequence voltage V1 from 5 V to 10.5 V. ➤ Addressed an issue where the oldest 180-cycle event was disappearing from the event history after the relay was power cycled or restarted with STA C. ➤ Added OFF to the setting range of the failover time setting, FTIME, to support fast failover switching in dual Ethernet models.	20160630

Table A.3 R100 Series Firmware Revision History (Sheet 2 of 2)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
	➤ Resolved an issue with AJU FECHA (SET DATE) and AJU HORA (SET TIME) commands when the port is set to the SPANISH language option. ➤ Resolved an issue related to breaker wear monitoring where the relay was incorrectly overwriting the data in the report.	
SEL-787-4-R100-V0-Z001001-D20141203	➤ Initial version.	20141203

SELBOOT Firmware Version and Relay Firmware Compatibility

The SELBOOT version and the compatible relay firmware versions are listed in *Table A.4*. The new SELBOOT firmware R600 ensures that the relay firmware upgrade file is digitally signed by SEL using a secure hash algorithm and that the file has been provided by SEL and that its contents have not been altered. R300 or higher firmware requires that the SELBOOT firmware be upgraded to R600.

Table A.4 SELBOOT Firmware Revision History

Boot Firmware Identification Number	Summary of Revisions	Firmware Version Supported	Release Date
SLBT7XX-R602-V0-Z000000-D20220826	➤ Improved the restart performance of the SELBOOT firmware.	R300 and higher	20220826
SLBT7XX-R601-V0-Z000000-D20211116	➤ Revised the SELBOOT firmware to allow replacement of the field-programmable gate array (FPGA) part.	R300 and higher	20211116
SLBT7XX-R600-V0-Z000000-D20200331	➤ The new SELBOOT supports zipped and digitally signed (.zds) firmware files.	R300 and higher	20200331
BOOTLDR-R502-V0-Z000000-D20211116	➤ Revised the SELBOOT firmware to allow replacement of the field-programmable gate array (FPGA) part.	R1*xx* to R2*xx*	20211116
BOOTLDR-R501-V0-Z000000-D20141203	➤ Initial version.	R100 to R201	20141203

SEL Display Package Versions

The SEL-787 with the touchscreen display option has display packages for the SEL display and default custom display. *Table A.5* lists the display package version, a description of modifications, and the instruction manual date code the corresponds to the display package versions. The most recent firmware version is listed first. The version number of this firmware is accessible through the Device Info folder.

Table A.5 SEL Display Package Revision History

SEL Display Package Version	Revisions	Release Date
3.0.50787.3007	➤ Added firmware support for new hardware component suppliers. ➤ Improved performance to allow touchscreen operation during a firmware downgrade.	20220826
3.0.50787.3005	➤ Added support for new hardware component suppliers. ➤ Modified the color touchscreen backlight brightness for more consistent dimming while in standby mode. ➤ Improved the performance of the touchscreen display in rotating display mode. ➤ Resolved an issue where the backlight could flicker during power up.	20211213

Table A.5 SEL Display Package Revision History

SEL Display Package Version	Revisions	Release Date
3.0.50787.3000	➤ Updated the keyboard layout on the touchscreen display for ease of data entry. ➤ Added pick list feature for settings that have a fixed list in the setting range. ➤ Added the ability to keep the backlight of the touchscreen display always on after the inactivity timer expires. Relays shipped after May 21, 2020 will support this feature.	20200331
1.0.50787.2013	➤ Added support for new hardware component suppliers.	20211213
1.0.50787.2000	➤ Initial release.	20180629

SEL Display Package and Relay Firmware Compatibility

The display package and the compatible relay firmware versions are listed in *Table A.6*. The version number of the display package is accessible through the Device Info folder. Display packages may be compatible with more than one relay firmware version.

Table A.6 SEL Display Package Compatibility With Relay Firmware

SEL Display Package Version	Revisions	Release Date
3.0.50787.3007	R300-V7 or higher	20220826
3.0.50787.3005	R300-V5 or higher	20211213
3.0.50787.3000	R300 or higher	20200331
1.0.50787.2013	R201-V3 or higher	20211213
1.0.50787.2000	R200 or higher	20180629

DeviceNet and Firmware Versions

The firmware on the DeviceNet interface is listed in *Table A.7*. The version number of this firmware is accessible via the DeviceNet interface.

Table A.7 DeviceNet Card Versions[a]

DeviceNet Card Software Revision	Revisions	Release Date
Major Rev: 1, Minor Rev: 5 (Rev 1.005)	Reads product code, DeviceNet card parameter descriptions, etc., from the relay.	20080407

[a] The DeviceNet file shown is for all models of the SEL-787.

The Electronic Data Sheet (EDS) file is not updated every time a firmware release is made. A new EDS file is released only when there is a change in the Modbus/DeviceNet parameters. The EDS file and an ICON file for the SEL-787-2, -3, -4 are zipped together on the SEL-787-2, -3, -4 Product Literature CD (SEL-*xxx*R*xxx*.zip). The file can also be downloaded from the SEL website at selinc.com

Table A.8 lists the compatibility among the EDS files and the various firmware versions of the relay.

Table A.8 EDS File Compatibility

EDS File	Firmware Revisions Supported	Release Date
SEL-787-4R300.EDS	R300	20200331
SEL-787-4R200.EDS	R200, R201	20180629
SEL-787-4R100.EDS	R100, R101	20141010

ICD File

Determining the ICD File Version

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-787-4-R200-V0-Z200006-D20180629
```

NOTE: ICD file ICD-787-4-Rxxx is for all models of the SEL-787.

The ICD revision number is after the R (e.g., 200) 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.

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., 200). The second three digits represent the ICD ClassFileVersion (e.g., 006). The ClassFileVersion increments when there is a major addition or change to the IEC 61850 implementation of the relay.

Table A.9 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.9 SEL-787-4 ICD File Revision History (Sheet 1 of 3)

configVersion	Summary of Revisions	Relay Firmware Compatibility	ClassFile Version	acSELerator Architect File Description	Manual Date Code
ICD-787-4-R204-V0-Z303006-D20240826	➤ Conformance related changes. ➤ Added logical nodes METW23MMXU8 and METW23MSQI8 to the MET logical device for combined winding 2 and winding 3 currents. ➤ Added logical node D87QPDIF13 to the PRO logical device for negative sequence differential element. ➤ Modified Pos attribute in W1XC-BR1, W2XCBR2, W3XCBR3, and W4XCBR4 logical node to report 52A|52B breaker status. ➤ Modified EnaOpn and EnaCls data-source in W1CILO1, W2CILO2, W3CILO3, and W4CILO4 logical node.	R303-V0 and higher	006	SEL-787-4 Edition 2, R303-V0 and higher	20240826

Table A.9 SEL-787-4 ICD File Revision History (Sheet 2 of 3)

configVersion	Summary of Revisions	Relay Firmware Compatibility	ClassFile Version	ACSELERATOR Architect File Description	Manual Date Code
	➤ Modified Pos attribute in W1CSWI1, W2CSWI2, W3CSWI3, and W4CSWI4 logical node to report 52A|52B breaker status.				
ICD-787-4-R203-V0-Z302006-D20220826	➤ Added system logical nodes LGOS, LTIM, LTMS, and LCCH. ➤ Added the IEC 61850 LTRK logical node for service tracking. ➤ Added the IEC 61850 feature for simulation mode. ➤ Added support for the IEC 61850 Local/Remote control feature defined in the IEC 61850-7-4 standard. Control messages need to include the orCat value associated with the active control authority. ➤ Added support for the IEC 61850 Functional naming feature. ➤ Added PRBGGIO logical nodes to support pulsing remote bits.	R302-V0 and higher	006	SEL787-4 Edition 2, R302-V0 or higher	20220826
ICD-787-4-R202-V0-Z300006-D20210910	➤ Added the blocked-by-interlocking AddCause to the control error response when an operation fails due to a control interlocking (CILO) check. ➤ Added the new W1CILO1, W2CILO2, W3CILO3 and W4CILO4 logical nodes and attributes to the PRO logical device for breaker control and status.	R300-V4 and higher	006	SEL787-4 Edition 2, R300-V4 or higher	20210910
ICD-787-4-R201-V0-Z300006-D20200331	➤ Added the ability to control mode and behavior through an MMS write to the LPHD logical node mode data object (Mod.ctlVal) in logical device CFG. ➤ Added new DC1CSWI1–DC12CSWI12, DC1CILO1–DC12CILO20, and DC1XSWI1–DC12XSWI20 Logical Nodes and attributes to PRO LDevice for Disconnect Control and Status. ➤ Added new SYN1RSYN1 and SYN2RSYN2 Logical Nodes and attributes to PRO LDevice for Synchronism Check element status.	R300 and higher	006	SEL-787-4 Edition 2, R300 or higher	20200331
ICD-787-4-R200-V0-Z200006-D20180629	➤ Initial ICD file release with Edition 2 support and compatibility. ➤ Updated ClassFileVersion to 006. ➤ Increased maximum GOOSE subscriptions to 64. ➤ Added MMS authentication support.	R200 and higher	006	SEL-787-4 Edition 2, R200 or higher	20180629

Table A.9 SEL-787-4 ICD File Revision History (Sheet 3 of 3)

configVersion	Summary of Revisions	Relay Firmware Compatibility	ClassFile Version	ACSELERATOR Architect File Description	Manual Date Code
	➤ Made MMS Inactivity Timeout user-configurable with a default value of 900 seconds. ➤ Added filehandling service. ➤ Added support for 61850 group switch, Simulated Goose and stSeld. ➤ Increased number of MMS reports to 14. ➤ Increased number of default datasets to 15. ➤ Removed maxEntries and maxMappedItems. ➤ Added new I1PTUV9, I1PTUV10, I1PTOV12, I1PTOV13, I1PTOV14, I1PTOV15, and FLTRDRE1, Logical Nodes and attributes to PRO LDevice. ➤ Modified Loc attribute of W1XCBR1, W2XCBR2, W3XCBR3, and W4XCBR4 Logical Nodes to report LOCAL/Remote Control status. ➤ Added new attribute Loc to W1CSWI1, W2CSWI2, W3CSWI3, and W4CSWI4 Logical Nodes to report Local/Remote Control status. ➤ Added new attributes W, Var, VA and PF to METMMXU7 Logical Node. ➤ Added new FLTGGIO33, B52GGIO35, DCALMGGIO34, DCST1GGIO32, DCST2GGIO33, PFLLIGGIO37, and SCGGIO36 Logical Nodes and attributes to ANN LDevice. ➤ Added new attributes Ind09–Ind14 to INCGGIO13, INDGGIO15, and INEGGIO17 Logical Nodes. ➤ Added new attributes Ind05–Ind08 to OUTCGGIO14, OUTDGGIO16, and OUTEGGIO18 Logical Nodes. ➤ Modified Ind01–Ind17 attributes of MISCGGIO31 Logical Node.				
ICD-787-4-R100-V0-Z100004-D20141107	➤ Initial ICD File release.	R100 or higher	004	787-4 Standard	20141203

Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date. *Table A.10* lists the instruction manual versions and revision descriptions. The most recent instruction manual version is listed first.

Table A.10 Instruction Manual Revision History (Sheet 1 of 12)

Date Code	Summary of Revisions
20241121	Appendix A ➤ Updated for firmware version R303-V1.
20240826	Section 1 ➤ Updated *Features*, *Protection Features*, including *Table 1.1: Current (ACI) and Voltage (AVI) Card Selection for SEL-787 Models*. ➤ Updated *Specifications*. Section 2 ➤ Updated *Current Card (Slot Z, 6 ACI)*, *Current/Voltage Card (Slot E, 4 ACI/3 AVI)*, *Current/Voltage Card (Slot E, 3 ACI/4 AVI)*, *Current/Voltage Card (Slot E, 1 ACI/3 AVI)*, and *Current Card (Slot E, 1 ACI)*. ➤ Added *Table 2.6: Title*, *Table 2.8: Title*, *Table 2.10: Title*, *Table 2.12: Title*, *Table 2.14: Title*, *Figure 2.12: (Relay MOT 07874XE1A3A9XL0L00210)*, and *Figure 2.13: (Relay MOT 07873EE1AA0BAL2810870)*. ➤ Updated *IRIG-B Time-Code Input*. ➤ Updated *Figure 2.21: Voltage Connections*. Section 4 ➤ Updated *Configuration Settings*, including *Table 4.2: Configurations and Ratings (Phase CTs, Power Transformer)* and *Table 4.3: Configurations and Ratings (Optional Neutral CT, Phase PT)*. ➤ Added *Low-Energy Analog (LEA) Sensor Inputs*. ➤ Updated *Differential Element*. ➤ Added *Negative-Sequence Differential Element*. ➤ Updated *Figure 4.9: REF Directional Element*. ➤ Updated *REF Element Logic*, including *Figure 4.10: REF1 Enable Logic*, *Figure 4.11: REF1, REF3A, and REF3B Directional Element*, *Figure 4.13: REF Element Trip Output*, and *Figure 4.15: REF Protection Output (Extremely Inverse-Time O/C)*. ➤ Updated *Table 4.6: Restricted Earth Fault Settings*, *Figure 4.7: Winding n Maximum Phase Overcurrent Settings*, *Figure 4.8: Winding 3 Per Phase Overcurrent Settings*, *Figure 4.10: Neutral Overcurrent Settings*, *Table 4.11: Winding n Negative-Sequence Overcurrent Settings*. ➤ Added *Figure 4.12: Title*. ➤ Added *LEA Ratio Correction*. ➤ Added *Combined Overcurrent Elements*. ➤ Updated *Table 4.14: Winding n Maximum Phase Time-Overcurrent*, *Table 4.15: Winding 3 Phase A, B, and C Time-Overcurrent*, *Table 4.17: Winding n Negative-Sequence Time-Overcurrent Settings*, *Table 4.18: Neutral Time-Overcurrent Settings*. ➤ Updated *Relay Word Bit ORED50T*. Section 4 ➤ Updated *Combined Time-Overcurrent Elements*, including *Table 4.17: Combined Winding Maximum Phase Time-Overcurrent Elements*, *Table 4.19: Combined Winding Maximum Phase Time-Overcurrent Elements*, *Table 4.20: Combined Winding Residual Ground Time-Overcurrent Elements*, *Figure 4.27: Combined Winding Maximum Phase Time-Overcurrent Elements*, and *Figure 4.28: Combined Winding Residual Time-Overcurrent Elements*. ➤ Updated *Relay Word Bit ORED51T*. ➤ Updated *Demand Metering*, including *Table 4.36: Demand Meter Settings*. ➤ Updated *LEA Ratio Correction Settings*, including *Table 4.52: LEA Ratio and Phase Correction Settings for Phase and Neutral Current*. ➤ Updated *Breaker Failure Setting*, including *Table 4.53: Breaker Failure Setting* and *Figure 4.71: Breaker Failure Logic*. Also added *Figure 4.xx: Breaker Failure Trip Logic*. ➤ Updated *Table 4.78: Example Settings and Displays*.

Table A.10 Instruction Manual Revision History (Sheet 2 of 12)

Date Code	Summary of Revisions
	Section 5 ➤ Updated *Table 5.1: Measured Fundamental Meter Values*. ➤ Updated *Through-Fault Event Monitoring*, including *Table 5.13: Through-Fault Element Settings* and *Figure 5.35: Through-Fault Diagram*. Settings Sheets ➤ Updated for LEA additions, REF enhancements, 87Q, and other range expansions. ➤ Added *Winding 12 Maximum Phase Overcurrent*, *Winding 12 Residual Overcurrent*, *Winding 23 Maximum Phase Overcurrent*, *Winding 23 Residual Overcurrent*, *Winding 23 Maximum Phase Time-Overcurrent*, *Winding 23 Residual Time-Overcurrent*, *Winding 34 Maximum Phase Overcurrent*, and *Winding 34 Residual Overcurrent*. ➤ Added *IEC 61850 Breaker CILO*. Section 7 ➤ Added *Network Storm Detection and Mitigation*. ➤ Updated *Figure 7.4: IRIG-B Input (Relay Terminals B01–B02)*, *Figure 7.5: IRIG-B Input Via EIA-232 Port 3 (SEL Communications Processor as Source)*, *Figure 7.6: IRIG-B Input Via EIA-232 Port 3 (SEL-2401/2407/2488 Time Source)*, and *Figure 7.8: IRIG-B Input Via Fiber-Optic EIA-232 Port 2 (SEL-2401/2407/2488 Time Source)*. Section 8 ➤ Updated *Table 8.17: Screens Available for the Rotating Display, HOME Pushbutton, and Programmable Pushbuttons*. Section 10 ➤ Updated *Table 10.2: Event Types*. Section 11 ➤ Added a note on the relay test system to *Low-Level Test Interface*. Appendix A ➤ Updated for firmware versions R302-V2 and R303-V0. Appendix E ➤ Updated *Table E.33: Modbus Register Labels for Use With SET M Command* and *Table E.34: Modbus Map*. Appendix G ➤ Updated *Control Interlocking*. ➤ Updated *Table G.36: Logical Device: PRO (Protection)*. Appendix K ➤ Added a note in *Setttings for Synchrophasors* about compatibility with different SEL-787 models. Appendix L ➤ Updated *Table L.1: SEL-787 Relay Word Bits* and *Table L.2: Relay Word Bit Definitions for the SEL-787*. Appendix M ➤ Updated *Table M.1: Analog Quantities*. Glossary ➤ Added Rogowski Coil.
20240329	Preface ➤ Updated *Compliance Approvals*, *Hazardous Locations Approvals*. ➤ Update *Trademarks*. Section 3 ➤ Updated *Table 3.1: SEL Software Solutions*. Section 7 ➤ Updated *R_S Command (Restore Factory Defaults)*. Section 8 ➤ Updated *Table 8.4: SEL-787 Front-Panel Operator Control Functions*.

Table A.10 Instruction Manual Revision History (Sheet 3 of 12)

Date Code	Summary of Revisions
	Appendix A ➤ Updated for firmware version R302-V1. Section G ➤ Updated *Optional Control Configurations*. ➤ Updated *Table G.37: Logical Device: MET (Metering)*. Appendix N ➤ Updated *Settings Erasure* for a note on the **R_S** command.
20231002	Section 1 Updated *Specifications*.
20220826	Preface ➤ Updated *Wire Sizes and Insulation*. Section 1 ➤ Updated *Specifications*, including *Compliance*, *Communications Protocols*, *Dielectric Strength and Impulse Tests*, and *EMC Emissions*. Section 2 ➤ Updated *Power Connections* and added *I/O Connections*. Section 4 ➤ Updated *Table 4.3: Configurations and Ratings (Optional Neutral CT, Phase PT)*. ➤ Updated *Voltage Input VS Connected Phase-to-Phase or Beyond Delta-Wye Transformer*, including *Table 4.31: Synchronism-Check Settings*. ➤ Updated *Loss-of-Potential (LOP) Protection*, including *Figure 4.56: Loss-of-Potential (LOP) Logic*. ➤ Updated *Table 4.34: Frequency Settings*, *Table 4.59: Ethernet Port Settings*, and *Table 4.74: Target LED Settings*. ➤ Updated *Relay Word Bit Aliases*. Settings Sheets ➤ Added *61850 Simulation Mode* and *61850 Local Remote*. ➤ Updated *Port 1* for the RSTP settings. ➤ Updated *Synchronism Check* and *Relay Word Bit Aliases*. Section 7 ➤ Updated *Table 7.4: Protocols Supported on the Various Ports*. ➤ Added *Switched Mode* and *Rapid Spanning Tree Protocol (RSTP)*. ➤ Added *Table 7.27: Warning and Error Codes for GOOSE Subscriptions*. ➤ Updated *ID Command* and added *RSTP Command*. Appendix A ➤ Updated for firmware versions R201-V5, R300-V7, and R302-V0. ➤ Updated *Table A.4: SELboot Firmware Revision History* for R602-V0. ➤ Updated *Table A.5: SEL Display Package Revision History* and *Table A.6: SEL Display Package Compatibility With Relay Firmware* for 3.0.50787.3007. ➤ Updated *Table A.9: SEL-787-4 ICD File Revision History* for R203-V0. Appendix B ➤ Updated *Table B.1: Firmware Upgrade Methods*. ➤ Added *Upgrade the SELBOOT Firmware Loader Using a Terminal Emulator*. Appendix E ➤ Updated *Table E.34: Modbus Map*.

Table A.10 Instruction Manual Revision History (Sheet 4 of 12)

Date Code	Summary of Revisions
	Appendix G ➤ Added *Functional Naming*, *Local Remote Control Authority*, and *Service Tracking*. ➤ Updated *Simulation Mode*. ➤ Updated *Table G.23: New Logical Node Extensions* and added *Table G.27: LCCH Physical Communication Channel Supervision*, *Table G.28: LGOS GOOSE Subscription*, and *Table G.29: LTMS Time Master Supervision*. ➤ Updated *Table G.36: Logical Device: PRO (Protection)*, *Table G.37: Logical Device: MET (Metering)*, *Table G.38: Logical Device: CON (Remote Control)*, *Table G.39: Logical Device: ANN (Annunciation)*, and *Table G.40: Logical Device: CFG (Configuration)*. Appendix L ➤ Updated *Table L.1: SEL-787 Relay Word Bits* and *Table L.2: Relay Word Bit Definitions for the SEL-787*. Appendix M ➤ Table *M.1: Analog Quantities*. Appendix N ➤ Updated *Table N.1: IP Port Numbers*. Glossary ➤ Added RSTP. Command Summary ➤ Added the **RSTP** command.
20220225	Appendix A ➤ Updated *Table A.1: R300 Series Firmware Revision History* for relay firmware revision R300-V6. ➤ Updated *Table A.2: R200 Series Firmware Revision History* for relay firmware revision R201-V4.
20211213	Appendix A ➤ Updated *Table A.1: R300 Series Firmware Revision History* for relay firmware revision R300-V5. ➤ Updated *Table A.2: R200 Series Firmware Revision History* for relay firmware revision R201-V3. ➤ Updated T*able A.4: SELBOOT Firmware Revision History* for firmware revisions R601-V0 and R502-V0. ➤ Updated *Table A.5: SEL Display Package Revision History* and *Table A.6: SEL Display Package Compatibility With Relay Firmware*.
20210910	Section 1 ➤ Updated *RFI and Interference Tests* conducted and radiated emissions. Appendix A ➤ Updated *Table A.1: R300 Series Firmware Revision History* for relay firmware revision R300-V4. ➤ Updated *Table A.2: R200 Series Firmware Revision History* for relay firmware revision R201-V2. ➤ Updated *Table A.9: SEL-787-4 ICD File Revision History*. Appendix G ➤ Added *Control Interlocking*, including *Figure G.4: CSWI Logical Node Direct Operate Command Request*. ➤ Updated *Table G.6: AddCause Descriptions*. ➤ Updated *Table G.28: Logical Device: PRO (Protection)*.
20210104	Section 2 ➤ Updated *Models*. Appendix A ➤ Updated *Table A.1: R300 Series Firmware Revision History* for relay firmware revision R300-V3. ➤ Updated *Table A.1: R200 Series Firmware Revision History* for relay firmware revision R201-V1. Appendix E ➤ Updated *Table E.34: Modbus Map*.
20200921	Appendix A ➤ Updated *Table A.1: R300 Series Firmware Revision History* for relay firmware revision R300-V2.

Table A.10 Instruction Manual Revision History (Sheet 5 of 12)

Date Code	Summary of Revisions
20200331	Preface ➤ Updated *Manual Overview*. ➤ Updated *Safety Information*, including *Compliance Approvals.* ➤ Updated *General Information*, including *Product Labels*. Section 1 ➤ Updated *Features* and *Specifications*. Section 2 ➤ Updated *Physical Location*. ➤ Added notes for IEC 60255-26 and IEC 60255-27 requirements. ➤ Updated *Communications Ports (Slot B)*, *Current Card (Slot E, 1 ACI)*, and *RTD Card (10 RTD)*. ➤ Updated *IRIG-B Time Code Input* for cable options. ➤ Updated *Figure 2.14: Control I/O Connection–Internal RTD Option*. Section 3 ➤ Updated *Overview* for the built-in web server. ➤ Added *Web Server*. ➤ Updated *Table 3.1: SEL Software Solutions* and *Figure 3.25: Save the Retrieved Event*. Section 4 ➤ Updated *Overview* and *Group Settings (SET Command)*. ➤ Updated *Unrestrained Element Current Pickup* for the minimum setting of U87P. ➤ Updated *RTD Trip/Warning Levels*. ➤ Updated *Frequency Elements*, including *Table 4.34: Frequency Settings* for trip delay ranges. ➤ Updated *Figure 4.56: Loss-of-Potential (LOP) Logic*, *Figure 4.60: Trip Logic*, and *Figure 4.61: Close Logic*. ➤ Added *Multiple Setting Groups*. ➤ Updated *Disconnect Switch Control Settings* and *Local/Remote Control*. ➤ Added *Precision Time Protocol (PTP)* and *PTP Timekeeping* to *Time and Date Management Settings*. ➤ Added a note regarding the MAXACC settings when using the DSABLSET setting. ➤ Updated *Table 4.59: Ethernet Port Settings* for PTP, IEC 61850 mode/behavior, and HTTP settings. ➤ Added a note to *PORT 1* regarding the Telnet LANG setting and the web server interface. ➤ Updated *Table 4.60: Port Number Settings That Must be Unique*. ➤ Updated *Event Report Settings*. ➤ Added *EtherNet/IP Assembly Map Settings (SET E Command)*. Section 6 ➤ Updated *Overview*, *Table 6.1: Methods of Accessing Settings*, *Table 6.2: SHOW Command Options*, and *Table 6.3: SET Command Options*. ➤ Added *Web Server*. Settings Sheets ➤ Updated *Frequency* for trip delay ranges. ➤ Added *Two-Position Disconnect*, *Three-Position Disconnect*, *IEC 61850 Mode Control*, *PTP Settings*, and *Ether/IP Settings*. ➤ Added HTTP settings to *PORT 1*. ➤ Updated *Table SET.3: Port Number Settings That Must be Unique*. ➤ Updated *Bay Control Two-Position Disconnect* and added *Bay Control Three-Position Disconnect*. ➤ Added *EtherNet/IP Assembly Map Settings (SET E Command)*.

Table A.10 Instruction Manual Revision History (Sheet 6 of 12)

Date Code	Summary of Revisions
	Section 7 ➤ Added *Telnet or Web Server* and *Embedded Web Server (HTTP)*. ➤ Updated *Ethernet Port* and added *TCP Keep Alive*. ➤ Updated *Table 7.4: Protocols Supported on the Various Ports*, *Table 7.5: Settings Associated With SNTP*, and *Table 7.7: Settings Associated With PTP*. ➤ Updated *Ethernet Protocols* for *EtherNet/Industrial Protocol (IP)*. ➤ Added *Precision Time Protocol (PTP)*, *COM PTP Command.*, *89CLOSE (Close Disconnect)*, *89OPEN (Open Disconnect)*. ➤ Updated *CEV Command*. ➤ Updated *Table 7.43: SET Command (Change Settings)* and *Table 7.45: SHOW Command (Show/View Settings) for EtherNet/IP*. ➤ Updated *TEST DB Command*. ➤ Updated *Virtual File Interface*, including *Table 7.56: FTP and MMS Virtual File Structure*, *Figure 7.29: CFG.TXT File*, and *Table 7.57: Settings Directory Files*. Section 8 ➤ Added notes for display update rates to *Contrast* and *Touchscreen Display HMI*. ➤ Updated *Table 8.7: Sidebar Buttons* and *Reports* for the Trigger Event button. ➤ Updated *Figure 8.47: Search Relay Word Bits*, *Figure 8.50: Event History*, *Figure 8.67: Authentication*, *Figure 8.72: Global Settings*, *Figure 8.73: General Settings*, *Figure 8.74: Set/Show Settings Edit*, *Figure 8.75: Touchscreen Settings*, and *Figure 8.76: Touchscreen Settings Edit*. Section 9 ➤ Updated *Disconnect Control Settings* and *Table 9.2: Two-Position Disconnect Settings* and added *Table 9.3: Three-Position Disconnect Settings*. ➤ Updated *Figure 9.1: Dual-Point Disconnect Status Logic*. ➤ Added *Figure 9.2: Disconnect Close Logic*, *Figure 9.3: Disconnect Open Logic*, and *Table 9.4: Disconnect Control Setting Guidelines*. ➤ Updated *Table 9.5: Two- and Three-Position Disconnect Symbols* and *Local/Remote Control*. ➤ Updated *Breaker/Disconnect Control Via Touchscreen*, *Table 9.7: Touchscreen Settings*, and *Bay Control Disconnect Switch Settings*. ➤ Updated *Figure 9.11: Project Analysis Pane: Constraints Summary Tab*, *Figure 9.12: Bay Control Single-Line Diagram Schematic*, *Figure 9.16: Drag-and-Drop Symbols*, *Figure 9.17: Selected Breaker Symbol Settings Displayed in the Properties Pane*, *Figure 9.18: Close/Open/Alarm Color Property Drop Down Menu*, *Figure 9.20: QuickSet Updated Single-Line Diagram and Corresponding Settings*, and *Figure 9.21: Final Bay Screen Builder Rendering*. ➤ Updated *Table 9.8: Symbols Required for the Single-Line Diagram Schematic in Figure 9.12*. ➤ Updated *Disconnect Settings*. Section 10 ➤ Updated *Length*, *Event Summaries*, *Viewing Compressed Event (CEV) Reports*, including *Figure 10.10: Sample CEV Report Viewed With SYNCHROWAVE* in *Event Reporting*. Appendix A ➤ Added *Table A.1: R300 Series Firmware Revision History* for relay firmware version R300-V1. ➤ Updated *Table A.2: R200 Series Firmware Revision History* for relay firmware version R201-V0. ➤ Added *SELBOOT Firmware Versions and Relay Firmware Compatibility*, including *Table A.4: SELBOOT Firmware Revision History*. ➤ Updated *Table A.5: SEL Display Package Revision History*, *Table A.6: SEL Display Package Compatibility With Relay Firmware*, *Table A.8: EDS File Compatibility*, *Table A.9: SEL ICD File Revision History*. Appendix B ➤ Added *Table B.1: Firmware Upgrade Methods* and updated *Required Equipment*. ➤ Added *Digitally Signed Firmware Files*, *Ethernet Firmware Upgrades*, *Special Instructions for Upgrading to R300 Series Firmware*, *Upgrade the Firmware Using the Web Server*, *Upgrade the Firmware Using File Transfer Protocol*, and *Upgrade the Firmware Via Terminal Emulator Using the FILE Command Over Telnet*. ➤ Updated *Upgrade Firmware Using QuickSet*.

Table A.10 Instruction Manual Revision History (Sheet 7 of 12)

Date Code	Summary of Revisions
	Appendix D ➤ Updated *Table D.7: Port DNP3 Protocol Settings* and *Table D.12: SEL-787 Object 12 Control Operations* ➤ Updated *Reference Data Map*, including *Table D.10: DNP3 Reference Data Map*. ➤ Updated *Figure D.4: Port MAP Command*. Appendix E ➤ Updated *Table E.7: 02h SEL-787 Inputs* for coil addresses and descriptions. ➤ Updated *Table E.33: Modbus Register Labels for Use With SET M Command*, *Table E.34: Modbus Register Map*, and *Table E.35: Trigger Conditions for Trip/Warn Status Register Bits*. Appendix F ➤ Added *EtherNet/IP Communications*. Appendix G ➤ Added *IEC 61850 Mode/Control*. ➤ Updated *Table G.17: IEC 61850 Settings*. ➤ Updated *Mode*, *Behavior*, and *Health* in *Logical Nodes*. ➤ Updated *Table G.20: Demand Metering Statistics Logical Node Class Definitions*. ➤ Updated *Table G.28: Logical Device: PRO (Protection)*, *Table G.29: Logical Device: MET (Metering)*, *Table G.30: Logical Device: CON (Remote Control)*, *Table G.31: Logical Device: ANN (Annunciation)*, and *Table G.32: Logical Device: CFG (Configuration)*. Appendix L ➤ Updated *Table L.1: SEL-787 Relay Word Bits* and *Table L.2: Relay Word Bit Definitions for the SEL-787*. Appendix M ➤ Updated *Table M.1: Analog Quantities*. Appendix N ➤ Added port numbers for PTP, web server, and EtherNet/IP to *Table N.1: IP Port Numbers*. ➤ Added *Firmware Hash Verification* and *Vulnerability Notification Process*. Command Summary ➤ Updated access level commands ACC and 2AC and SER command descriptions. ➤ Added 89C and 89O commands.
20200117	Appendix A ➤ Updated *Table A.1: R200 Series Firmware Revision History* for firmware revision R200-V1.
20180629	Preface ➤ Updated *Hazardous Locations Safety Marks*. ➤ Updated *Compliance Approvals*, *Hazardous Locations Approvals*, including the compliance label. ➤ Updated *Product Labels* for the high- and low-voltage supply models. ➤ Added *Copyrighted Software*. Section 1 ➤ Updated *Overview* and *Features* for the new relay models (2X, 21, 2E). ➤ Updated *Table 1.1: Current (ACI) and Voltage (AVI) Card Selection for SEL-787 Models*, *Table 1.2: SEL-787 Protection Elements*, and *Table 1.4: Available Differential and REF Elements* for the new relay models (2X, 21, 2E). ➤ Updated *Table 1.3: SEL-787 Front-Panel Options* for the touchscreen display model. ➤ Updated *Specifications*, *Compliance* for the touchscreen relay model hazardous locations and ATEX; *Type Tests*; and *Communications Protocols* for IEC 61850 Edition 2, IEC 60870-5-103, and PRP. Section 2 ➤ Updated *Physical Location* and *Relay Mounting* for specific installation and location requirements and for the touchscreen display relay. ➤ Updated *Figure 2.2: Slot Allocations for Different Cards*. ➤ Updated *Card Configuration Procedure* for the touchscreen display relay. ➤ Added *High-Speed, High-Current Interrupting Tripping Outputs*.

Table A.10 Instruction Manual Revision History (Sheet 8 of 12)

Date Code	Summary of Revisions
	Section 3 ➤ Updated *Table 3.1: SEL Software Solutions* for ACSELERATOR Bay Screen Builder SEL-5036 Software and SEL-5601-2 SYNCHROWAVE Event Software. ➤ Added *Touchscreen Settings and Bay Screen Builder*. Section 4 ➤ Updated *Table 4.1: Identifier Settings* for the new relay models. ➤ Updated *Table 4.3: Configurations and Ratings (Optional Neutral CT, Phase PT)* for the new relay models. ➤ Updated *Table 4.6: Restricted Earth Fault Settings* for the new relay models. ➤ Updated *Time-Overcurrent Elements* for the new relay models. ➤ Added *Inverse-Time Undervoltage Protection* and *Inverse-Time Overvoltage Protection*. ➤ Updated *Demand Metering*, including *Table 4.36: Demand Meter Settings* for the new relay models. ➤ Updated *Trip/Close Logic Settings*, including *Table 4.37: Trip/Close Logic Settings* for the new relay models. ➤ Updated *52A and 52B Breaker Status Conditions SELOGIC Control Equations* for disconnect switches and local/remote control. ➤ Updated *Loss-of-Potential (LOP) Protection*, including *Figure 4.56: Loss-of-Potential (LOP) Logic*. ➤ Updated *Table 4.39: Latch Bits Equation Settings* and *Table 4.43: SELOGIC Variable Settings* for the new relay models. ➤ Updated *General Settings*, including *Table 4.47: General Global Settings*, for an additional FAULT default setting for the new relay models and the METHRES setting. ➤ Added *89A and 89B Disconnect Switch Status SELOGIC Control Equations* and *Local/Remote Breaker Control*. ➤ Updated *Port Settings (SET P Command)* for EPORT and MAXACC setting information and communications protocols. ➤ Updated *Front-Panel Settings (SET F Command)* for front-panel options and settings. ➤ Updated *Table 4.66: LCD Settings*, *Table 4.74: Target LED Settings*, *Table 4.75: Pushbutton LED Settings*, and *Table 4.77: SER Trigger Settings* for the touchscreen display/new relay models. Section 5 ➤ Updated *Fundamental Metering*, *Table 5.1: Measured Fundamental Meter Values* and *Figure 5.3: METER Command Report for SEL-787-3E Models* and added *Figure 5.4: METER Command Report for SEL-787-21 Models*. ➤ Updated *Maximum and Minimum Metering*, *Table 5.5: Maximum and Minimum Meter Values* and added *Figure 5.11: METER M Command Report for the SEL-787-2E*. ➤ Updated *Harmonic Metering*, *Table 5.8: Measured Harmonic Meter Values* and added *Figure 5.19: METER H Command Report for the SEL-787-3S Models* and *Figure 5.20: METER H Command Report for the SEL-787-2X Model*. ➤ Added *Remote Analog Metering*. Section 6 ➤ Added *View/Change Settings With the Touchscreen Front-Panel*. Settings Sheets ➤ Updated *Group Settings (SET Command)*, *Logic Settings (SET L Command)*, *Global Settings (SET G Command)*, *SET PORT p (p = F, 1, 2, 3, or 4) Command*, *Front-Panel Settings (SET F Command)*, *Report Settings (SET R Command)*, and *DNP3 Map Settings (SET DNP n Command)*. Section 7 ➤ Updated *Ethernet Port* for PRP. ➤ Added *PRP Connection Mode* under *Dual Network Port Operation*. ➤ Updated *Access Levels* for the EPORT and MAXACC settings. ➤ Updated *CLOSE n Command (Close Breaker n, where n = 1, 2, 3, or 4)* for LOCAL control. ➤ Updated *GOOSE Command*, *Table 7.17: GOOSE Command Variants*, *Table 7.18: GOOSE IED Description*, and *Figure 7.24: GOOSE Command Response*. ➤ Updated *GROUP Command* for SS*n* SELOGIC control equation priority. ➤ Updated *OPEN n Command (Open Breaker n, where n = 1, 2, 3, or 4)* for LOCAL control. ➤ Added *TEST DB Command*. ➤ Added *Language Support* and *Virtual File Interface*.

Table A.10 Instruction Manual Revision History (Sheet 9 of 12)

Date Code	Summary of Revisions
	Section 8 ➤ Updated *Overview*; added *Figure 8.1: SEL-787 Front-Panel Options*. ➤ Updated *Two-Line Display Front-Panel*, including *Figure 8.2: SEL-787-21/2X Front-Panel Overview* and *Figure 8.3: SEL-787-2E Front-Panel Overview*. ➤ Added *Language Support*. ➤ Updated *Operation and Target LEDs*, *Programmable LEDs*, and *Front-Panel Operator Control Pushbuttons*. ➤ Added *Touchscreen Display Front Panel*. Section 9 ➤ Added *Section 9: Bay Control*. Section 10 ➤ Updated *Event Summaries* for the unique reference number, added a note for the reset of the unique reference number to 10000 using the **HIS CA** command, and added *Event Logs* and *Event Reference Number*. ➤ Updated *Event History* for the unique reference number and *Clearing* for the unique reference number and **HIS CA** command. ➤ Updated *Viewing Compressed Event (CEV) Reports*, including a note for compensated magnitudes and added *COMTRADE File Format Event Reports*. Section 11 ➤ Updated *Figure 11.1: Low-Level Test Interface (J2 and J3)*, *Table 11.2: SEL-700G Cable Connection Options for SEL-787-2X*, *Table 11.3: SEL-700G Cable Connection Options for SEL-787-21*, and *Table 11.4: SEL-700G Cable Connection Options for SEL-787-2E*. ➤ Updated *Self-Test*, including *Table 11.13: Relay Self-Tests* and added a note for SALARM and access level changes. ➤ Updated *Table 11.14: Troubleshooting*. Appendix A ➤ Updated *Table A.1: R200 Series Firmware Revision History* for firmware revision R200. ➤ Added *SEL Display Package Versions*, including *Table A.3: SEL Display Package Revision History* and *SEL Display Package and Relay Firmware Compatibility*, including *Table A.4: SEL Display Package Compatibility with Relay Firmware*. ➤ Updated *Table A.6: EDS File Compatibility* for firmware revision R200. ➤ Updated *Table A.7: SEL-787 ICD File Revision History*. Appendix B ➤ Updated *Upgrade Firmware Using a Terminal Emulator* for a note about saving the touchscreen settings before upgrading the firmware and a note to change the relay serial port data rate before issuing the **L_D** command. Appendix C ➤ Updated *SEL Fast Meter*, *Fast Operate*, *Fast SER*, *and Unsolicited Write*. Appendix D ➤ Updated *DNP3 in the SEL-787*, including *Table D.7: Port DNP3 Protocol Settings* for the number of DNP sessions. ➤ Updated *DNP3 Documentation*, including *Table D.9: SEL-787 DNP Object List* for the number of DNP sessions, *Table D10: DNP3 Reference Data Map* for STFAIL and STWARN, *Table D.11: DNP3 Default Data Map*, and *Table D.12: SEL-787 Object 12 Control Operations*. ➤ Updated *Figure D.6: Analog Input Map Entry in QuickSet*, *Figure D.7: AI Point Scaling and Deadband in QuickSet*, *Figure D.9: Analog Output Map Entry in QuickSet*, and *Figure D.11: Binary Output Map Entry in QuickSet*. Appendix E ➤ Added a note to *06h Preset Single Register Command* on the LOCAL Relay Word bit. ➤ Updated *Table E.7: 02h SEL-787 Inputs*, *Table E.14: 01h, 05h SEL-787 Output*, *Table E.33: Modbus Register Labels for Use With SET M Command*, and *Reading History Data Using Modbus and Modbus Register Map*, including *Table E.34: Modbus Register Map*.

Table A.10 Instruction Manual Revision History (Sheet 10 of 12)

Date Code	Summary of Revisions
	Appendix F ➤ Updated *Features*, *Introduction to IEC 61850*, *IEC 61850 Operation*, *IEC 61850 Configuration*, *Logical Nodes*, *Protocol Implementation Conformance Statement*, and *ASCI Conformance Statements*. ➤ Added *Simulation Mode* and *Potential Client and Automation Application Issues With Edition 2 Updates*. ➤ Updated *Figure F.1: SEL-787 Datasets* and *Figure F.2: SEL-787 Predefined Reports*. Appendix H ➤ Added a note about the discontinuation of the DeviceNet option. Appendix J ➤ Updated *Table J.14: Example Synchrophasor SELOGIC Settings*. Appendix K ➤ Updated *Table K.1: SEL-787 Relay Word Bits* and *Table K.2: Relay Word Bit Definitions for the SEL-787*. Appendix L ➤ Updated for IEC 61850 and IEC 60870-5-103. ➤ Updated *Table L.1: Analog Quantities*. Appendix M ➤ Added *Appendix M: Cybersecurity Features*. Appendix N ➤ Updated for new relay models. Glossary ➤ Updated. Index ➤ Updated. Command Summary ➤ Updated for new commands. ➤ Updated for Spanish commands.
20160815	Preface ➤ Added caution statement at the beginning of *Safety Information*. ➤ Updated product labels and the compliance label. ➤ Updated *Safety Marks*. ➤ Updated *Wire Sizes and Insulation*. Section 1 ➤ Updated *Accessories*. ➤ Added Fuse Ratings to *Specifications*. ➤ Updated Enclosure Protection under *Type Tests* in *Specifications*. Section 10 ➤ Updated *Figure 10.7: Delta Voltage Source Connections*. ➤ Updated *Table 10.8: Power Quantity Accuracy–Delta Voltages*.
20160630	Preface ➤ Added *Safety Information* and *General Information*. ➤ Updated the product labels and compliance label. ➤ Updated *Wire Sizes and Insulation*. Section 1 ➤ Changed the *Certifications* section title to *Compliance* and relocated the updated section to the beginning of *Specifications*. ➤ Updated *AC Current Input*, *Power Supply*, and *Output Contacts*. ➤ Added the applied current at which the burden is measured for I_{NOM} = 1 A and 5 A. ➤ Added information on analog quantities to *Protection and Control Processing* under *Processing Specification and Oscillography*. ➤ Updated the *Type Test* compliance specifications.

Table A.10 Instruction Manual Revision History (Sheet 11 of 12)

Date Code	Summary of Revisions
	Section 2 ➤ Updated the note on CT circuits for applicable current card descriptions. ➤ Updated *Table 2.16: Typical Maximum RTD Lead Length*. ➤ Added a note regarding fast hybrid output contacts and FAILSAFE mode in *Fail-Safe/Nonfail-Safe Tripping* in *AC/DC Control Connection Diagrams*. ➤ Updated *Figure 2.16: Single-Phase Voltage Connections*, *Figure 2.17: Voltage Connections*, *Figure 2.18: Application Example of an SEL-787-4X Providing 3-Winding Transformer Differential Protection, REF Protection, Overcurrent Protection, and Fan Bank Control With LTC Monitoring*, *Figure 2.19: Application Example of an SEL-787-3S Providing 3-Winding Transformer Differential Protection, Overcurrent Protection, Voltage Protection, and Synchronism Check*, and *Figure 2.20: Application Example of an SEL-787-3E Providing Auto-Transformer Differential Protection, REF Protection, Overcurrent Protection, and Voltage-Based Protection*. Section 4 ➤ Updated *Harmonic Blocking*, including *Table 4.4: Differential Element Settings*. ➤ Added *Connection Compensation Settings* and *Table 4.5: WnCTC Setting: Corresponding Phase and Direction of Correction*. ➤ Updated *Current TAP*, *Unrestrained Element Current Pickup*, *CT Ratio Selection*, and *REF Element Logic*. ➤ Updated *Setting Descriptions and Applications* for the REF function criteria. ➤ Updated *Selection of the Polarizing Quantity* in *Setting Calculation*. ➤ Updated *Figure 4.17: Single-Wye Winding REF Application*. ➤ Added *REF Current Pickup Level*. ➤ Updated *Overvoltage Function*. ➤ Updated *Loss-of-Potential (LOP) Protection* and *Figure 4.51: Loss-of-Potential (LOP) Logic*. ➤ Updated *Figure 4.59: Trip Logic*. ➤ Updated *SELOGIC Control Equation Operators* and added *Example 4.4: Improving the Accuracy of Math Operations*. ➤ Added a note to *General Settings* about target LED settings. ➤ Updated *Table 4.50: Ethernet Port Settings*, *Table 4.58: Settings That Always, Never, and Conditionally Hide a Display Point*, and *Table 4.63: Example Settings and Displays*. Section 5 ➤ Updated *Overview*. ➤ Updated *Table 5.9: Synchrophasor Measured Values*. ➤ Updated *Figure 5.27: Input INxxx Connected to Trip Bus for Breaker Monitor Initiation*. Section 6 ➤ Updated *Table 6.6: Setting Interdependency Error Messages*. Settings Sheets ➤ Updated setting ranges for transformer differential TAP settings, FAILOVER TIMEOUT, PRIMARY NET PORT, and DNP3 protocol settings. ➤ Added *IEC 60870-5-103 Map Settings (SET I Command)*. Section 7 ➤ Updated *Failover Mode* and *NETPORT Selection*. ➤ Updated *+5 Vdc Power Supply*. ➤ Updated *Table 7.3: Protocols Supported on the Various Ports*. ➤ Updated *IEEE C37.118 Protocol*. ➤ Updated *PULSE Command* description. ➤ Added a note for the STA S report and available SELOGIC capacity. Section 8 Updated *Figure 8.1: Front-Panel Overview* and *Figure 8.26: Operator Control Pushbuttons and LEDs*. Section 10 ➤ Updated the note on CT circuits. ➤ Updated *Table 10.10: Relay Self Tests*. ➤ Added the *SEL-787-3, -4 Relay Commissioning Test Worksheet*.

Table A.10 Instruction Manual Revision History (Sheet 12 of 12)

Date Code	Summary of Revisions
	Appendix A ➤ Updated for firmware version R101. ➤ Added a note regarding SEL-787-4-Rxxx firmware in *Determining the Firmware Version in Your Relay*. ➤ Updated *DeviceNet and Firmware Versions* and added a note for the DeviceNet files. ➤ Added a note regarding ICD-787-4-Rxxx files in *Determining the ICD File Version in Your Relay*. Appendix D ➤ Updated *Table D.7: Port DNP3 Protocol Settings*. ➤ Updated *Device Profile* and added a note on the DNP3 Device Profile document. Appendix E ➤ Updated *Table E.34: Modbus Register Map*. Appendix F ➤ Updated the device bits and GOOSE subscriptions note in GOOSE to include remote analogs. Appendix J ➤ Updated *Overview*. ➤ Updated *Table J.2: Synchrophasor Order in Data Stream (Voltages and Currents)*. ➤ Updated *Ethernet Port Settings for IEEE C.37.118 Synchrophasors* and *Table J.6: SEL-787 Ethernet Port Settings for Synchrophasors*. ➤ Added *PMOTS1 and PMOTS2*, *PMOIPA1 and PMOIPA2*, *PMOTCP1 and PMOTCP2*, and P*MOUDP1 and PMOUDP2*. ➤ Updated *Table J.8: Time Synchronization Relay Word Bits*. ➤ Updated *Synchrophasor Relay Word Bits*, updated *Table J.9: TQUAL Bits Translation to Time Quality*, and added a note to for the jitter measurement for the IRIG signal. Appendix K ➤ Updated *Table K.2: Relay Word Bit Definitions for the SEL-787*. Appendix L ➤ Added information on analog quantities for rms data. ➤ Updated *Table L.1: Analog Quantities*. Appendix M ➤ Added protection application examples for transformer winding and CT connection and compensation settings. Spanish Command Summary ➤ Updated the *SEL-787-3, -4 Relay Command Summary* commands.
20141203	➤ Initial version.

Appendix B
Firmware Upgrade Instructions

Overview

These instructions guide you through the process of upgrading the firmware in the device. The firmware upgrade will be either a standard release or a point release. A standard release adds new functionality to the firmware beyond the specifications of the existing version. A point release is reserved for modifying firmware functionality to conform to the specifications of the existing version.

A standard release is identified by a change in the R-number of the device firmware identification (FID) string.

Existing firmware:

FID=SEL-787-**R100**-V0-Z001001-D*xxxxxxxx*

Standard release firmware:

FID=SEL-787-**R101**-V0-Z001001-D*xxxxxxxx*

A point release is identified by a change in the V-number of the device FID string.

Existing firmware:

FID=SEL-787-R100-**V0**-Z001001-D*xxxxxxxx*

Point release firmware:

FID=SEL-787-R100-**V1**-Z001001-D*xxxxxxxx*

SEL occasionally offers firmware upgrades to improve the performance of your relay. Because SEL-787 relays store firmware in flash memory, changing physical components is unnecessary. Upgrade the relay firmware by downloading a file from a personal computer to the relay via the Ethernet port through the web server, FTP, or Telnet. You can also use the front-panel serial port through ACSELERATOR QuickSet SEL-5030 Software or a terminal emulator, as outlined in the following sections. For relays with the IEC 61850 option, verify the IEC 61850 protocol after the upgrade (see *Protocol Verification for Relays With IEC 61850 Option*).

Table B.1 details the available firmware upgrade methods. Available methods depend on your existing firmware and the firmware version to which you are upgrading.

Table B.1 Firmware Upgrade Methods

Existing Firmware	Upgrade Version	SELBOOT Upgrade Required?	Firmware Upgrade Methods Supported	
			Serial	Ethernet
R1*xx*	R2*xx*	NA	Terminal emulator QuickSet	—
R1*xx* or R2*xx*	R3*xx*	Yes (R600 or higher)	Terminal emulator[a]	—
R3*xx*	R3*xx*[b]	No	Terminal emulator QuickSet	Web server FTP FILE command Terminal emulator

[a] When upgrading from R1xx or R2xx to R3xx, you must first perform the Special Instructions for Upgrading to R300 Series Firmware and then follow the Upgrade the Firmware Using a Terminal Emulator instructions to upgrade your relay firmware.
[b] In firmware versions R302-V0 and higher, the relay firmware retains the IP address, subnet mask, and default router settings during a firmware upgrade from any previous R3xx firmware version.

Required Equipment

Gather the following equipment before starting this firmware upgrade:

- PC
- Terminal emulation software that supports Xmodem/CRC or 1k Xmodem/CRC protocol
- Serial communications cable (SEL-C234A or equivalent, or a null-modem cable) or Ethernet cable
- Disk containing the firmware upgrade file (e.g., r*xxx*-v*x*787.s19, r*xxx*-v*x*787.z19, or r*xxx*-v*x*787.zds)
- QuickSet software

Digitally Signed Firmware Files

The SEL-787 supports digitally signed firmware files for firmware versions R300 and higher. These firmware files are compressed to reduce file transfer times and are 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 the firmware is uploaded to the relay, the signature of the firmware is verified with a public key number that is stored on the relay from the factory. 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*-v*x*787.zds, where r*xxx*-v*x* is the firmware revision number, 787 indicates the relay type, and .zds is the file extension reserved for digitally signed files. Firmware files with the .s19 or .z19 extension are not available for firmware versions R300 and higher.

Ethernet Firmware Upgrades

NOTE: The relay pulses the SALARM bit and writes an entry to the relay SER log whenever a firmware upgrade is attempted over Ethernet. Monitoring the SALARM bit and reviewing the SER log can help identify possible unauthorized firmware upgrade attempts.

You can upgrade firmware over an Ethernet connection by sending a .zds firmware upgrade file via FTP, HTTP, or Telnet protocols to a relay running SELBOOT firmware version R600 or higher and relay firmware version R300 and higher. Firmware upgrade versions and upgrade method compatibility are listed in *Table B.1*. FTP, HTTP, and Telnet are plain text protocols and do not inherently support message encryption (e.g., relay passwords, etc.). Because of this, SEL strongly recommends using a security gateway between your relay and your network to encrypt communications. You can also use SEL Software Defined Networking (SDN) technology to enhance your network cybersecurity.

Special Instructions for Upgrading to R300 Series Firmware

The SELBOOT firmware in relays shipped with firmware versions earlier than R300 must be upgraded before you can use digitally signed firmware files. The SELBOOT firmware can be upgraded from version R500, R501, or R502 to version R601 by uploading a special SELBOOT Loader firmware to the relay.

The following instructions assume you have a working knowledge of your PC terminal emulation software.

NOTE: Make sure that the relay and SELBOOT firmware revisions are compatible. Refer to Firmware, ICD, and Manual Versions in this manual. If needed, upgrade the SELBOOT firmware prior to upgrading the relay firmware.

NOTE: To save the calibration settings, perform **SHO C** from the terminal by logging into Access Level C using the Access Level C password. The factory-default password for Access Level C is CLARKE.

NOTE: When you are upgrading an SEL-787 with a touchscreen front-panel display, save all of the relay settings, including the touchscreen settings, using QuickSet.

NOTE: Change the data rate of the relay serial port to 9600 before issuing the **L_D** command to start the upgrade process.

Step 1. If the relay is in service, open the relay control circuits.

Step 2. Connect the PC to the front-panel serial port and enter Access Level 2.

Step 3. Save the present relay settings.

You can use the PC software (see *Section 3: PC Interface*) to save and restore settings, or you can use the following steps:

a. Issue the following commands at the ASCII prompt: **SHO**, **SHO L**, **SHO G**, **SHO P**, **SHO F**, **SHO R**, **SHO C**, etc.

b. Record all the settings for possible reentry after the firmware upgrade.

We recommend that you save all stored data in the relay, including events, before the upgrade.

Step 4. Change the data rate of the communications software to 9600 bps and press **<Enter>**.

Step 5. Download the SELBOOT Loader firmware to the relay.

a. Issue the **L_D** command.

b. Type **Y <Enter>** at the following prompt:

```
Disable relay to receive firmware (Y/N)?
```

c. Type **Y <Enter>** at the following prompt:

```
Are you sure (Y,N)?
```

The relay sends the `!>` prompt.

Step 6. Issue the **REC** command to receive the new firmware.

Step 7. Type **Y** to confirm that the existing SELBOOT and relay firmwares can be erased.

Step 8. Press any key (e.g., **<Enter>**) when the relay sends a prompt.

Step 9. Use the Xmodem protocol to send end the special SELBOOT Loader firmware (e.g., slbtldr_r6017*xx*.s19) to the relay. The special SELBOOT Loader firmware erases the existing SELBOOT and relay firmwares and loads SELBOOT firmware version SLBT7XX-R601-V0-Z000000-D20211116.

The file transfer typically takes less than 5 minutes at 9600 bps, depending on the product. After the transfer is complete, the relay reboots and displays the SELBOOT `!>` prompt. After the SELBOOT upgrade is complete, upgrade your relay firmware using a terminal emulator. It is not necessary to save the relay settings and other data again during the firmware upgrade process if you saved them before upgrading SELBOOT. Proceed to *Step 5* in *Upgrade the Firmware Using a Terminal Emulator*.

Figure B.1 shows the entire special SELBOOT upgrade process.

```
=>>L_D <Enter>
Disable relay to receive firmware (Y,N)? Y <Enter>
Are you sure (Y,N)? Y <Enter>
Relay Disabled


BFID=BOOTLDR-R501-V0-Z000000-D20140224
!>REC <Enter>
This command uploads new firmware.
When new firmware is uploaded successfully, IED will erase old firmware,
load new firmware and reboot.

Are you sure you want to erase the existing firmware(Y,N)? Y <Enter>
Press any key to begin transfer and then start transfer at the terminal.
Erasing firmware.
Erase successful.
Writing new firmware.
Upload completed successfully. Attempting a restart.

Upgrading SELBoot


 Preparing S Record...

 Validating S Record...


* * * * * * * * * W A R N I N G * * * * * * * * *

 Do not turn off or cycle power to the relay or it may
 become inoperative and require factory repair !!!

  Performing this operation will require firmware
      to be downloaded to relay after reboot.

 * * * * * * * * * * * * * * * * * * * * * * * * *

 Removing Old SELBoot...

 Writing New SELBoot...

 Removing SELBoot Loader

 SELBoot Loader cleared... Resetting Relay!!!


BFID=SLBT7XX-R601-V0-Z000000-D20211116
!>
```

Figure B.1 Special SELBOOT Upgrade Process

Upgrade the SELBOOT Firmware Loader Using a Terminal Emulator

NOTE: Make sure the relay and SELBOOT firmware revisions are compatible. Refer to Appendix A: Firmware, ICD, and Manual Versions in this manual. If needed, upgrade the SELBOOT firmware prior to upgrading the relay firmware.

The process for upgrading SELBOOT is similar to *Upgrade the Firmware Using a Terminal Emulator on page B.6*. To determine if SELBOOT must be updated, do the following:

Step 1. Establish communication between the relay and a personal computer.

Step 2. From the computer, type **ID <Enter>**.

The relay responds with the following:

```
=ID <Enter>

"FID=SEL-787-4-X441-V0-Z005003-D20220627","091E"
"BFID=SLBT7XX-R600-V0-Z000000-D20200331","0949"
"CID=30A8","0259"
"DEVID=SEL-787-3S","0483"
"DEVCODE=79","0317"
"PARTNO=07874XE1A4X0XA585A670","076F"
"CONFIG=111002010","0419"
"SPECIAL=0","02DE"
"SEL DISPLAY PACKAGE=3.0.40787.4390","089A"
"CUSTOMER DISPLAY PACKAGE=1.575719065","099D"
"iedName=SEL_787d4_1","0671"
"type=SEL_787d4","04F0"
"configVersion=ICD-787-4-X205-V0-Z302006-D20220401","0D8A"
"LIB61850ID=DF8157E4","04ED"
```

Step 3. Locate the Boot Firmware Identifier String (BFID).

Step 4. Find the SELBOOT revision number in the BFID (R*xxx*). If the revision number is lower than the one you see on the firmware CD, follow the process mentioned below. Otherwise, upgrade the relay firmware using one of the methods mentioned later in the section.

Step 5. To upgrade SELBOOT, locate the new SELBOOT file (r*xxx*7*xx*.zds) on the desk provided with the firmware upgrade materials. Follow the instructions under *Upgrade the Firmware Using a Terminal Emulator on page B.6*. In *Step 6*, 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 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.
```

Change the data rate of the communications software to 9600 bps and press **<Enter>**.

Step 8. Type **EXI <Enter>** at the SELBOOT `!>` prompt to exit SELBOOT. The relay should display the = prompt.

If the relay does not return 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 later in the section. It is not necessary to save the relay settings and other data again if you did this before upgrading SELBOOT.

Upgrade the Firmware Using a Terminal Emulator

NOTE: Make sure that the relay and SELBOOT firmware revisions are compatible. Refer to Firmware, ICD, and Manual Versions in this manual. If needed, upgrade the SELBOOT firmware prior to upgrading the relay firmware.

NOTE: To save the calibration settings, perform **SHO C** from the terminal by logging into Access Level C using the Access Level C password. The factory-default password for Access Level C is CLARKE.

NOTE: When you are upgrading an SEL-787 with a touchscreen front-panel display, save all of the relay settings, including the touchscreen settings, using QuickSet.

NOTE: Change the data rate of the relay serial port to 9600 bps before issuing the **L_D** command to start the upgrade process.

NOTE: If you have difficulty at 115200 bps, choose a slower data transfer rate (e.g., 38400 bps or 57600 bps). Be sure to match the relay and PC data rates.

The following instructions assume you have a working knowledge of your PC terminal emulation software.

Step 1. If the relay is in service, open the relay control circuits.

Step 2. Connect the PC to the front-panel serial or Ethernet port and enter Access Level 2.

Step 3. Save the present relay settings.

You can use the PC software (see *Section 3: PC Interface*) to save and restore settings, or you can use the following steps:

a. Issue the following commands at the ASCII prompt: **SHO**, **SHO L**, **SHO G**, **SHO P**, **SHO F**, **SHO R**, **SHO C**, etc.

b. Record all the settings for possible re-entry after the firmware upgrade.

We recommend that you save all stored data in the relay, including events, before the upgrade.

Step 4. Start upgrading the firmware.

a. Issue the **L_D** command.

b. Type **Y <Enter>** at the following prompt:

```
Disable relay to receive firmware (Y/N)?
```

c. Type **Y <Enter>** at the following prompt:

```
Are you sure (Y,N)?
```

The relay sends the `!>` prompt.

If you are using an Ethernet port, proceed to *Step 6*.

Step 5. Change the data rate, if necessary.

a. Type **BAU 115200 <Enter>**.

This changes the data rate of the communications port to 115200 bps.

b. Change the data rate of the PC to 115200 bps to match the relay.

Step 6. Issue the **REC** command to receive the new firmware.

Step 7. Type **Y** to confirm that the existing firmware can be erased.

Step 8. Press any key (e.g., **<Enter>**) when the relay sends a prompt.

Step 9. Start the file transfer.

Use the Xmodem protocol to send the file that contains the new firmware (e.g., r*xxx*-v*x*787-4.s19, r*xxx*-v*x*787-4.z19, or r*xxx*-v*x*787-4.zds).

Firmware files for firmware versions R1*xx* and R2*xx* have .s19 or .z19 extensions. Firmware files for firmware versions R300 and higher have .zds extensions. Firmware files with the .s19 or .z19 extension are not available for firmware versions R300 and higher.

The file transfer typically takes less than 15 minutes at 115200 bps, depending on the product. After the transfer is complete, the relay reboots and returns to Access Level 0.

Figure B.2 shows the entire upgrade process.

```
=>>L_D <Enter>

Disable relay to receive firmware (Y,N)? Y <Enter>
Are you sure (Y,N)? Y <Enter>
Relay Disabled

BFID=SLBT7XX-R600-V0-Z000000-D20200331
!>BAU 115200 <Enter>
!>REC <Enter>
This command uploads new firmware.
When new firmware is uploaded successfully, IED will erase old firmware,
load new firmware and reboot.

Are you sure you want to erase the existing firmware(Y,N)? Y <Enter>
Press any key to begin transfer and then start transfer at the terminal. <Enter>
Erasing firmware.
Erase successful.
Writing new firmware.
Upload completed successfully. Attempting a restart.
```

Figure B.2 Firmware File Transfer Process

Step 10. The relay front-panel **ENABLED** LED illuminates if the relay settings are retained through the download.

If the **ENABLED** LED is illuminated, proceed to *Step 11*.

If the **ENABLED** LED is not illuminated or the front panel displays `STATUS FAIL Non_Vol Failure`, use the following procedure to restore the factory-default settings:

a. Set the communications software settings to 9600 bps, 8 data bits, and 1 stop bit.

b. Enter Access Level 2 by issuing the **2AC** command.

c. Issue the **R_S** command to restore the factory-default settings.

The relay then reboots with the factory-default settings.

d. Enter Access Level 2.

e. Issue the **STATUS** command.

If the relay is enabled, go to *Step f*.

If the STATUS report shows option card `FAIL` and `Relay Disabled` and the message:

`Confirm Hardware Config`

`Accept & Reboot (Y/N)?`

Enter **Y**. This saves the relay calibration settings.

The relay responds:

`Config Accepted`

The relay reboots and comes up enabled.

f. Restore relay settings back to the settings saved in *Step 3*.

Step 11. Change the data rate of the PC to match that of the relay prior to *Step 4*, and enter Access Level 2.

Step 12. Issue the **STATUS** command; verify all relay self-test results are OK.

Step 13. Apply current and voltage signals to the relay.

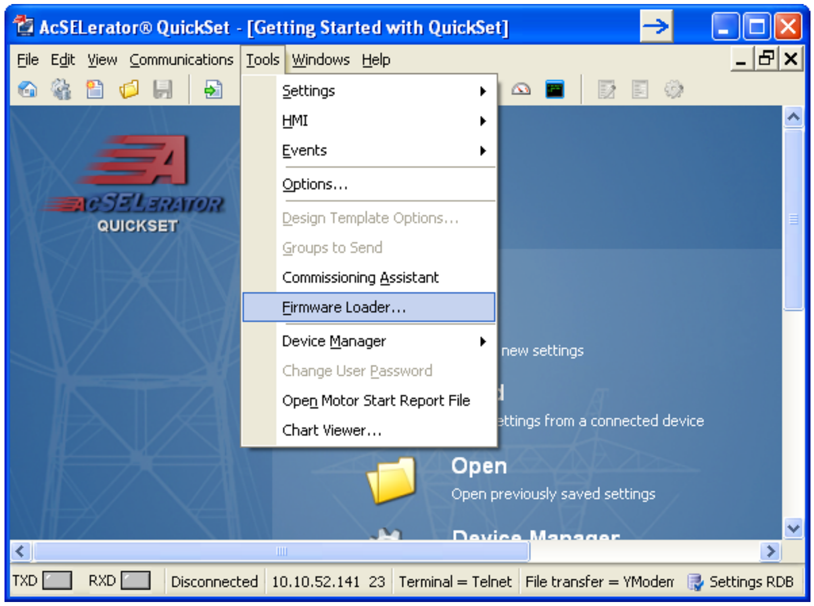
Step 14. Issue the **METER** command; verify that the current and voltage signals are correct.

Step 15. Autoconfigure the SEL communications processor port if you have a communications processor connected.

This step re-establishes automatic data collection between the SEL communications processor and the SEL relay. Failure to perform this step can result in automatic data collection failure when cycling communications processor power.

Upgrade the Firmware Using QuickSet

Select **Tools** > **Firmware Loader** from the QuickSet menu bar to launch a wizard that walks you through the steps to load firmware into your SEL device. Refer to *Section 3: PC Interface* for setup and connection procedures for QuickSet.



NOTE: The firmware loader is not supported on Ethernet port connections.

NOTE: In instances where SELBOOT needs to be upgraded, the web server cannot be used to upgrade the relay firmware. Use a terminal emulator to upgrade SELBOOT and then upgrade the relay firmware.

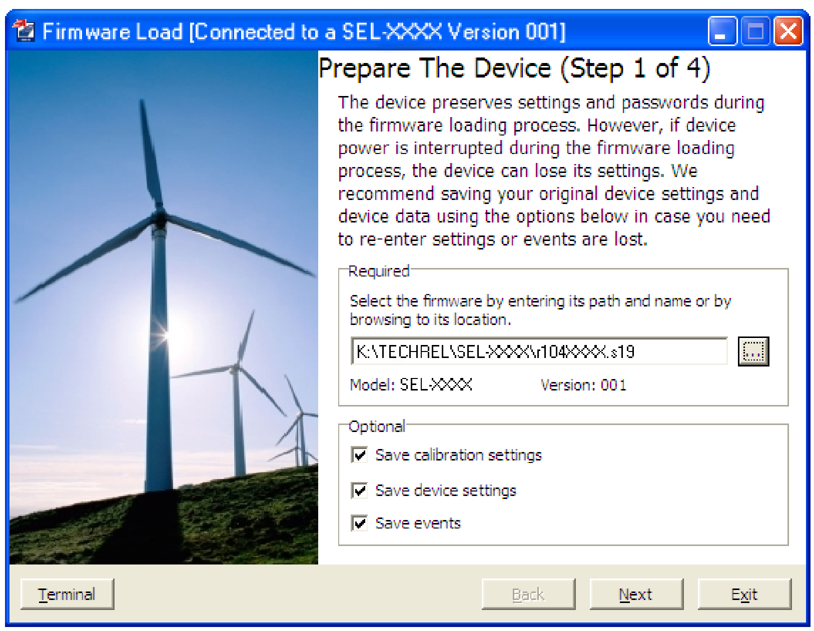
Firmware Loader does not start if:

- ➤ The device is unsupported by QuickSet.
- ➤ The device is not connected to the computer with a communications cable.
- ➤ The device is disabled.

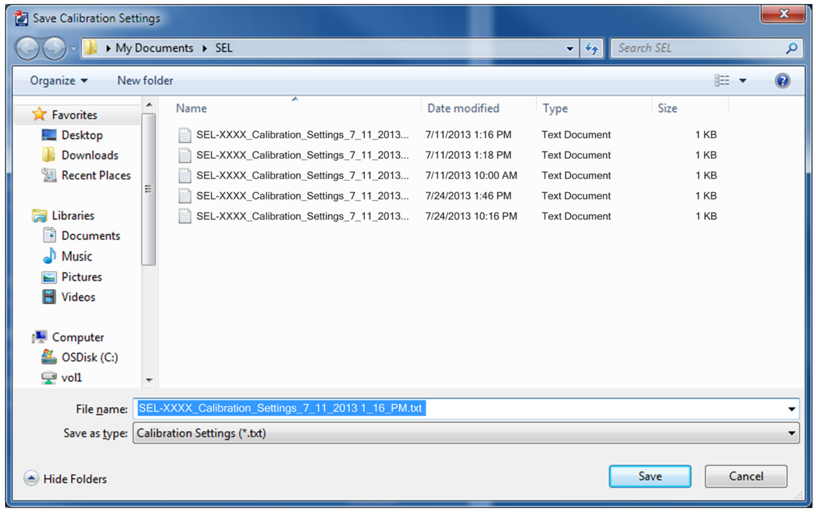
Step 1. If the relay is in service, open the relay control circuits.

Step 2. Prepare the device.

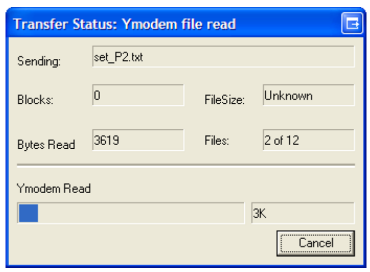
a. Select the firmware to be loaded using the browse control and select **Save calibration settings**, **Save device settings**, and **Save events**. Select **Next** to continue the wizard.

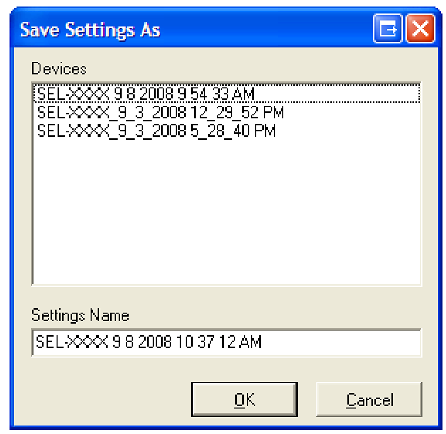


b. Select a file name to save the selected settings or accept the defaults as shown. Click **Save**.



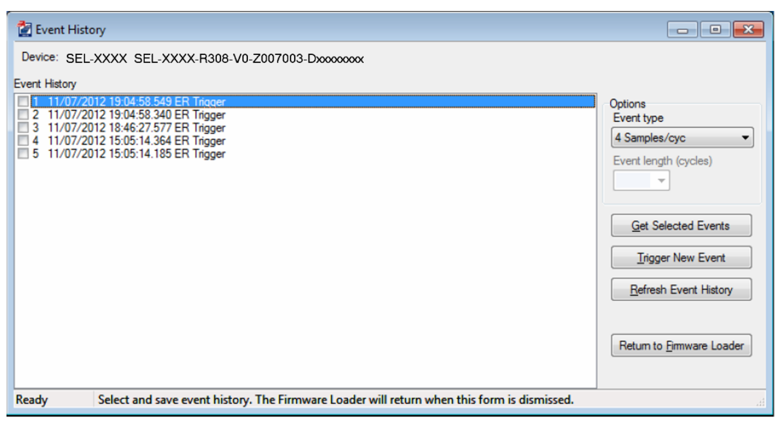
c. The **Transfer Status: Ymodem file read** window shows the transfer progress of the settings file. Clicking **Cancel** stops the transfer.
After the device settings are downloaded, select a file name and path to save the settings or accept the default, as shown.





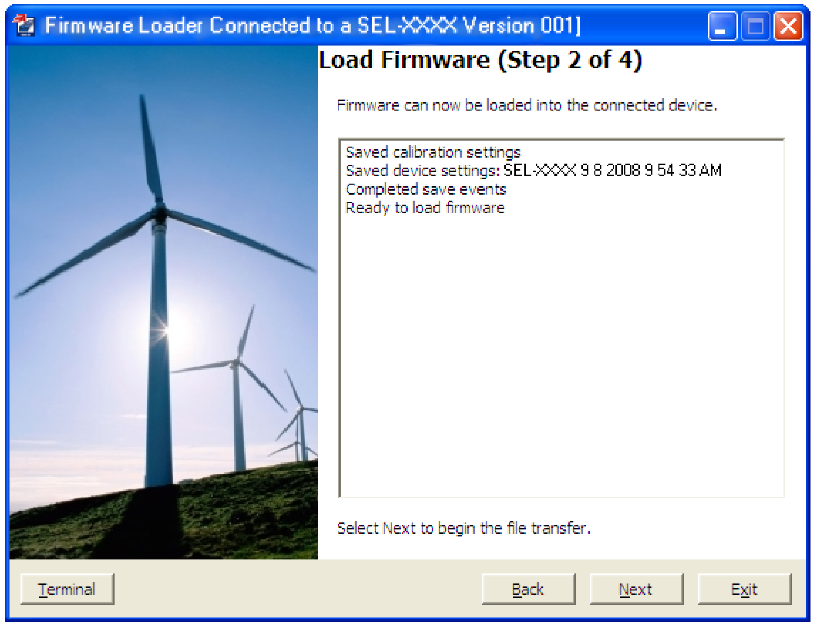
d. Click **Return to Firmware Loader** if this product does not have any event reports.

If there are any event reports to be saved, click the **Get Selected Event** button after selecting the events. After saving them, click the **Return to Firmware Loader** button.



Step 3. Transfer firmware.

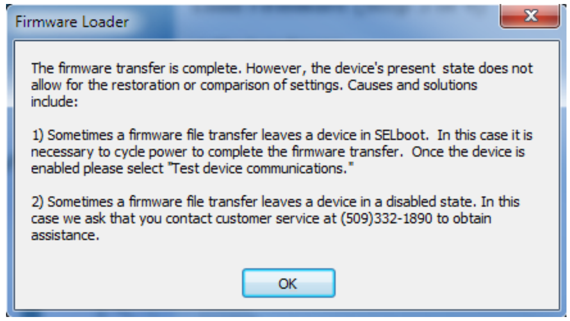
Click **Next** to begin the firmware transfer.



Step 4. Load firmware.

During this step, the device is put into SELBOOT. The transfer speed is maximized and the firmware transfer begins.

NOTE: The following screen can appear if you have one of the two conditions mentioned.



If the relay is disabled as a result of a settings mismatch between a previous firmware version and a new firmware version, check for the **ENABLED** LED on the front panel of the relay. If the **ENABLED** LED is not illuminated or the front panel displays `STATUS FAIL` `Non_Vol Failure` on the two-line display model or a settings mismatch notification screen on the touchscreen models, use the following procedure to restore the factory-default settings:

a. Click the Terminal button on the Firmware Load screen of QuickSet.

b. Set the communications software settings to 9600 baud, 8 data bits, and 1 stop bit.

c. Enter Access Level 2 by issuing the **2AC** command.

d. Issue the **R_S** command to restore the factory-default settings

The relay reboots and comes up enabled.

Note that the port settings will be restored to the default settings due to the **R_S** command.

If the relay is still disabled, use the following proocedure:

e. Enter Access Level 2.

f. Issue the **STATUS** command.

If the STATUS report shows option card `FAIL` and `Relay Disabled` and the message:

```
Confirm Hardware Config
Accept & Reboot (Y/N)?
```

Enter **Y**.

This saves the relay calibration settings. The relay responds:

```
Config Accepted
```

The relay reboots and comes up enabled.

Step 5. Verify device settings.

Select from four verification options, which perform as follows.

Test Device Communications. If the device cannot be restarted, then turn power off and back on to restart it. Once the device is enabled, this option reconnects and re-initializes the device.

Compare Device Settings. This option verifies settings by reading them from the device and comparing them with settings saved to the database.

Restore Device Settings. This option restores settings by writing settings saved in the database to the device. Settings are converted automatically, if necessary.

Load Firmware Into Another Device. Returns the wizard to *Step 2*: *Prepare Device* to repeat the firmware-loading process with another device.

Upgrade the Firmware Using the Web Server

NOTE: The relay pulses the SALARM bit and writes an entry to the relay SER log whenever a firmware upgrade is attempted over Ethernet. Monitoring the SALARM bit and reviewing the SER log can help identify possible unauthorized firmware upgrade attempts.

The web server offers a convenient method for upgrading the relay firmware. Located on the left navigation pane of the screen, the System menu contains the File Management category that allows you to upgrade firmware in the relay. To upgrade the firmware using the web server, the firmware in your relay must be R300 or higher. The firmware is designated with a .zds extension. Refer to *Section 3: PC Interface* for connecting and logging in to the SEL-787 web server using the Ethernet port.

To upgrade relay firmware by using the web server, set the Port 1 settings HTTPACC := 2 and EETHFWU := Y. If EETHFWU is set to N, you cannot upgrade the firmware over Ethernet, regardless of the HTTPACC setting.

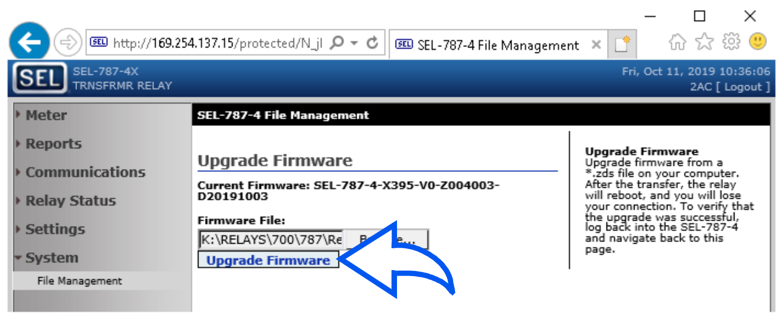
Step 1. In QuickSet, save the current relay settings and other data.

Step 2. Proceed with the firmware upgrade process by performing the following steps:

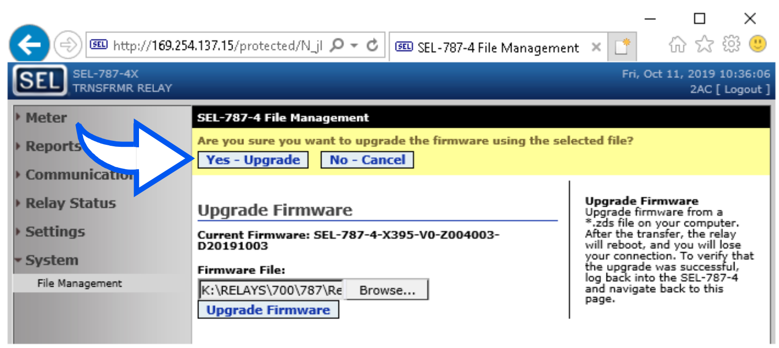
a. Click **System > File Management** from the left navigation pane of the webpage.

b. Click **Browse** to select the firmware you want to send to the relay.

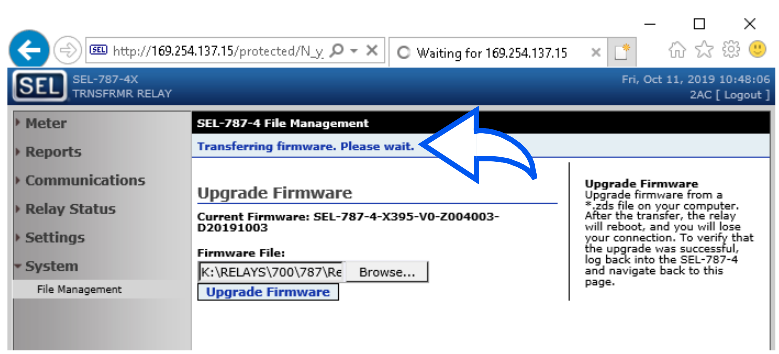
c. Click **Upgrade Firmware** to start the upgrade process.



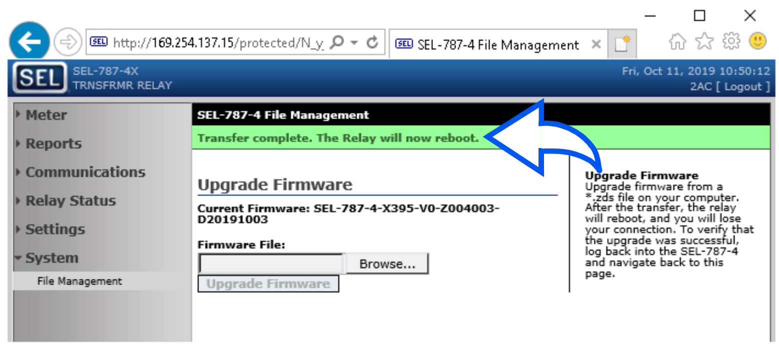
Step 3. Click **Yes - Upgrade** if you want to upgrade using the file selected.



Once the upgrade process is in progress, the relay acknowledges the transfer with the message, **Transferring firmware. Please wait**.



After the relay finishes the firmware transfer, an acknowledgment message appears and the relay reboots.



NOTE: After the relay reboots, if the **ENABLED** is not illuminated or if the front panel displays STATUS FAIL Non_Vol Failure on the two-line display, or a settings mismatch notification on the touchscreen model, then open a terminal emulator using the serial port and use the following procedure to restore the factory-default settings. Refer to Upgrade the Firmware Using a Terminal Emulator for terminal emulator setup and connections.

a. Set the communications software settings to 9600 bps, 8 data bits, and 1 stop bit.

b. Enter Access Level 2 by issuing the **2AC** command.

c. Issue the **R_S** command to restore the factory default.

The relay reboots and comes up enabled.

Note that the port settings will be restored to the factory-default settings due to the **R_S** command.

If the relay is still disabled, use the following procedure:

d. Enter Access Level 2.

e. Issue the **STATUS** command.

If the STATUS report shows option card `FAIL` and `Relay Disabled` and the message:

```
Confirm Hardware Config
Accept & Reboot (Y/N)?
```

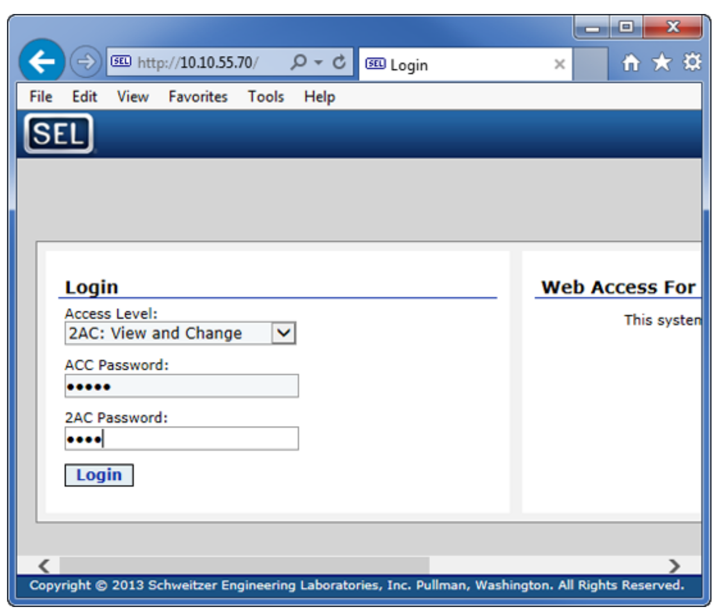
Enter **Y**.

This saves the relay calibration settings. The relay responds:

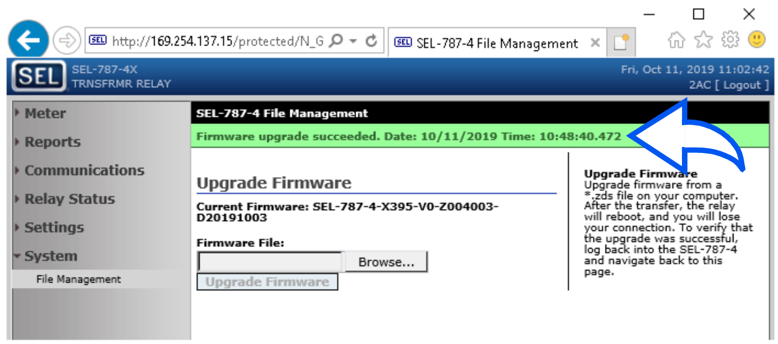
```
Config accepted
```

The relay reboots and comes up enabled.

Step 4. After the relay reboots, the Login screen appears on the web server. Log in to the relay to verify completion of the firmware upgrade process.



An acknowledgment message appears that verifies a successful firmware upgrade.



Step 5. Check that the relay firmware version matches the version that was used for the upgrade and that the relay is enabled.

Click on **Relay Status** > **Self-Tests** to view the status report.

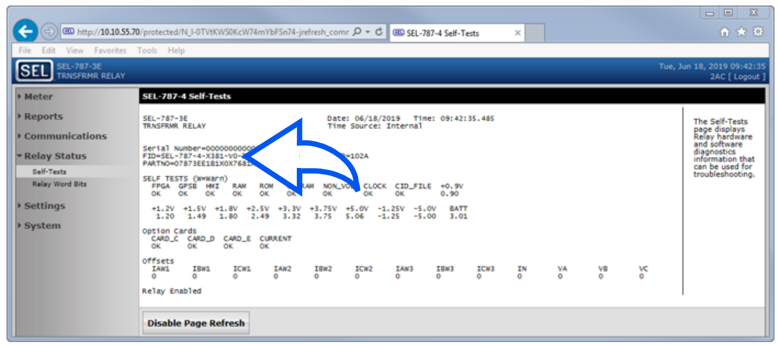


Table B.2 provides messages displayed in the web browser and the message meaning.

Table B.2 Ethernet Firmware Upgrade User Messages

User Message	Relay Condition
Firmware upgrade succeeded.	The previous firmware upgrade with a .zds file was successful.
Invalid upgrade file.	The .zds file was not successfully received or validated by the relay.
Upgrade in progress on another interface.	A firmware upgrade is presently being performed through another connection.
Errors during Upgrade File Transfer.	Upgrade failed due to errors during file transfer.

Upgrade the Firmware Using File Transfer Protocol

NOTE: Make sure that the relay and SELBOOT firmware revisions are compatible. Refer to Firmware, ICD, and Manual Versions in this manual. If needed, upgrade the SELBOOT firmware prior to upgrading the relay firmware.

NOTE: The relay pulses the SALARM bit and writes an entry to the relay SER log whenever a firmware upgrade is attempted over Ethernet. Monitoring the SALARM bit and reviewing the SER log can help identify possible unauthorized firmware upgrade attempts.

To upgrade firmware using File Transfer Protocol (FTP), the firmware in your relay must be R300 or higher. The firmware is designated with a .zds extension.

To upgrade relay firmware by using FTP, set the Port 1 settings FTPACC := 2 or C and EETHFWU := Y. If EETHFWU is set to N, you cannot upgrade the firmware over Ethernet, regardless of the FTPACC setting.

The following instructions assume you have a working knowledge of the Windows command prompt.

Step 1. If the relay is in service, open the relay control circuits.

Step 2. Connect the PC to the Ethernet port and enter Access Level 2.

Step 3. Save the present relay settings.

You can use the PC software (see *Section 3: PC Interface*) to save and restore settings, or you can use the following steps:

a. Issue the following commands at the ASCII prompt: **SHO**, **SHO L**, **SHO G**, **SHO P**, **SHO F**, **SHO R**, **SHO C**, etc.

b. Record all the settings for possible re-entry after the firmware upgrade.

We recommend that you save all stored data in the relay, including events, before the upgrade.

NOTE: To save the calibration settings, perform **SHO C** from the terminal by logging into Access Level C using the Access Level C password. The factory-default password for Access Level C is CLARKE.

NOTE: When you are upgrading an SEL-787 with a touchscreen front-panel display, save all of the relay settings, including the touchscreen settings, using QuickSet.

NOTE: File name RELAY.zds is not case sensitive.

Step 4. Rename the r*xxx*-v*x*751.zds file as RELAY.zds.

Step 5. Create an FTP session to connect to the relay using the relay IP address.

Step 6. Enter your FTP username and password.

Step 7. Issue the **CD UPGRADE** command to switch the present relay directory to the UPGRADE directory.

Step 8. Issue the **PUT RELAY.ZDS** command to place the RELAY.zds file in the UPGRADE directory and to send the file to the relay.

When the download is complete, the relay reboots and comes up enabled.

During this upgrade process, you will lose the FTP connection, and you must reestablish the FTP connection after the upgrade is complete. Then navigate to the relay UPGRADE directory and review the ERR.txt file for any error messages. If the firmware upgraded properly, no errors occurred during the upgrade process and the file is empty. If messages are contained within the file, see *Table B.2* for the error message and a description.

Figure B.3 shows the entire upgrade process via Windows command prompt.

```
Microsoft Windows [Version 10.0.17763.805]
(c) 2018 Microsoft Corporation. All rights reserved.

Y:\>FTP 10.39.94.180 <Enter>
Connected to 10.39.94.180.
220 FTP SERVER
550 NOOP requested action not taken.
User (10.39.94.180:(none)): xxxxxx <Enter>
331 User name okay, need password.
Password: xxxxxx <Enter>
230 User logged in, proceed.
ftp> CD UPGRADE <Enter>
250 CWD  requested file action okay, completed.
ftp> PUT RELAY.ZDS <Enter>
200 PORT Command okay.
150 File status okay; about to open data connection.
Connection closed by remote host.
ftp>
```

Figure B.3 Firmware Upgrade Via FTP

Upgrade the Firmware Via Terminal Emulator Using the FILE Command Over Telnet

NOTE: Make sure that the relay and SELBOOT firmware revisions are compatible. Refer to Firmware, ICD, and Manual Versions in this manual. If needed, upgrade the SELBOOT firmware prior to upgrading the relay firmware.

NOTE: The relay pulses the SALARM bit and writes an entry to the relay SER log whenever a firmware upgrade is attempted over Ethernet. Monitoring the SALARM bit and reviewing the SER log can help identify possible unauthorized firmware upgrade attempts.

To upgrade firmware using the **FILE** command over Telnet, the firmware in your relay must be R300 or higher. The firmware is designated with a .zds extension.

To upgrade relay firmware by using the **FILE** command over Telnet, set the Port 1 settings MAXACC := 2 or C and EETHFWU := Y. If EETHFWU is set to N, you cannot upgrade the firmware over Ethernet, regardless of the MAXACC setting.

The following procedure assumes that you have a working knowledge of the software being used to upgrade the firmware via **FILE** command.

Step 1. If the relay is in service, open the relay control circuits.

Step 2. Connect the PC to the Ethernet port and enter Access Level 2.

Step 3. Save the present relay settings.

You can use the PC software (see *Section 3: PC Interface*) to save and restore settings, or you can use the following steps:

a. Issue the following commands at the ASCII prompt: **SHO**, **SHO L**, **SHO G**, **SHO P**, **SHO F**, **SHO R**, **SHO C**, etc.

b. Record all the settings for possible re-entry after the firmware upgrade.

We recommend that you save all stored data in the relay, including events, before the upgrade.

NOTE: To save the calibration settings, perform **SHO C** from the terminal by logging into Access Level C using the Access Level C password. The factory-default password for Access Level C is CLARKE.

NOTE: When you are upgrading an SEL-787 with a touchscreen front-panel display, save all of the relay settings, including the touchscreen settings, using QuickSet.

NOTE: File name RELAY.zds is not case sensitive.

Step 4. Rename the r*xxx*-v*x*751.zds file as RELAY.zds.

Step 5. Save the RELAY.zds file to a directory.

Step 6. Update the active directory to be the directory where the RELAY.zds file is saved.

Step 7. Issue the **FILE WRITE RELAY.ZDS** command to the relay.

Step 8. Send the RELAY.zds file to the relay via Ymodem transfer.

When the upgrade is complete, the relay reboots and comes up enabled.

During this upgrade process, you will lose the Telnet connection, and you must reestablish the Telnet connection after the upgrade is complete. Then navigate to the relay UPGRADE directory and review the ERR.txt file for any error messages. If the firmware upgraded properly, no errors occurred during the upgrade process and the file is empty. If messages are contained within the file, see *Table B.2* for the error message and a description.

Protocol Verification for Relays With IEC 61850 Option

NOTE: A relay with optional IEC 61850 protocol requires the presence of one valid CID file to enable the protocol. You should only transfer a CID file to the relay if you want to implement a change in the IEC 61850 configuration or if new relay firmware does not support the current CID file version. If you transfer an invalid CID file, the relay disables the IEC 61850 protocol, because it no longer has a valid configuration. To restart IEC 61850 protocol operation, you must transfer a valid CID file to the relay.

Perform the following steps to verify that the IEC 61850 protocol is still operational after a relay firmware upgrade and, if not, re-enable it. This procedure assumes that IEC 61850 was operational with a valid CID file immediately before initiating the relay firmware upgrade.

Step 1. Establish an FTP connection to the relay Ethernet port.

Step 2. Open the ERR.TXT file.

If the ERR.TXT file is empty, the relay found no errors during CID file processing and IEC 61850 should be enabled. Go to *Step 3* if ERR.TXT is empty.

If the ERR.TXT file contains error messages relating to CID file parsing, the relay has disabled the IEC 61850 protocol. Use ACSELERATOR Architect SEL-5032 Software to convert the existing CID file and make it compatible again.

a. Install the Architect software upgrade that supports your required CID file version.
b. Run Architect and open the project that contains the existing CID file for the relay.
c. Download the CID file to the relay.

Step 3. Upon connecting to the relay, Architect detects the upgraded relay firmware and prompts you to allow it to convert the existing CID file to a supported version. Once converted, downloaded, and processed, the valid CID file allows the relay to re-enable the IEC 61850 protocol.

Step 4. In the Telnet session, type **GOO <Enter>**.

Step 5. View the GOOSE status and verify that the transmitted and received messages are as expected.

The relay is now ready for your commissioning procedure.

Technical Support

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

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2350 NE Hopkins Court
Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.338.3838
Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com

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Appendix C
SEL Communications Processors

SEL Communications Protocols

The SEL-787 Transformer Protection Relay supports SEL protocols and command sets shown in *Table C.1*.

Table C.1 Supported Serial Command Sets

Command Set	Description
SEL ASCII	Use this protocol to send ASCII commands and receive ASCII responses that are human readable with an appropriate terminal emulation program.
SEL Compressed ASCII	Use this protocol to send ASCII commands and receive Compressed ASCII responses that are comma-delimited for use with spreadsheet and database programs or for use by intelligent electronic devices.
SEL Fast Meter	Use this protocol to send binary commands and receive binary meter and target responses.
SEL Fast Operate	Use this protocol to receive binary control commands.
SEL Fast SER	Use this protocol to receive binary Sequential Events Recorder unsolicited responses.
SEL Fast Message	Use this protocol to write remote analog data via unsolicited writes.

SEL ASCII Commands

We originally designed SEL ASCII commands for communication between the relay and a human operator via a keyboard and monitor or a printing terminal. A computer with a serial port can also use the SEL ASCII protocol to communicate with the relay, collect data, and issue commands.

SEL Compressed ASCII Commands

The relay supports a subset of SEL ASCII commands identified as Compressed ASCII commands. Each of these commands results in a comma-delimited message that includes a checksum field. Most spreadsheet and database programs can directly import comma-delimited files. Devices with embedded processors connected to the relay can execute software to parse and interpret comma-delimited messages without expending the customization and maintenance labor needed to interpret nondelimited messages. The relay calculates a checksum for each line by numerically summing all of the bytes that precede the checksum field in the message. The program that uses the data can detect transmission errors in the message by summing the characters of the received message and comparing this sum to the received checksum.

Most commands are available only in SEL ASCII or Compressed ASCII format. Selected commands have versions in both standard SEL ASCII and Compressed ASCII formats. Compressed ASCII reports generally have fewer characters than conventional SEL ASCII reports because the compressed reports reduce blanks, tabs, and other white space between data fields to a single comma.

Table C.2 lists the Compressed ASCII commands and contents of the command responses.

Table C.2 Compressed ASCII Commands

Command	Response	Access Level
BNAME	ASCII names of Fast Meter status bits	0
CASCII	Configuration data of all Compressed ASCII commands available at access levels > 0	0
CEVENT	Event report	1
CHISTORY	List of events	1
CLDP	Load Profile Data	1
CMETER	Metering data, including fundamental, differential, thermal, demand, peak demand, energy, harmonic, max/min, rms, analog inputs, remote analogs, and math variables	1
CSE	Sequence Of Events Data	1
CSTATUS	Relay status	1
CSUMMARY	Summary of an event report	1
CTFE	Through-fault event report	1
DNAME	ASCII names of digital I/O reported in Fast Meter	0
ID	Relay identification	0
SNS	ASCII names for SER data reported in Fast Meter	0

Interleaved ASCII and Binary Messages

SEL relays have two separate data streams that share the same physical serial port. Human data communications with the relay consist of ASCII character commands and reports that you view through use of a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information; the ASCII data stream continues after the interruption. This mechanism uses a single communications channel for ASCII communication (transmission of an event report, for example) interleaved with short bursts of binary data to support fast acquisition of metering data. The device connected to the other end of the link requires software that uses the separate data streams to exploit this feature. However, you do not need a device to interleave data streams to use the binary or ASCII commands. Note that XON, XOFF, and CAN operations operate on only the ASCII data stream.

An example of using these interleaved data streams is when the SEL-787 communicates with an SEL communications processor. These SEL communications processors perform autoconfiguration by using a single data stream and SEL Compressed ASCII and binary messages. In subsequent operations, the SEL communications processor uses the binary data stream for Fast Meter and Fast Operate messages to populate a local database and to perform SCADA operations. At the same time, you can use the binary data stream to connect transparently to the SEL-787 and use the ASCII data stream for commands and responses.

SEL Fast Meter, Fast Operate, Fast SER, and Unsolicited Write

SEL Fast Meter is a binary message that you solicit with binary commands. Fast Operate is a binary message for control. The relay can also send unsolicited Fast SER messages automatically and receive unsolicited SEL Fast Messages (used in the SEL-787 for Remote Analogs). If the relay is connected to an SEL communications processor, these messages provide the mechanism that the communications processor uses for SCADA or DCS functions that occur simultaneously with ASCII interaction.

SEL Communications Processor

NOTE: If the SEL-787 is connected to any SEL communications processor (SEL-203x or RTAC), the corresponding language port setting must be set to English.

SEL offers SEL communications processors, powerful tools for system integration and automation. The SEL-2030 series and the SEL-2020 communications processors are similar, except that the SEL-2030 series has two slots for network protocol cards. The SEL-3530 Real Time Automation Controller (RTAC) has Ethernet ports as well as serial ports to connect to your SEL relay. These devices provide a single point of contact for integration networks with a star topology, as shown in *Figure C.1*.

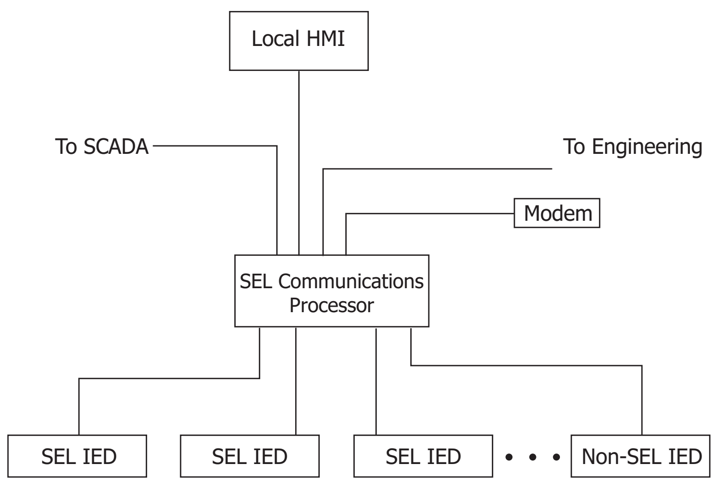

Figure C.1 SEL Communications Processor Star Integration Network

In the star topology network in *Figure C.1* the SEL communications processor offers the following substation integration functions:

- Collection of real-time data from SEL and non-SEL IEDs
- Calculation, concentration, and aggregation of real-time IED data into databases for SCADA, HMI, and other data consumers
- Access to the IEDs for engineering functions including configuration, report data retrieval, and control through local serial, remote dial-in, and Ethernet network connections
- Distribution of IRIG-B time-synchronization signal to IEDs based on external IRIG-B input, internal clock, or protocol interface
- Simultaneous collection of SCADA data and engineering connection to SEL IEDs over a single cable
- Automated dial-out on alarms

The SEL communications processors have 16 serial ports plus a front port. This port configuration does not limit the size of a substation integration project, because you can create a multitiered solution as shown in *Figure C.2*. In this multitiered system, the lower-tier SEL communications processors forward data to the upper-tier SEL communications processor that serves as the central point of access to substation data and substation IEDs.

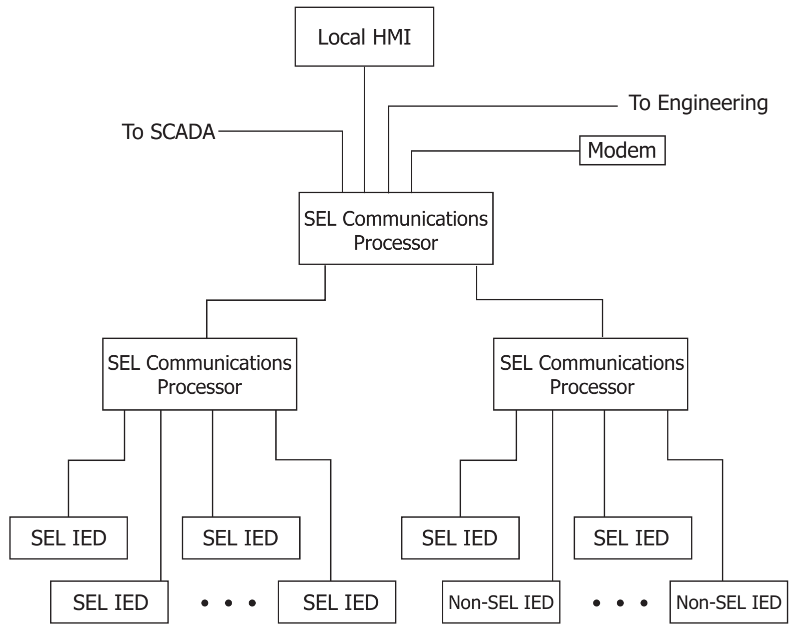

Figure C.2 Multitiered SEL Communications Processor Architecture

You can add additional communications processors to provide redundancy and eliminate possible single points of failure. SEL communications processors provide an integration solution with a reliability comparable to that of SEL relays. In terms of MTBF (mean time between failures), SEL communications processors are 100 to 1000 times more reliable than computer-based and industrial technology-based solutions.

Configuration of an SEL communications processor is different from other general-purpose integration platforms. You can configure SEL communications processors with a system of communication-specific keywords and data movement commands rather than programming in C or another general-purpose computer language. SEL communications processors offer the protocol interfaces listed in *Table C.3*.

Table C.3 SEL Communications Processors Protocol Interfaces (Sheet 1 of 2)

Protocol	Connect to
DNP3 Level 2 Slave	DNP3 masters
Modbus RTU Protocol	Modbus masters
SEL ASCII/Fast Message Slave	SEL protocol masters
SEL ASCII/Fast Message Master	SEL protocol slaves including other communications processors and SEL relays
ASCII and Binary auto messaging	SEL and non-SEL IED master and slave devices
Modbus Plus[a]	Modbus Plus peers with global data and Modbus Plus masters

Table C.3 SEL Communications Processors Protocol Interfaces (Sheet 2 of 2)

Protocol	Connect to
FTP (File Transfer Protocol)[b]	FTP clients
Telnet[b]	Telnet servers and clients
UCA2 GOMSFE[b]	UCA2 protocol masters
UCA2 GOOSE[b]	UCA2 protocol and peers

[a] Requires SEL-2711 Modbus Plus protocol card.
[b] Requires SEL-2701 Ethernet Processor.

SEL Communications Processor and Relay Architecture

You can apply SEL communications processors and SEL relays in a limitless variety of applications that integrate, automate, and improve station operation. Most system integration architectures utilizing SEL communications processors involve either developing a star network or enhancing a multidrop network.

Developing Star Networks

The simplest architecture using both the SEL-787 and an SEL communications processor is shown in *Figure C.1*. In this architecture, the SEL communications processor collects data from the SEL-787 and other station IEDs. The SEL communications processor acts as a single point of access for local and remote data consumers (local HMI, SCADA, engineers). The communications processor also provides a single point of access for engineering operations including configuration and the collection of report-based information.

By configuring a data set optimized to each data consumer, you can significantly increase the utilization efficiency on each link. A system that uses an SEL communications processor to provide a protocol interface to an RTU has a shorter lag time (data latency); communication overhead is much less for a single data exchange conversation to collect all substation data (from a communications processor) than for many conversations required to collect data directly from each individual IED. You can further reduce data latency by connecting any SEL communications processor directly to the SCADA master and eliminating redundant communication processing in the RTU.

The SEL communications processor is responsible for the protocol interface, so you can install, test, and even upgrade the system in the future without disturbing protective relays and other station IEDs. This insulation of the protective devices from the communications interface assists greatly in situations where different departments are responsible for SCADA operation, communication, and protection.

SEL communications processors equipped with an SEL-2701 Ethernet Processor can provide a UCA2 interface to SEL-787 relays and other serial IEDs. The SEL-787 data appear in models in a virtual device domain. The combination of the SEL-2701 with an SEL communications processor offers a significant cost savings because you can use existing IEDs or purchase less expensive IEDs. For full details on applying the SEL-2701 with an SEL communications processor, see the SEL-*2701 Ethernet Processor Instruction Manual*.

The engineering connection can use either an Ethernet network connection through the SEL-2701 or a serial port connection. This versatility accommodates the channel that is available between the station and the engineering center. SEL software can use either a serial port connection or an Ethernet network connection from an engineering workstation to the relays in the field.

Enhancing Multidrop Networks

You can also use an SEL communications processor to enhance a multidrop architecture similar to the one shown in *Figure C.3*. In this example, the SEL communications processor enhances a system that uses the SEL-2701 with an Ethernet HMI multidrop network. In the example, there are two Ethernet networks, the SCADA LAN and the Engineering LAN. The SCADA LAN provides real-time data directly to the SCADA Control Center via a protocol gateway and to the HMI.

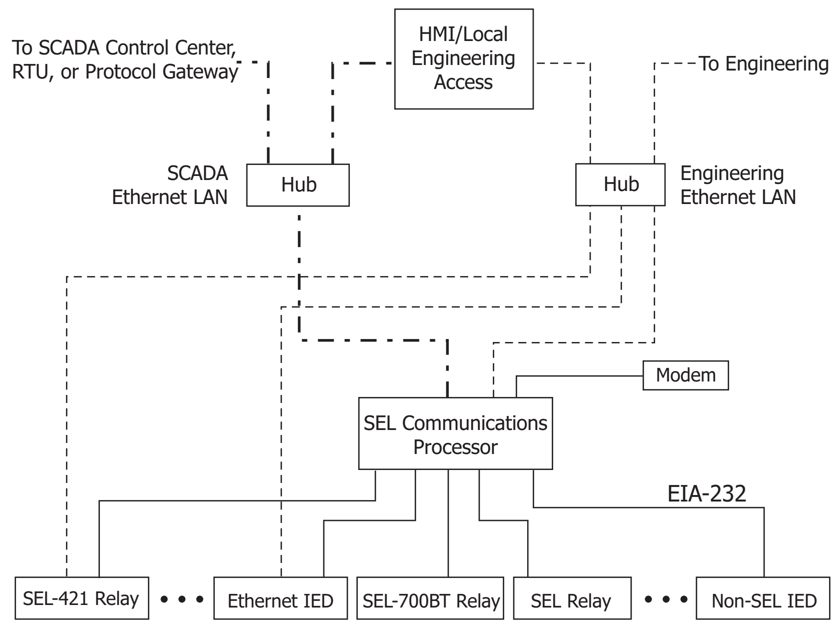

Figure C.3 Enhancing Multidrop Networks With SEL Communications Processors

In this example, the SEL communications processor provides the following enhancements when compared to a system that employs only the multidrop network:

- ➤ Ethernet access for IEDs with serial ports
- ➤ Backup engineering access through the dial-in modem
- ➤ IRIG-B time signal distribution to all station IEDs
- ➤ Integration of IEDs without Ethernet
- ➤ Single point of access for real-time data for SCADA, HMI, and other uses
- ➤ Significant cost savings by use of existing IEDs with serial ports

SEL Communications Processor Example

This example demonstrates the data and control points available in the SEL communications processor when you connect an SEL-787. The physical configuration used in this example is shown in *Figure C.4*. In this example, the communications processor is an RTAC that is connected to the SEL-787 by using SEL Protocol via ACSELERATOR RTAC software. For more information regarding the RTAC and ACSELERATOR RTAC software, refer to selinc.com.

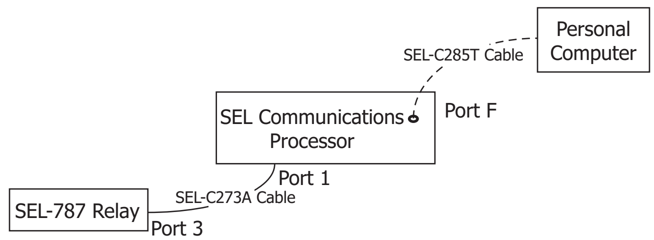

Figure C.4 Example of SEL Relay and SEL Communications Processor Configuration

Table C.4 shows the Port 1 settings for the RTAC.

Table C.4 RTAC Port 1 Settings (Sheet 1 of 2)

Setting	Range	Value
Communications		
SERIAL COMMUNICATIONS PORT	The number of ports depends on the RTAC MOT	Com_01
SERIAL COMMUNICATIONS PORT TYPE	EIA-232, EIA-485/EIA-422	EIA232
BAUD RATE	Auto-Baud, 300, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200	115200
DATA BITS	8	8
PARITY BIT	None	None
STOP BIT	1	1
RTS_CTS	True, False	False
XON/XOFF	True, False	True
LEVEL 1 PASSWORD	0–32 characters	**********
LEVEL 2 PASSWORD	0–32 characters	**********
ENABLE PASSWORD MONITOR	True, False	False
POLL CASCII RETRIES	0–255	3
POLL CASCII INACTIVITY TIMEOUT	100–65535 ms	8000
POLL BINARY RETRIES	0–255	3
POLL BINARY INACTIVITY TIMEOUT	<min>–65535 ms	2500
SLOW POLL MODE MULTIPLIER	1–65535	5

Table C.4 RTAC Port 1 Settings (Sheet 2 of 2)

Setting	Range	Value
TRANSMIT FAST UNSOLICITED WRITE MESSAGING ON STARTUP	True, False	False
Date-Time		
UTC OFFSET	–720 to 840 minutes	0
DST ENABLED	True, False	True
Event		
ENABLE EVENT COLLECTION	True, False	False
ENABLE COMTRADE COLLECTION	True, False	False
LIST OF EVENT TYPES TO BE COLLECTED		HR
SEL		
VIRTUAL PORT NUMBER	1–254	1

After these settings are configured to align with the Port 3 settings of the SEL-787, the RTAC will auto-configure the connection. Refer to *Figure C.5* for an example as to what a healthy connection looks like after auto-configuration is complete. Note that ENO and EN are TRUE and that Offline is FALSE.

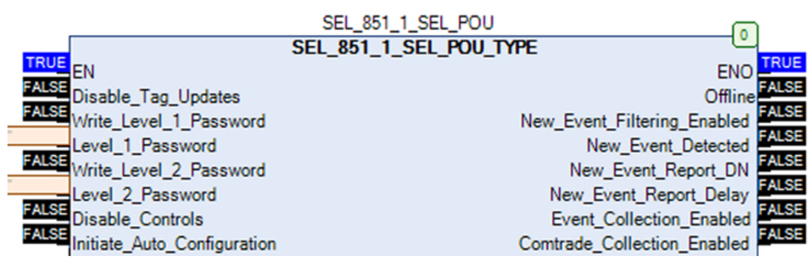

Figure C.5 Healthy Communications Between an RTAC and an SEL Relay

Data Collection

In this example, the RTAC is configured to collect data from the SEL-787 via SEL Protocol, using the list in *Table C.5*.

Table C.5 RTAC Data Collection Automessages

Message Name	Message Type	Command	Poll Period
History	Compressed ASCII	CHI	0
Load Data	Compressed ASCII	CLDP	0
SER	Compressed ASCII	CSE	0
Status	Compressed ASCII	CST	0
Demand Meter	Fast Meter	D2	0
Meter	Fast Meter	D1	1000
Peak Meter	Fast Meter	D3	0

You have the ability to set the poll period for each of the commands in *Table C.5*.

Control Points

The RTAC can automatically pass control messages, called Fast Operate messages, to the SEL-787. You must enable Fast Operate messages by using the FASTOP setting in the SEL-787 port settings for the port connected to the SEL communications processor.

NOTE: To use the Fast Operate function, the Breaker jumper must be installed (see Figure 2.7).

When you enable Fast Operate functions, the SEL communications processor automatically sends messages to the relay for changes in remote bits RB01–RB32 on the corresponding SEL communications processor port.

SEL Communications Processor to SEL-787 Unsolicited Write Remote Analog Example

There are two settings that must be configured in the RTAC if you need to write to remote analogs in the SEL-787. In this example, the required settings needed to write to RA_001.Val and RA_002.Val are provided. The first set of settings is under the Tx UW Messages tab. See *Figure C.6*.

Unsolicited Write TX	Unsolicited Write TX Period	Unsolicited Write TX Port	Unsolicited Write TX Start Address
1	1000	Com_001	0xf800
2	1000	Com_001	0xf802

Figure C.6 Unsolicited Write Remote Analogs Tx UW Messages Settings

In the settings, note the unsolicited write Tx starting addresses. After these two settings are properly configured, Tx UW Message 1 must be configured. See *Figure C.7*. Note the Tag Types being MV and the Datatype being REAL. Use a similar setup to write to all of the remote analogs.

Drag a column header here to group by that column

Enable	Tag Name	Tag Type	Tag Alias	Address Range Start	Address Range Stop	Bit Index	Treat As	Status Value
True	SEL_851_1_SEL.Tx_UW_1_F800	MV		0xf800	0xf801		REAL	
True	SEL_851_1_SEL.Tx_UW_1_F802	MV		0xf802	0xf803		REAL	

Figure C.7 Tag Type and Datatype for RA_001.Val–RA_032.Val

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Appendix D
DNP3 Communications

Overview

The SEL-787 Transformer Protection Relay provides a Distributed Network Protocol Version 3.0 (DNP3) Level 2 Outstation interface for direct serial and LAN/WAN network connections to the device.

This section covers the following topics:

- *Introduction to DNP3 on page D.1*
- *DNP3 in the SEL-787 on page D.6*
- *DNP3 Documentation on page D.14*

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 Recommended Practice for Data Communications Between Remote Terminal Units and Intelligent Electronic Devices in a Substation.

The DNP Users Group maintains and publishes DNP3 standards. See the DNP Users Group website, 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 D.1*.

Table D.1 DNP3 Implementation Levels

Level	Description	Equipment Types
1	Simple: limited communication requirements	Meters, simple IEDs
2	Moderately complex: monitoring and metering devices and multifunction devices that contain more data	Protective relays, RTUs
3	Sophisticated: devices with great amounts of data or complex communication requirements	Large RTUs, SCADA masters
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 discussions and examples of specific features of DNP3.

Data Handling

Objects

DNP3 uses a system of data references called objects, defined by the Basic 4 standard object library. 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.

If there can be more than one instance of a type of object, then each instance of the object includes an index that makes it unique. For example, each binary status point (Object 1) has an index. If there are 16 binary status points, these points are Object 1, Index 0 through Object 1, Index 15.

Each object also includes multiple versions called variations. For example, Object 1 (binary inputs) has three variations: 0, 1, and 2. You can use Variation 0 to request all variations, 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 D.2*.

Table D.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 includes 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 data (static data). Classes 1, 2, and 3 are event data classes. The meaning of Classes 1 to 3 is arbitrary and defined by the application at hand. With 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 D.3*.

The access methods listed in *Table D.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. To properly evaluate which access method provides optimum performance for your application, you must also consider overall system size and the volume of data communication expected.

Table D.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. *Table D.12* describes control point operation for the SEL-787.

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 interpretability.

DNP3 Serial Network Issues

Data Link Layer Operation

DNP3 employs a three-layer version of the seven-layer OSI (Open System Interconnection) 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 reduces 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 must provide a mechanism to resolve the resulting network medium contention. For example, unsolicited reporting results in network medium contention if you do not design your 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 must use application confirmation to provide a retry mechanism for messages lost in 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 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 provides a reliable delivery mechanism, which is backed up at the application layer by confirmations when required.

- DNP3 shall use the IP suite to transport messages over a LAN/WAN
- Ethernet is the recommended physical link, although you can use others
- TCP must be used for WANs
- TCP is strongly recommended for LANs
- UDP may be used for highly reliable single segment LANs
- UDP is necessary if broadcast messages are required
- The DNP3 protocol stack shall be retained in full
- Link layer confirmations shall be disabled

The technical committee has registered a standard port number, 20000, for DNP3 with the Internet Assigned Numbers Authority (IANA). This port is used for either TCP or UDP.

TCP/UDP Selection

The committee recommends the selection of TCP or UDP protocol as per the guidelines in *Table D.4*.

Table D.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-787

The SEL-787 is a DNP3 Level 2 remote (outstation) device.

Data Access

Table D.5 lists DNP3 data access methods along with corresponding SEL-787 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 in Table D.5, the suffix n represents the DNP3 session number from 1 to 5. All settings with the same numerical suffix comprise the complete DNP3 session configuration.

Table D.5 Configuring DNP3 Access Methods

Access Method	Master Polling	SEL-787 Settings
Polled static	Class 0	Set ECLASSB*n*, ECLASSC*n*, ECLASSA*n* to 0; UNSOL*n* to No
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 No
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 Yes and PUNSOL*n* to Yes or No
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 Yes.

The SEL-787 is an outstation device without dual end point. For a TCP connection, the relay sends out unsolicited messages only if a DNP3 master has already established a session and enabled unsolicited messaging for that session. However, for a serial/modem/UDP connection, the relay automatically dials out and sends unsolicited messages as defined by the settings.

In both the unsolicited report-by-exception and quiescent polling methods shown in *Table D.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-787, 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 resends the information 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.

The SEL-787 allows you to set the conditions for transmitting unsolicited event data on a class-by-class basis. It also allows you to assign points to event classes on a point-by-point basis (see *DNP3 Documentation on page D.14*). You can prioritize data transmission with these event class features. For example, you might place high-priority points in event Class 1 and set it with low thresholds (NUMEVE*n* and AGEEVE*n* settings) so that changes to these points are sent to the master quickly. You may then place low priority data in event Class 2 with higher thresholds.

If the SEL-787 does not receive an Application Confirm in response to unsolicited data, it waits for ETIMEO*n* seconds and then repeats the unsolicited message. To prevent clogging of the network with unsolicited data retries, the SEL-787 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-787 pauses UTIMEO*n* seconds and then transmits the unsolicited data again. *Figure D.1* provides an example with URETRY*n* = 2.

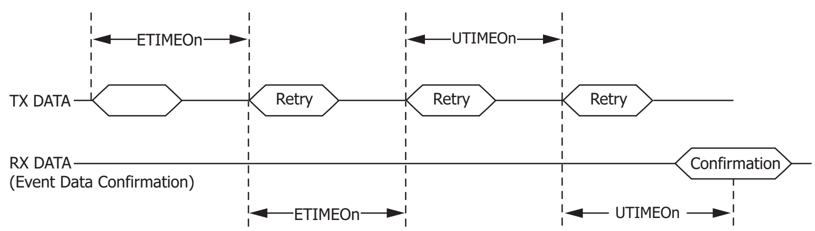

Figure D.1 Application Confirmation Timing With URETRY n = 2

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.

The SEL-787 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-787 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-787 inserts a random delay of 50 to 100 ms between the end of carrier detection and the start of data transmission (see *Figure D.2*).

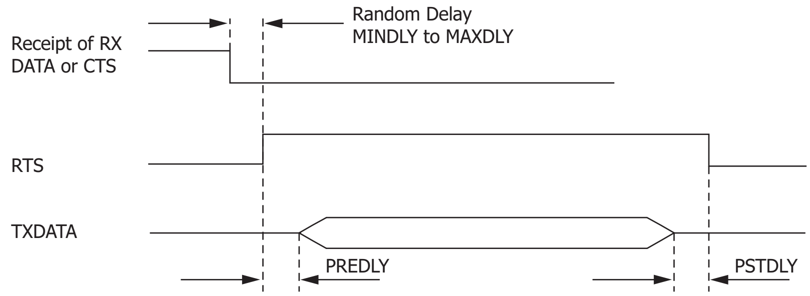

Figure D.2 Message Transmission Timing

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 D.2*). For example, an EIA-485 transceiver typically requires 10 to 20 ms to change from receive to transmit. If you set the pre-delay to 30 ms, you avoid data loss resulting from data transmission beginning at the same time as RTS signal assertion.

Event Data

DNP3 event data objects contain change-of-state and time-stamp information that the SEL-787 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 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 twice per second to generate events. You can configure the SEL-787 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 Session *n*. You can use the classes as a simple priority system for collecting event data. The SEL-787 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-787.

For event data collection you must also consider and enter appropriate settings for deadband and scaling operation on analog points shown in *Table D.7*. You can either:

- set and use default deadband and scaling according to data type, or
- use a custom data map to select deadbands on a point-by-point basis.

See *DNP3 Documentation* for a discussion of how to set scaling and deadband operation on a point-by-point basis. You can modify deadbands for analog inputs at run-time by writing to Object 34.

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, you must use scaling to send digits after the decimal point and avoid rounding to a simple integer value.

With no scaling, the value of 12.632 would be sent as 12. With a scaling setting of 1, the value transmitted is 126. With a scaling setting of 3, the value transmitted is 12632. You must make certain that the maximum value does not exceed 32767 if you are polling the default 16-bit variations for Objects 30 and 32, but you can send some decimal values using this technique. You must also configure the master to perform the appropriate division on the incoming value to display it properly.

You can set the default analog value 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.

The SEL-787 uses the NUMEVE*n* and AGEEVE*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 NUMEVE*n*. The device also sends an unsolicited report if the age of the oldest event in the master n buffer exceeds AGEEVE*n*. The SEL-787 has the buffer capacities listed in *Table D.6*.

Table D.6 SEL-787 Event Buffer Capacity

Type	Maximum Number of Events
Binary	1024
Analog	100
Counters	32

Binary Controls

The SEL-787 provides more than one way to control individual points. The SEL-787 maps incoming control points either to remote bits or to internal command bits that cause circuit breaker operations. *Table D.12* lists control points and control methods available in the SEL-787.

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 shown in *Configurable Data Mapping on page D.26*.

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. 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-787 accepts and ignores time set requests (TIMERQ*n* = I for “ignore”). (This mode allows the SEL-787 to use a high accuracy, IRIG time source, but still interoperate with DNP3 masters that send time-synchronization messages.) You can set the SEL-787 to request time synchronization periodically by setting the TIMERQ*n* setting to the desired period. You can also set it to not request, but accept, time synchronization (TIMERQ*n* = M for “master”).

The SEL-787 prioritizes its time-synchronization sources. These time sources fall under one of two categories. The first category is called primary time sources and the second category is called secondary time sources. IRIG-B (BNC and serial), PTP, and SNTP are primary time sources. All other time sources such as DNP, IEC 60870-5-103, Modbus, and serial port **TIME** and **DATE** commands are secondary time sources.

If an IRIG-B BNC time source is available, the SEL-787 will synchronize its time with that time source regardless of what other time sources are available. If an IRIG-B BNC time source is not available and an IRIG-B serial time source is, the SEL-787 will synchronize its time with that IRIG-B serial time source even if other time sources are available. If an IRIG-B serial time source is not available and PTP is, the SEL-787 will synchronize its time with that PTP time source even if other time sources are available. If IRIG-B (BNC and serial) and PTP are not available, but SNTP is, the SEL-787 will synchronize its time with that SNTP time source even if other time sources are available. Finally, if IRIG-B (BNC and serial), PTP, and SNTP are not available, the SEL-787 will synchronize with the remaining time sources that could be available. They include DNP, IEC 60870-5-103, Modbus, or serial port **TIME** and **DATE** commands. These four time sources take on the same priority. At any given time, the relay will synchronize with the one that most recently established synchronization with the relay. In summary, time-synchronization prioritization starts with IRIG-B BNC and is followed by IRIG-B serial, PTP, SNTP, and DNP, IEC 60870-5-103, Modbus, or serial port **TIME** and **DATE** commands.

Note that when IRIG-B BNC or IRIG-B serial time sources are available, any remaining time source that could be available can be used to update the year only.

Modem Support

The SEL-787 DNP implementation includes modem support for serial ports. Your DNP3 master can dial-in to the SEL-787 and establish a DNP3 connection. The SEL-787 can automatically dial out and deliver unsolicited DNP3 event data.

When the device dials out, it waits for the “CONNECT” message from the local modem and for assertion of the device CTS line before continuing the DNP transaction. This requires a connection from the modem DCD to the device CTS line.

NOTE: Contact SEL for information on serial cable configurations and requirements for connecting your SEL-787 to other devices.

NOTE: To enable hardware handshaking, set the modem settings for the selected port equal to Y if you are using a null modem cable for DNP protocol implementation.

You can either connect the modem to a computer and configure it before connecting it to the SEL-787, or program the appropriate modem setup string in the modem startup string setting MSTR. You should use the PH_NUM1 and (optional) PH_NUM2 settings to set the phone numbers that you want the SEL-787 to call. The SEL-787 automatically sends the ATDT modem dial command and then the contents of the PH_NUM1 setting when dialing the modem. If PH_NUM2 is set, use the RETRY1 setting to configure the number of times the SEL-787 tries to dial PH_NUM1 before dialing PH_NUM2. Similarly, the RETRY2 setting is the number of attempts the SEL-787 tries to dial PH_NUM2 before trying PH_NUM1. MDTIME sets the length of time from initiating the call to declaring it failed because of no connection, and MDRET sets the time between dial-out attempts.

NOTE: RTS/CTS hardware flow control is not available for a DNP3 modem connection. You must use either X-ON/X-OFF software flow control or set the port data speed slower than the effective data rate of the modem.

The settings PH_NUM1 and PH_NUM2 must conform to the AT modem command set dialing string standard, including:

- ➤ A comma (,) inserts a four second pause
- ➤ If necessary, use a 9 to reach an outside line
- ➤ Include a 1 and the area code if the number requires long distance access
- ➤ Add any special codes your telephone service provider designates to block call waiting and other telephone line features.

DNP3 Settings

The DNP3 port configuration settings available on the SEL-787 are shown in *Table D.7*. You can enable DNP3 on Ethernet Port 1 or on any of the serial Ports 2 through 4, to a maximum of five concurrent DNP3 sessions. 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 on Port 1, the Ethernet port. Likewise, settings applicable to serial DNP3 are visible only when configuring a serial port.

Table D.7 Port DNP3 Protocol Settings (Sheet 1 of 3)

Name	Description	Range	Default
EDNP[a]	Enable DNP3 Sessions	0–5	0
DNPNUM[a]	DNP3 TCP and UDP Port	1–65534	20000
DNPADR	Device DNP3 address	0–65519	0
Session 1 Settings			
DNPIP1[a,b]	DNP Master IP address (zzz.yyy.xxx.www)	15 characters	“”
DNPTR1[a]	Transport protocol	UDP, TCP	TCP
DNPUDP1[a]	UDP response port	REQ, 1–65534	20000
REPADR1	DNP3 address of the Master to send messages to	0–65519	1
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	Currents scaling decimal places	0–3	1
DECPLV1	Voltages scaling decimal places	0–3	1
DECPLM1	Misc data scaling decimal places	0–3	1
ANADBA1	Amperes reporting deadband counts; hidden if ECLASSA1 set to 0	0–32767	100
ANADBV1	Volts reporting deadband counts; hidden if ECLASSA1 set to 0	0–32767	100
ANADBM1	Misc data reporting deadband counts; hidden if ECLASSA and ECLASSC set to 0	0–32767	100
TIMERQ1	Time for 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[a,c]	Send Data Link Heartbeat, seconds; hidden if DNPTR1 set to UDP	0.0–7200	120
DRETRY1[d]	Data link retries	0–15	0

Table D.7 Port DNP3 Protocol Settings (Sheet 2 of 3)

Name	Description	Range	Default
DTIMEO1[d]	Data link time-out, seconds; hidden if DRETRY1 set to 0	0.0–5.0	1
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	Enable unsolicited reporting at turn on; hidden and set to N if UNSOL1 set to N	Y, N	N
NUMEVE1[e]	Number of events to transmit on	1–200	10
AGEEVE1[e]	Oldest event to transmit on, seconds	0.0–99999.0	2.0
URETRY1[e]	Unsolicited messages maximum retry attempts	2–10	3
UTIMEO1[e]	Unsolicited messages offline timeout, seconds	1–5000	60
Session 2 Settings			
DNPIP2[a,b]	DNP Master IP address (zzz.yyy.xxx.www)	15 characters	“”
DNPTR2[a]	Transport protocol	UDP, TCP	TCP
• • •			
URETRY2[a, e]	Unsolicited messages maximum retry attempts	2–10	3
UTIMEO2[a, e]	Unsolicited messages offline timeout, seconds	1–5000	60
Session 3 Settings			
DNPIP3[a,b]	DNP Master IP address (zzz.yyy.xxx.www)	15 characters	“”
DNPTR3[a]	Transport protocol	UDP, TCP	TCP
• • •			
URETRY3[a, e]	Unsolicited messages maximum retry attempts	2–10	3
UTIMEO3[a, e]	Unsolicited messages offline timeout, seconds	1–5000	60
Session 4 Settings			
DNPIP4[a,b]	DNP Master IP address (zzz.yyy.xxx.www)	15 characters	“”
DNPTR4[a]	Transport protocol	UDP, TCP	TCP
• • •			
URETRY4[a, e]	Unsolicited messages maximum retry attempts	2–10	3
UTIMEO4[a, e]	Unsolicited messages offline timeout, seconds	1–5000	60
Session 5 Settings			
DNPIP5[a,b]	DNP Master IP address (zzz.yyy.xxx.www)	15 characters	“”
DNPTR5[a]	Transport protocol	UDP, TCP	TCP
• • •			
URETRY5[a, e]	Unsolicited messages maximum retry attempts	2–10	3
UTIMEO5[a, e]	Unsolicited messages offline timeout, seconds	1–5000	60
Serial Port Settings			
MINDLY[d]	Minimum delay from DCD to TX, seconds	0.00–1.00	0.05
MAXDLY[d]	Maximum delay from DCD to TX, seconds	0.00–1.00	0.10

Table D.7 Port DNP3 Protocol Settings (Sheet 3 of 3)

Name	Description	Range	Default
PREDLY[d]	Settle time from RTS on to TX; Off disables PSTDLY	OFF, 0.00–30.00	0.00
PSTDLY[d]	Settle time from TX to RTS off; hidden if PREDLY set to Off	0.00–30.00	0.00

[a] Available only on Ethernet ports. Set DNPIPn = 0.0.0.0 to accept connections from any DNP master.
[b] Set DNPIPn = 0.0.0.0 to accept connections from any DNP master.
[c] DNPINAn (n = 1–5) allows you to set the wait time to detect a bad TCP connection. The relay closes the unused TCP connection after the DNPINAn response timeout. Set this value to be less than 20 seconds. Disabling DNPINAn violates the DNP3 standard and should only be done for testing.
[d] Available only on serial ports.
[e] Hidden if UNSOLn set to N.

The modem settings in *Table D.8* are only available for DNP3 serial port sessions.

Table D.8 Serial Port DNP3 Modem Settings

Name	Description	Range	Default
MODEM	Modem connected to port; all following settings are hidden if MODEM set to N	Y, N	N
MSTR	Modem startup string	As many as 30 characters	“E0X0& D0S0 = 4”
PH_NUM1	Primary phone number for dial-out	As many as 30 characters	“”
PH_NUM2	Secondary phone number for dial-out	As many as 30 characters	“”
RETRY1	Retry attempts for primary dial-out; hidden and unused if PH_NUM2 set to “”	1–20	5
RETRY2	Retry attempts for secondary dial-out; hidden and unused if PH_NUM2 set to “”	1–20	5
MDTIME	Time from initiating call to failure because of no connection, seconds	5–300	60
MDRET	Time between dial-out attempts	5–3600	120

DNP3 Documentation

Object List

Table D.9 lists the objects and variations with supported function codes and qualifier codes available in the SEL-787. The list of supported objects conforms to the format laid out in the DNP specifications and includes both supported and unsupported objects for DNP3 implementation Level 2 and higher and non-supported objects for DNP3 implementation Level 2 only. Those that are supported include the function and qualifier codes. The objects that are not supported are shown without any corresponding function and qualifier codes.

Table D.9 SEL-787 DNP Object List (Sheet 1 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
0	211	Device Attributes—User-specific sets of attributes	1	0	129	0,17
0	212	Device Attributes—Master data set prototypes	1	0	129	0,17
0	213	Device Attributes—Outstation data set prototypes	1	0	129	0,17
0	214	Device Attributes—Master data sets	1	0	129	0,17
0	215	Device Attributes—Outstation data sets	1	0	129	0,17
0	216	Device Attributes—Max binary outputs per request	1	0	129	0,17
0	219	Device Attributes—Support for analog output events	1	0	129	0,17
0	220	Device Attributes—Max analog output index	1	0	129	0,17
0	221	Device Attributes—Number of analog outputs	1	0	129	0,17
0	222	Device Attributes—Support for binary output events	1	0	129	0,17
0	223	Device Attributes—Max binary output index	1	0	129	0,17
0	224	Device Attributes—Number of binary outputs	1	0	129	0,17
0	225	Device Attributes—Support for frozen counter events	1	0	129	0,17
0	226	Device Attributes—Support for frozen counters	1	0	129	0,17
0	227	Device Attributes—Support for counter events	1	0	129	0,17
0	228	Device Attributes—Max counter index	1	0	129	0,17
0	229	Device Attributes—Number of counters	1	0	129	0,17
0	230	Device Attributes—Support for frozen analog inputs	1	0	129	0,17
0	231	Device Attributes—Support for analog input events	1	0	129	0,17
0	232	Device Attributes—Max analog input index	1	0	129	0,17
0	233	Device Attributes—Number of analog inputs	1	0	129	0,17
0	234	Device Attributes—Support for double-bit events	1	0	129	0,17
0	235	Device Attributes—Max double-bit binary index	1	0	129	0,17
0	236	Device Attributes—Number of double-bit binaries	1	0	129	0,17
0	237	Device Attributes—Support for binary input events	1	0	129	0,17
0	238	Device Attributes—Max binary input index	1	0	129	0,17
0	239	Device Attributes—Number of binary inputs	1	0	129	0,17
0	240	Device Attributes—Max transmit fragment size	1	0	129	0,17

Table D.9 SEL-787 DNP Object List (Sheet 2 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
0	241	Device Attributes—Max receive fragment size	1	0	129	0,17
0	242	Device Attributes—Device manufacturer's software version	1	0	129	0,17
0	243	Device Attributes—Device manufacturer's hardware version	1	0	129	0,17
0	245	Device Attributes—User-assigned location name	1	0	129	0,17
0	246	Device Attributes—User assigned ID code/number	1	0	129	0,17
0	247	Device Attributes—User assigned ID code/number	1	0	129	0,17
0	248	Device Attributes—Device serial number	1	0	129	0,17
0	249	Device Attributes—DNP subset and conformance	1	0	129	0,17
0	250	Device Attributes—Device manufacturer's product name and model	1	0	129	0,17
0	252	Device Attributes—Device manufacturer's name	1	0	129	0,17
0	254	Device Attributes—Non-specific all attributes request	1	0	129	0,17
0	255	Device Attributes—List of attribute variations	1	0	129	0,17
1	0	Binary Input—All Variations	1	0, 1, 6, 7, 8, 17, 28		
1	1	Binary Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
1	2[e]	Binary Input With Status	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
2	0	Binary Input Change—All Variations	1	6, 7, 8		
2	1	Binary Input Change Without Time	1	6, 7, 8	129	17, 28
2	2[e]	Binary Input Change With Time	1	6, 7, 8	129, 130	17, 28
2	3	Binary Input Change With Relative Time	1	6, 7, 8	129	17, 28
10	0	Binary Output—All Variations	1	0, 1, 6, 7, 8		
10	1	Binary Output				
10	2[e]	Binary Output Status	1	0, 1, 6, 7, 8	129	0, 1
12	0	Control Block—All Variations				
12	1	Control Relay Output Block	3, 4, 5, 6	17, 28	129	echo of request
12	2	Pattern Control Block	3, 4, 5, 6	7	129	echo of request
12	3	Pattern Mask	3, 4, 5, 6	0, 1	129	echo of request
20	0	Binary Counter—All Variations	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28		
20	1	32-Bit Binary Counter	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	2	16-Bit Binary Counter	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	3	32-Bit Delta Counter				
20	4	16-Bit Delta Counter				
20	5	32-Bit Binary Counter Without Flag	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	6[e]	16-Bit Binary Counter Without Flag	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	7	32-Bit Delta Counter Without Flag				
20	8	16-Bit Delta Counter Without Flag				

Table D.9 SEL-787 DNP Object List (Sheet 3 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
21	0	Frozen Counter—All Variations				
21	1	32-Bit Frozen Counter				
21	2	16-Bit Frozen Counter				
21	3	32-Bit Frozen Delta Counter				
21	4	16-Bit Frozen Delta Counter				
21	5	32-Bit Frozen Counter With Time of Freeze				
21	6	16-Bit Frozen Counter With Time of Freeze				
21	7	32-Bit Frozen Delta Counter With Time of Freeze				
21	8	16-Bit Frozen Delta Counter With Time of Freeze				
21	9	32-Bit Frozen Counter Without Flag				
21	10	16-Bit Frozen Counter Without Flag				
21	11	32-Bit Frozen Delta Counter Without Flag				
21	12	16-Bit Frozen Delta Counter Without Flag				
22	0	Counter Change Event—All Variations	1	6, 7, 8		
22	1	32-Bit Counter Change Event Without Time	1	6, 7, 8	129	17, 28
22	2[e]	16-Bit Counter Change Event Without Time	1	6, 7, 8	129, 130	17, 28
22	3	32-Bit Delta Counter Change Event Without Time				
22	4	16-Bit Delta Counter Change Event Without Time				
22	5	32-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
22	6	16-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
22	7	32-Bit Delta Counter Change Event With Time				
22	8	16-Bit Delta Counter Change Event With Time				
23	0	Frozen Counter Event—All Variations				
23	1	32-Bit Frozen Counter Event Without Time				
23	2	16-Bit Frozen Counter Event Without Time				
23	3	32-Bit Frozen Delta Counter Event Without Time				
23	4	16-Bit Frozen Delta Counter Event Without Time				
23	5	32-Bit Frozen Counter Event With Time				
23	6	16-Bit Frozen Counter Event With Time				
23	7	32-Bit Delta Counter Change Event With Time				
23	8	16-Bit Delta Counter Change Event With Time				
30[f]	0	Analog Input—All Variations	1	0, 1, 6, 7, 8, 17, 28		
30[f]	1	32-Bit Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30[f]	2	16-Bit Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30[f]	3	32-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30[f]	4	16-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30[f]	5	Short Floating Point Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28

Table D.9 SEL-787 DNP Object List (Sheet 4 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
30	6	Long Floating Point Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
31	0	Frozen Analog Input—All Variations				
31	1	32-Bit Frozen Analog Input				
31	2	16-Bit Frozen Analog Input				
31	3	32-Bit Frozen Analog Input With Time of Freeze				
31	4	16-Bit Frozen Analog Input With Time of Freeze				
31	5	32-Bit Frozen Analog Input Without Flag				
31	6	16-Bit Frozen Analog Input Without Flag				
31	7	Short Floating Point Frozen Analog Input				
31	8	Long Floating Point Frozen Analog Input				
32	0	Analog Change Event—All Variations	1	6, 7, 8		
32[f]	1	32-Bit Analog Change Event Without Time	1	6, 7, 8	129	17, 28
32[f]	2	16-Bit Analog Change Event Without Time	1	6, 7, 8	129, 130	17, 28
32[f]	3	32-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
32[f]	4	16-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
32[f]	5	Short Floating Point Analog Change Event	1	6, 7, 8	129	17, 28
32[f]	6	Long Floating Point Analog Change Event	1	6, 7, 8	129	17, 28
32[f]	7	Short Floating Point Analog Change Event With Time	1	6, 7, 8	129	17, 28
32[f]	8	Long Floating Point Analog Change Event With Time	1	6, 7, 8	129	17, 28
33	0	Frozen Analog Event—All Variations				
33	1	32-Bit Frozen Analog Event Without Time				
33	2	16-Bit Frozen Analog Event Without Time				
33	3	32-Bit Frozen Analog Event With Time				
33	4	16-Bit Frozen Analog Event With Time				
33	5	Short Floating Point Frozen Analog Event				
33	6	Long Floating Point Frozen Analog Event				
33	7	Short Floating Point Frozen Analog Event With Time				
33	8	Long Floating Point Frozen Analog Event With Time				
34	0	Analog Deadband—All Variations				
34	1[e]	16-Bit Analog Input Reporting Deadband Object	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	2	32-Bit Analog Input Reporting Deadband Object	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	3	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—All Variations	1	0, 1, 6, 7, 8	129	
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

Table D.9 SEL-787 DNP Object List (Sheet 5 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
41	0	Analog Output Block—All Variations				
41	1	32-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
41	2[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
50	0	Time and Date—All Variations				
50	1	Time and Date	1, 2	7, 8 index = 0	129	07, quantity = 1
50	2	Time and Date With Interval				
50	3	Time and Date Last Recorded	2	7 quantity = 1	129	
51	0	Time and Date CTO—All Variations				
51	1	Time and Date CTO				
51	2	Unsynchronized Time and Date CTO			129	07, quantity = 1
52	0	Time Delay—All Variations				
52	1	Time Delay, Coarse				
52	2	Time Delay, Fine			129	7, quantity = 1
60	0	All Classes of Data	1, 20, 21	6, 7, 8		
60	1	Class 0 Data	1, 20, 21	6, 7, 8		
60	2	Class 1 Data	1	6, 7, 8		
60	3	Class 2 Data	1, 20, 21	6, 7, 8		
60	4	Class 3 Data	1, 20, 21	6, 7, 8		
70	1	File Identifier				
70	2	Authentication Object				
70	3	File Command Object				
70	4	File Command Status Object				
70	5	File Transport Object				
70	6	File Transport Status Object				
70	7	File Descriptor Object				
80	1	Internal Indications	2	0, 1 index = 7		
81	1	Storage Object				
82	1	Device Profile				
83	1	Private Registration Object				
83	2	Private Registration Object Descriptor				
90	1	Application Identifier				
100	1	Short Floating Point				
100	2	Long Floating Point				
100	3	Extended Floating Point				
101	1	Small Packed Binary-Coded Decimal				
101	2	Medium Packed Binary-Coded Decimal				

Table D.9 SEL-787 DNP Object List (Sheet 6 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
101	3	Large Packed Binary-Coded Decimal				
110	all	Octet String				
111	all	Octet String Event				
112	All	Virtual Terminal Output Block				
113	All	Virtual Terminal Event Data				
N/A		No object required for the following function codes: 13 cold start 14 warm start 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] Default variation specified by serial port setting DVARAI (or DVARAIn for Ethernet session n [n = 1, 2, 3, 4, or 5]).

Device Profile

NOTE: The DNP3 Device Profile document is for all models of the SEL-787.

The DNP3 Device Profile document (dnp_r*xxx*787-4.zip), available on the supplied CD or as a download from the SEL website, contains the standard device profile information for the SEL-787. This information is also available in XML format. Please refer to this document for complete information on DNP3 Protocol support in the SEL-787.

Reference Data Map

NOTE: Deadband changes via Object 32 are not stored in nonvolatile memory. Be sure to reissue the Object 34 deadband changes you want to retain after changing DNP port settings, issuing an **STA C** command, or cold-starting the relay (power cycle).

NOTE: Although the reference maps do not include Relay Word bit labels, you can use these labels in creating custom maps.

Table D.10 shows the SEL-787 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-787 to retrieve only the points required by your application.

The SEL-787 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 D.10 DNP3 Reference Data Map (Sheet 1 of 3)

Object	Labels	Description
Binary Inputs		
01, 02	STFAIL	Relay diagnostic failure (HALARM is latched)
	STWARN	Relay diagnostic warning (HALARM is pulsed)
	STSET	Relay settings change or restart
	Enabled–TLED_06[a]	Relay Word Elements Target Row 0 (see *Table L.1*)
	50P11T–SC850BM[a]	Relay Word elements (see *Table L.1*)
	PFL	Power factor leading for three-phase currents
	PFAL	Power factor leading for Phase A current
	PFBL	Power factor leading for Phase B current
	PFCL	Power factor leading for Phase C current
	0	Logical 0
	1	Logical 1

Table D.10 DNP3 Reference Data Map (Sheet 2 of 3)

Object	Labels	Description
Binary Outputs		
10, 12	RB01–RB32	Remote bits RB01–RB32
	RB01:RB02 RB03:RB04 RB05:RB06 … RB29:RB30 RB31:RB32	Remote bit pairs RB01–RB32
10, 12	OC1	Pulse Open Circuit Breaker 1 command
10, 12	CC1	Pulse Close Circuit Breaker 1 command
10, 12	OC1:CC1	Open/Close pair for Circuit Breaker 1
10, 12	OC2	Pulse Open Circuit Breaker 2 command
10, 12	CC2	Pulse Close Circuit Breaker 2 command
10, 12	OC2:CC2	Open/Close pair for Circuit Breaker 2
10, 12	OC3	Pulse Open Circuit Breaker 3 command
10, 12	CC3	Pulse Close Circuit Breaker 3 command
10, 12	OC3:CC3	Open/Close pair for Circuit Breaker 3
10, 12	OC4	Pulse Open Circuit Breaker 4 command
10, 12	CC4	Pulse Close Circuit Breaker 4 command
10, 12	OC4:CC4	Open/Close pair for Circuit Breaker 4
10, 12	89OC2P1–89OC2P16	Pulse Open Two-Position Disconnects 1–16 command
10, 12	89CC2P1–89CC2P16	Pulse Close Two-Position Disconnects 1–16 command
10,12	89OC2P1:89CC2P1 89OC2P2:89CC2P2 … 89OC2P16:89CC2P16	Open/Close pair for Two-Position Disconnects 1–16
10, 12	89OC3PL1	Pulse Open Three-Position In-Line Disconnect 1 command
10, 12	89CC3PL1	Pulse Close Three-Position In-Line Disconnect 1 command
10, 12	89OC3PL1:89CC3PL1	Open/Close pair for Three-Position In-Line Disconnect 1
10, 12	89OC3PL2	Pulse Open Three-Position In-Line Disconnect 2 command
10, 12	89CC3PL2	Pulse Close Three-Position In-Line Disconnect 2 command
10,12	89OC3PL2:89CC3PL2	Open/Close pair for Three-Position In-Line Disconnect 2
10, 12	89OC3PE1	Pulse Open Three-Position Earthing Disconnect 1 command
10, 12	89CC3PE1	Pulse Close Three-Position Earthing Disconnect 1 command
10,12	89OC3PE1:89CC3PE1	Open/Close pair for Three-Position Earthing Disconnect 1

Table D.10 DNP3 Reference Data Map (Sheet 3 of 3)

Object	Labels	Description
10, 12	89OC3PE2	Pulse Open Three-Position Earthing Disconnect 2 command
10, 12	89CC3PE2	Pulse Close Three-Position Earthing Disconnect 2 command
10,12	89OC3PE2:89CC3PE2	Open/Close pair for Three-Position Earthing Disconnect 2
Counters		
20, 22	SC*xx*	SELOGIC counter values (*xx* = 01–32)
	GROUP	Active settings group
Analog Inputs		
30, 32, 34	IAW1_MAG–FVG[b, c]	Analog quantities from *Appendix M* with an “x” in the DNP column
	SER_NUM	Serial number
	0	Numeric 0
	1	Numeric 1
Analog Outputs		
40, 41	RA*xxx*	Remote analogs (RA001 to RA128)
	GROUP	Active settings group
	NOOP	No operation, no error

[a] Valid Relay Word bits depend on the relay model.
[b] Valid analog inputs depend on the relay model.
[c] Refer to Default Analog Inputs for default analog input scaling and deadbands.

NOTE: When setting EN_LRC := Y (see Table 9.6), the Relay Word bit LOCAL supervises the CCn and OCn bits (n = 1–4), 89CC2Pm and 89OC2Pm (m = 1–16), and 89CC3Pnm and 89OC3Pnm (m = 1–2, n = L or E). To set the binaries, the relay should be in remote control mode (i.e., LOCAL = 0). The Relay Word bit LOCAL is determined by the LOCAL SELOGIC control equation (see SELOGIC Table 9.6).

NOTE: All fault information analog inputs contain data from the latest captured event (See Appendix M: Analog Quantities).

Default Data Map

The default data map is an automatically generated subset of the reference map. All data maps are initialized to the default values, based on the SEL-787 part number. *Table D.11* shows the SEL-787 default data map. If the default maps are not appropriate, you can also use the custom DNP mapping commands **SET DNP** and **SHOW DNP** to create the map required for your application.

Table D.11 DNP3 Default Data Map (Sheet 1 of 2)

Object	Default Index	Point Label
01, 02	0	ENABLED
	1	TRIPXFMR
	2	TRIP1
	3	TRIP2
	4	STFAIL
	5	STSET
	6	IN101
	7	IN102
	8–99	A portion of these binary inputs can have default values as described in *Default Binary Inputs on page D.22*. Outside that scope, they contain the value NA.
10, 12	0–31	RB01–RB32 Remote Bits
20, 22	0–31	NA
30, 32, 34	0	IAW1_MAG
	1	IBW1_MAG

Table D.11 DNP3 Default Data Map (Sheet 2 of 2)

Object	Default Index	Point Label
	2	ICW1_MAG
	3	IGW1_MAG
	4	IAW2_MAG
	5	IBW2_MAG
	6	ICW2_MAG
	7	IGW2_MAG
	8	I1W1_MAG
	9	I1W2_MAG
	10	3I2W1MAG
	11	3I2W2MAG
	12–99	A portion of these analog inputs can have default values as described in *Default Analog Inputs on page D.22*. Outside that scope, they contain the value NA.
40, 41	0–31	NA

Default Binary Inputs

The SEL-787 dynamically creates the default binary input map after you issue an **R_S** command. The SEL-787 uses the part number to determine the presence of digital input cards in Slots 3, 4, and 5. If present, each digital input point label, IN*x*0*y* (where *x* is the slot number and *y* is the point), is added to the default map in numerical order.

Default Analog Inputs

NOTE: Deadband changes via Object 32 are not stored in nonvolatile memory. Be sure to reissue the Object 34 deadband changes you want to retain after changing DNP port settings, issuing an **STA C** command, or cold-starting the relay (power cycle).

The SEL-787 dynamically creates the default analog input map after you issue an **R_S** command. The SEL-787 first checks for a voltage option in the part number, and if voltages are present, adds VAB_MAG, VBC_MAG, VCA_MAG, V1_MAG, 3V2_MAG, P, Q, S, PF, and FREQ to the default DNP map. The SEL-787 then uses the part number to determine the presence of analog input cards in Slots 3, 4, and 5. If present, each analog input point label, AI*x*0*y* (where *x* is the slot and *y* is the point number), is added to the default map in numerical order.

Device Attributes (Object 0)

Table D.9 includes the supported Object 0 device attributes and variations. In response to Object 0 requests, the SEL-787 sends attributes that apply to that particular DNP3 session. Because the SEL-787 supports custom DNP3 maps, these values are likely to be different for each session. The SEL-787 uses its internal settings for the following variations:

- Variation 242—FID string
- Variation 243—Part number
- Variation 245—TID setting
- Variation 246—RID setting
- Variation 247—RID setting
- Variation 248—Serial number

Variation 249 shall contain the DNP subset and conformance, “2:2009”. Variation 250 shall contain the product model, “SEL-787” and Variation 252 shall contain “SEL”.

Binary Inputs

Binary inputs (Objects 1 and 2) are supported as defined by *Table D.11*. 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 twice 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 communications protocols such as DNP and EtherNet/IP. For example, STWARN and STFAIL are derived from the diagnostic task data. Another binary input, STSET, is derived from the SER and carries the time stamp of actual occurrence. Static reads of this input always show 0.

Binary Outputs

Binary output status (Object 10, Variation 2) is supported. Static reads of points RB01–RB32, OC*n*/CC*n* (where *n* = 1, 2, 3, or 4), 89OC2P*m*/89CC2P*m* (where *m* = 1 to 16), or 89OC3P*nm*/89CC3P*nm* (where *n* = L or E and *m* = 1 or 2) respond with the online bit set and the state of the requested bit. Reads from control-only binary output points respond with the online bit set and a state of 0.

The SEL-787 supports Control Relay Output Block objects (Object 12, Variation 1). The control relays correspond to the remote bits and other functions as shown previously. Each DNP control message contains a Trip/Close code (TRIP, CLOSE, or NUL) and an Operation type (PULSE ON, LATCH ON, LATCH OFF, or NUL). The Trip/Close code works with the Operation Type to produce set, clear, and pulse operations.

Control operations differ slightly for single-point controls compared to paired outputs. Paired outputs correspond to the complementary two-output model, and single-point controls follow the complementary latch or activation model. In the complementary two-output model, paired points only support Trip or Close operations, when issued, Pulse On the first or second point in the pair, respectively. An operation in progress may be cancelled by issuing a NUL Trip/Close Code with a NUL Operation Type. Single output points support both Pulse and Latch operations. See *Configurable Data Mapping* for details on control operations.

The Status field is used exactly as defined. All other fields are ignored. A pulse operation is asserted for a single processing interval. You should exercise caution if sending multiple remote bit pulses in a single message (i.e., point count > 1), because this can result in some of the pulse commands being ignored and the return of an already active status message. The SEL-787 honors only the first 10 points in an Object 12, Variation 1 request. Any additional points in the request return the DNP3 status code TOO_MANY_OBJS.

The SEL-787 also supports Pattern Control Blocks (Object 12, Variations 2 and 3) to control multiple binary output points. Variation 2 defines the control type (Trip/Close, Set/Clear, or Pulse) and the range of points to operate. Variation 3 provides a pattern mask that indicates which points in that range should be operated. Object 12, Variations 2 and 3 define the entire control command: the DNP3 master must send both for a successful control. For example, the DNP3 master sends an Object 12, Variation 2 message to request a Trip of the range of indices 0–7. The DNP3 master then sends an Object 12, Variation 3 message with a hexadecimal value of “BB” as the pattern mask (converted to binary notation: 10111011). Read right to left in increasing bit order, the Pattern Block Control command results in a TRIP of indexes 0, 1, 3 to 5, and 7. Multiple binary output point control operations are not guaranteed to occur during the same processing interval.

Control Point Operation

Use the Trip and Close, Latch On/Off and Pulse On operations with Object 12 control relay output block command messages to operate the points shown in *Table D.12*. Pulse operations provide a pulse with duration of one protection processing interval.

When setting EN_LRC := Y (see *Table 9.6*), the Relay Word bit LOCAL supervises the CC*n* and OC*n* bits (*n* = 1–4), 89CC2P*m* and 89OC2P*m* (*m* = 1–16), and 89CC3P*nm* and 89OC3P*nm* (*m* = 1–2, *n* = L or E). If the LOCAL bit is asserted (LOCAL = 1), the relay does not set the bits. The Relay Word bit LOCAL is determined by the LOCAL SELOGIC control equation (see *Table 9.6*).

Table D.12 SEL-787 Object 12 Control Operations (Sheet 1 of 2)

Label	Close/Pulse On	Trip/Pulse On	Nul/Latch On	Nul/Latch Off	Nul/Pulse On
RB01–RB32	Pulse Remote Bit RB01–RB32	Pulse Remote Bit RB01–RB32	Set Remote Bit RB01–RB32	Clear Remote Bit RB01–RB32	Pulse Remote Bit RB01–RB32
RB*xx*:RB*yy*	Pulse RB*yy* RB01–RB32	Pulse RB*xx* RB01–RB32	Pulse RB*yy* RB01–RB32	Pulse RB*xx* RB01–RB32	Pulse RB*yy* RB01–RB32
OC1	Open Circuit Breaker (Pulse OC1)	Open Circuit Breaker (Pulse OC1)	Open Circuit Breaker (Pulse OC1)	No action	Open Circuit Breaker (Pulse OC1)
CC1	Close Circuit Breaker (Pulse CC1)	Close Circuit Breaker (Pulse CC1)	Close Circuit Breaker (Pulse CC1)	No action	Close Circuit Breaker (Pulse CC1)
OC1:CC1	Close Circuit Breaker (Pulse CC1)	Open Circuit Breaker (Pulse OC1)	Close Circuit Breaker (Pulse CC1)	Open Circuit Breaker (Pulse OC1)	Close Circuit Breaker (Pulse CC1)
OC2	Open Circuit Breaker (Pulse OC2)	Open Circuit Breaker (Pulse OC2)	Open Circuit Breaker (Pulse OC2)	No action	Open Circuit Breaker (Pulse OC2)
CC2	Close Circuit Breaker (Pulse CC2)	Close Circuit Breaker (Pulse CC2)	Close Circuit Breaker (Pulse CC2)	No action	Close Circuit Breaker (Pulse CC2)
OC2:CC2	Close Circuit Breaker (Pulse CC2)	Open Circuit Breaker (Pulse OC2)	Close Circuit Breaker (Pulse CC2)	Open Circuit Breaker (Pulse OC2)	Close Circuit Breaker (Pulse CC2)
OC3	Open Circuit Breaker (Pulse OC3)	Open Circuit Breaker (Pulse OC3)	Open Circuit Breaker (Pulse OC3)	No action	Open Circuit Breaker (Pulse OC3)
CC3	Close Circuit Breaker (Pulse CC3)	Close Circuit Breaker (Pulse CC3)	Close Circuit Breaker (Pulse CC3)	No action	Close Circuit Breaker (Pulse CC3)
OC3:CC3	Close Circuit Breaker (Pulse CC3)	Open Circuit Breaker (Pulse OC3)	Close Circuit Breaker (Pulse CC3)	Open Circuit Breaker (Pulse OC3)	Close Circuit Breaker (Pulse CC3)
OC4	Open Circuit Breaker (Pulse OC4)	Open Circuit Breaker (Pulse OC4)	Open Circuit Breaker (Pulse OC4)	No action	Open Circuit Breaker (Pulse OC4)
CC4	Close Circuit Breaker (Pulse CC4)	Close Circuit Breaker (Pulse CC4)	Close Circuit Breaker (Pulse CC4)	No action	Close Circuit Breaker (Pulse CC4)
OC4:CC4	Close Circuit Breaker (Pulse CC4)	Open Circuit Breaker (Pulse OC4)	Close Circuit Breaker (Pulse CC4)	Open Circuit Breaker (Pulse OC4)	Close Circuit Breaker (Pulse CC4)
89OC2P1–89OC2P16	Open 2-Position Disconnect (Pulse 89OC2P1–89OC2P16)	Open 2-Position Disconnect (Pulse 89OC2P1–89OC2P16)	Open 2-Position Disconnect (Pulse 89OC2P1–89OC2P16)	No Action	Open 2-Position Disconnect (Pulse 89OC2P1–89OC2P16)

Table D.12 SEL-787 Object 12 Control Operations (Sheet 2 of 2)

Label	Close/Pulse On	Trip/Pulse On	Nul/Latch On	Nul/Latch Off	Nul/Pulse On
89CC2P1–89CC2P16	Close 2-Position Disconnect (Pulse 89CC2P1–89CC2P16)	Close 2-Position Disconnect (Pulse 89CC2P1–89CC2P16)	Close 2-Position Disconnect (Pulse 89CC2P1–89CC2P16)	No Action	Close 2-Position Disconnect (Pulse 89CC2P1–89CC2P16)
89OC2P*m*: 89CC2P*m*	Close 2-Position Disconnect (Pulse 89CC2P1–89CC2P16)	Open 2-Position Disconnect (Pulse 89OC2P1–89OC2P16)	Close 2-Position Disconnect (Pulse 89CC2P1–89CC2P16)	Open 2-Position Disconnect (Pulse 89OC2P1–89OC2P16)	Close 2-Position Disconnect (Pulse 89CC2P1–89CC2P16)
89OC3PL1	Open 3-Position In-Line Disconnect (Pulse 89OC3PL1)	Open 3-Position In-Line Disconnect (Pulse 89OC3PL1)	Open 3-Position In-Line Disconnect (Pulse 89OC3PL1)	No Action	Open 3-Position In-Line Disconnect (Pulse 89OC3PL1)
89CC3PL1	Close 3-Position In-Line Disconnect (Pulse 89CC3PL1)	Close 3-Position In-Line Disconnect (Pulse 89CC3PL1)	Close 3-Position In-Line Disconnect (Pulse 89CC3PL1)	No Action	Close 3-Position In-Line Disconnect (Pulse 89CC3PL1)
89OC3PL1: 89CC3PL1	Close 3-Position In-Line Disconnect (Pulse 89CC3PL1)	Open 3-Position In-Line Disconnect (Pulse 89OC3PL1)	Close 3-Position In-Line Disconnect (Pulse 89CC3PL1)	Open 3-Position In-Line Disconnect (Pulse 89OC3PL1)	Close 3-Position In-Line Disconnect (Pulse 89CC3PL1)
89OC3PL2	Open 3-Position In-Line Disconnect (Pulse 89OC3PL2)	Open 3-Position In-Line Disconnect (Pulse 89OC3PL2)	Open 3-Position In-Line Disconnect (Pulse 89OC3PL2)	No Action	Open 3-Position In-Line Disconnect (Pulse 89OC3PL2)
89CC3PL2	Close 3-Position In-Line Disconnect (Pulse 89CC3PL2)	Close 3-Position In-Line Disconnect (Pulse 89CC3PL2)	Close 3-Position In-Line Disconnect (Pulse 89CC3PL2)	No Action	Close 3-Position In-Line Disconnect (Pulse 89CC3PL2)
89OC3PL2: 89CC3PL2	Close 3-Position In-Line Disconnect (Pulse 89CC3PL2)	Open 3-Position In-Line Disconnect (Pulse 89OC3PL2)	Close 3-Position In-Line Disconnect (Pulse 89CC3PL2)	Open 3-Position In-Line Disconnect (Pulse 89OC3PL2)	Close 3-Position In-Line Disconnect (Pulse 89CC3PL2)
89OC3PE1	Open 3-Position Earthing Disconnect (Pulse 89OC3PE1)	Open 3-Position Earthing Disconnect (Pulse 89OC3PE1)	Open 3-Position Earthing Disconnect (Pulse 89OC3PE1)	No Action	Open 3-Position Earthing Disconnect (Pulse 89OC3PE1)
89CC3PE1	Close 3-Position Earthing Disconnect (Pulse 89CC3PE1)	Close 3-Position Earthing Disconnect (Pulse 89CC3PE1)	Close 3-Position Earthing Disconnect (Pulse 89CC3PE1)	No Action	Close 3-Position Earthing Disconnect (Pulse 89CC3PE1)
89OC3PE1: 89CC3PE1	Close 3-Position Earthing Disconnect (Pulse 89CC3PE1)	Open 3-Position Earthing Disconnect (Pulse 89OC3PE1)	Close 3-Position Earthing Disconnect (Pulse 89CC3PE1)	Open 3-Position Earthing Disconnect (Pulse 89OC3PE1)	Close 3-Position Earthing Disconnect (Pulse 89CC3PE1)
89OC3PE2	Open 3-Position Earthing Disconnect (Pulse 89OC3PE2)	Open 3-Position Earthing Disconnect (Pulse 89OC3PE2)	Open 3-Position Earthing Disconnect (Pulse 89OC3PE2)	No Action	Open 3-Position Earthing Disconnect (Pulse 89OC3PE2)
89CC3PE2	Close 3-Position Earthing Disconnect (Pulse 89CC3PE2)	Close 3-Position Earthing Disconnect (Pulse 89CC3PE2)	Close 3-Position Earthing Disconnect (Pulse 89CC3PE2)	No Action	Close 3-Position Earthing Disconnect (Pulse 89CC3PE2)
89OC3PE2: 89CC3PE2	Close 3-Position Earthing Disconnect (Pulse 89CC3PE2)	Open 3-Position Earthing Disconnect (Pulse 89OC3PE2)	Close 3-Position Earthing Disconnect (Pulse 89CC3PE2)	Open 3-Position Earthing Disconnect (Pulse 89OC3PE2)	Close 3-Position Earthing Disconnect (Pulse 89CC3PE2)

Analog Inputs

NOTE: Deadband changes via Object 34 are not stored in nonvolatile memory. Be sure to reissue the Object 34 deadband changes you want to retain after changing DNP port settings, issuing an **STA C** command, or cold-starting the relay (power-cycle).

Analog Inputs (30) and Analog Change Events (32) are supported as defined in *Table D.9* and *Table D.10*. The DVARAI1 (DVARAI*n* for DNP3 LAN/WAN Session *n*) setting defines the default variation for both static and event inputs. Only the Read function code (1) is allowed with these objects. Unless otherwise indicated, analog values are reported in primary units. See *Appendix M: Analog Quantities* for a list of all available analog inputs.

For all currents, the default scaling is the DECPLA setting on magnitudes and scale factor of 100 on angles. The default deadband for currents is ANADBV on magnitudes and ANADBM on angles. For all voltages, the default scaling is the DECPLV setting on magnitudes and scale factor of 100 on angles. The default deadband for voltages is ANADBV on magnitudes and ANADBM on angles. For all powers and energies, the default scaling is the DECPLM setting and default deadband is ANADBM. For all other quantities, the default scaling is 1 and default deadband is ANADBM.

Default scaling and deadbands can be overridden by per-point scaling and deadband. See *Configurable Data Mapping* for more information. Deadbands for analog inputs can also be modified by writing to Object 34.

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. The voltage and current phase angles only generate an event if, in addition to their deadband check, the corresponding magnitude changes beyond its own deadband. Analog inputs are scanned approximately twice per second. All events generated during a scan use the time the scan was initiated.

Configurable Data Mapping

One of the most powerful features of the SEL-787 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-787 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 may use any of the three available DNP3 maps simultaneously with as many as five unique DNP3 masters. Each map is initially populated with default data points, as described in *Default Data Map on page D.21*. You may remap the points in a default map to create a custom map with as many as:

- ➤ 100 Binary Inputs
- ➤ 32 Binary Outputs
- ➤ 100 Analog Inputs
- ➤ 32 Analog Outputs
- ➤ 32 Counters

You can use the **SHOW DNP *x* <Enter>** command to view the DNP3 data map settings, where *x* is the DNP3 map number from 1 to 3. See *Figure D.3* for an example display of Map 1.

```
=>>SHO DNP 1 <Enter>

DNP Map 1 Settings

Binary Input Map
BI_00    := ENABLED
BI_01    := T01_LED
BI_02    := T02_LED
BI_03    := T03_LED
…
BI_97    := IN101
BI_98    := IN102
BI_99    := 52A

Binary Output Map
BO_00    := RB01
BO_01    := RB02
BO_02    := RB03
…
BO_29    := RB30
BO_30    := RB31
BO_31    := RB32


Analog Input Map
AI_00    := IAW1_MAG
AI_01    := IBW1_MAG
AI_02    := ICW1_MAG
…
AI_95    := FREQ
AI_96    := P
AI_97    := Q
AI_98    := S
AI_99    := PF

Analog Output Map
AO_00    := GROUP
AO_01    := RA001
AO_02    := RA002
…
AO_29    := RA029
AO_30    := RA030
AO_31    := RA031

Counter Map
CO_00    := SC01
CO_01    := SC02
CO_02    := SC03
…
CO_29    := SC30
CO_30    := SC31
CO_31    := SC32

=>>
```

Figure D.3 Sample Response to SHO DNP Command

You can also use the **MAP DNP *y s* <Enter>** command to display DNP3 maps, but the parameter ***y*** is the port number from 1 to 4. Because Port 1, the Ethernet port, can support multiple DNP3 sessions, it may have a different map assigned to each session selected by parameter *s* for Sessions 1 to 5. See *Figure D.4* for an example of a **MAP** command.

```
=>MAP DNP 1 1 <Enter>

SEL-787-3S                                    Date: 05/02/2013   Time: 14:43:54.161
TRNSFRMR RELAY                                Time Source: External

Map                            1
Transport                      TCP
Device IP Address              10.10.52.243
Master IP Address              192.168.1.3
Device DNP TCP and UDP Port    20000
Device DNP Address             0
Master DNP Address             1
```

Figure D.4 Port MAP Command

```
Binary Inputs
-------------------------------------------------------------------------------
  INDEX  POINT LABEL  EVENT CLASS  SER TIMESTAMP
  0      ENABLED      1
  1      TRIP_LED     1
  2      TLED_01      1
  3      TLED_02      1
  4      TLED_03      1
  5      TLED_04      1
  6      TLED_05      1
  7      TLED_06      1
  8      STFAIL       1
  9      STSET        1
  10     IN101        1
  11     IN102        1
  12     IN501        1
  13     IN502        1
  14     IN503        1
  15     IN504        1

Binary Outputs
-------------------------------------------------------------------------------
  INDEX  POINT LABEL
  0      RB01
  1      RB02
  2      RB03
  3      RB04
  4      RB05
  5      RB06
  6      RB07
  7      RB08
  8      RB09
  9      RB10
  10     RB11
  11     RB12
  12     RB13
  13     RB14
  14     RB15
  15     RB16
  16     RB17
  17     RB18
  18     RB19
  19     RB20
  20     RB21
  21     RB22
  22     RB23
  23     RB24
  24     RB25
  25     RB26
  26     RB27
  27     RB28
  28     RB29
  29     RB30
  30     RB31
  31     RB32
```

Figure D.4 Port MAP Command (Continued)

```
Counters
-------------------------------------------------------------------------------
Analog Inputs
-------------------------------------------------------------------------------
  INDEX  POINT LABEL   EVENT  CLASS  SCALE FACTOR  DEADBAND
  0      IAW1_MAG       2                10.0000  100
  1      IBW1_MAG       2                10.0000  100
  2      ICW1_MAG       2                10.0000  100
  3      IGW1_MAG       2                10.0000  100
  4      IN_MAG         2                10.0000  100
  5      I1W1_MAG       2                10.0000  100
  6      3I2W1MAG       2                10.0000  100
  7      FREQ           2                 1.0000  100
  8      VAB_MAG        2                10.0000  100
  9      VBC_MAG        2                10.0000  100
  10     VCA_MAG        2                10.0000  100
  11     V1_MAG         2                10.0000  100
  12     3V2_MAG        2                10.0000  100
  13     P              2                10.0000  100
  14     Q              2                10.0000  100
  15     S              2                10.0000  100
  16     PF             2                10.0000  100

Analog Outputs
-------------------------------------------------------------------------------
  INDEX  POINT LABEL
  0      GROUP
  1      RA001
  2      RA002
  ...    ...
  ...    ...
  30     RA030
  31     RA031

=>
```

Figure D.4 Port MAP Command (Continued)

You can use the command **SET DNP *x***, where ***x*** is the map number, to edit or create custom DNP3 data maps. You can also use QuickSet SEL-5030 Software, which is recommended for this purpose.

Scaling factors allow you to overcome the limitations imposed by the integer nature of the default variations of Objects 30 and 32. For example, the device rounds a value of 11.4 A to 11 A. You may use scaling to include decimal point values by multiplying by a number larger than one. If you use 10 as a scaling factor, 11.4 A is transmitted as 114. You must divide the value by 10 in the master to see the original value including one decimal place.

You can also use scaling to avoid overflowing the 16-bit maximum integer value of 32767. For example, if you have a value that can reach 157834, you cannot send it using DNP3 16-bit analog object variations. You could use a scaling factor of 0.1 so that the maximum value reported is 15783. You can then multiply the value by 10 in the master to see a value of 157830. You lose some precision as the last digit is rounded off in the scaling process, but you can transmit the scaled value using standard DNP3 Objects 30 and 32.

You can customize the DNP3 analog input map with per-point scaling, and deadband settings. Per-point customization is not required, but class scaling (DECPLA, DECPLV, and DECPLM) and deadband (ANADBA, ANADBV, and ANADBM) settings are applied to indices that do not have per-point entries. Unlike per-point scaling described above, 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.

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 those data together within your custom map. For example, if you want all the currents to be coherent, you should group points IAW1_MAG, IBW1_MAG, ICW1_MAG, and IGW1_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 DNP** 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 QuickSet to simplify custom data map creation.

Consider a case where you want to set the AI points in a map, as shown in *Table D.13*.

Table D.13 Sample Custom DNP3 AI Map

Desired Point Index	Description	Label	Scaling	Deadband
0	Winding 1, IA magnitude	IAW1_MAG	default	default
1	Winding 1, IB magnitude	IBW1_MAG	default	default
2	Winding 1, IC magnitude	ICW1_MAG	default	default
3	Winding 2, IA magnitude	IAW2_MAG	default	default
4	3-Phase Real Power	P	5	default
5	AB Phase-to-Phase Voltage Magnitude	VAB_MAG	default	default
6	AB Phase-to-Phase Voltage Angle	VAB_ANG	1	15
7	Frequency	FREQ	.01	1

To set these points as part of custom map 1, you can use the command **SET DNP 1 AI_00 TERSE <Enter>** command as shown in *Figure D.5*.

```
=>>SET DNP 1 AI_00 TERSE <Enter>
Analog Input Map

DNP Analog Input Label Name (23 characters)
AI_00   := NA
? > IAW1_MAG <Enter>

AI_01   := NA
? > IBW1_MAG <Enter>

AI_02   := NA
? > ICW1_MAG <Enter>

AI_03   := NA
? > IAW2_MAG <Enter>

AI_04   := NA
? > P:5 <Enter>

AI_05   := NA
? > VAB_MAG <Enter>

AI_06   := NA
? > VAB_ANG:1:15 <Enter>

AI_07   := NA
? > FREQ:.01:1 <Enter>

AI_08   := NA
? > end <Enter>

Save changes (Y/N) ? Y <Enter>

=>>
```

Figure D.5 Sample Custom DNP3 AI Map Settings

You may also use QuickSet to enter the above AI map settings as shown in the screen capture in *Figure D.6*. You can enter scaling and deadband settings in the same pop-up dialog used to select the AI point, as shown in *Figure D.7*.

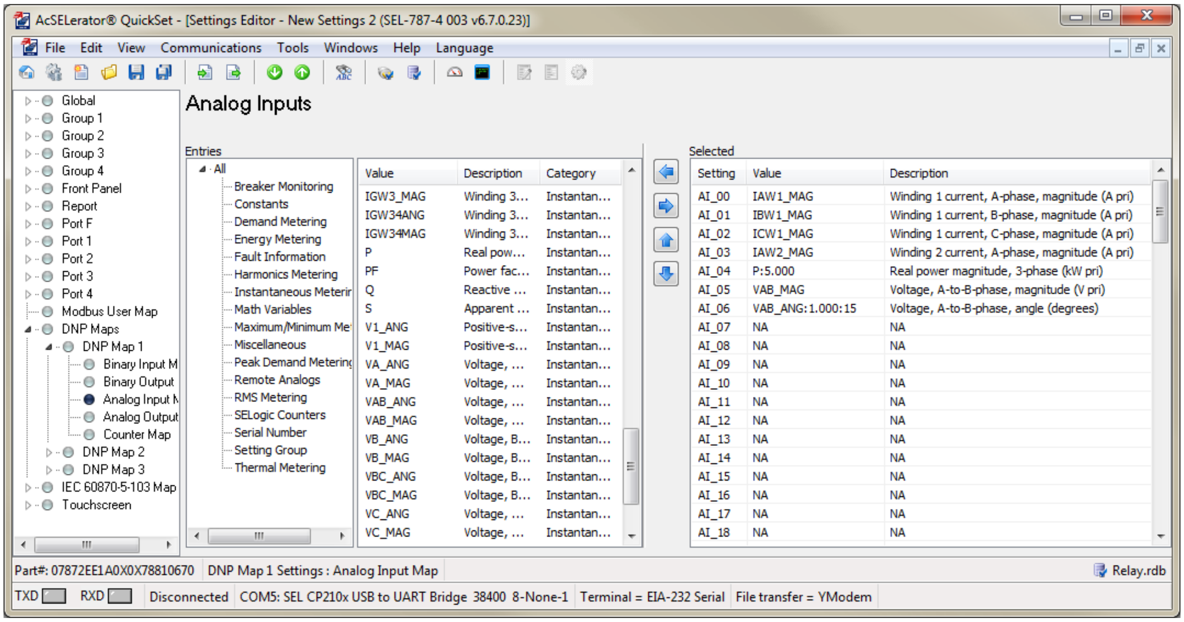

Figure D.6 Analog Input Map Entry in QuickSet

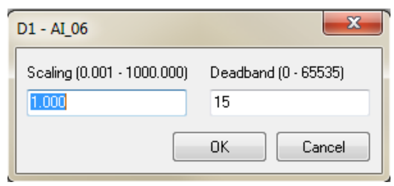

Figure D.7 AI Point Scaling and Deadband in QuickSet

The **SET DNP x AO_00 <Enter>** command allows you to populate the DNP analog output map with any of the 128 remote analogs (RA001–RA128) or the GROUP variable (present settings group) as shown in *Figure D.8*.

```
=>>SET DNP 1 AO_00 TERSE <Enter>

DNP Map 1 Settings

Analog Output Map

DNP Analog Output Label Name (6 characters) AO_00 := NA ? group
DNP Analog Output Label Name (6 characters) AO_01 := NA ? ra001
DNP Analog Output Label Name (6 characters) AO_02 := NA ? ra002
DNP Analog Output Label Name (6 characters) AO_03 := NA ? ra120
DNP Analog Output Label Name (6 characters) AO_04 := NA ? ra128
DNP Analog Output Label Name (6 characters) AO_05 := NA ?
DNP Analog Output Label Name (6 characters) AO_06 := NA ? end
Save changes (Y,N)? y
Settings Saved

=>>
```

Figure D.8 Sample Custom DNP3 AO Map Settings

You can also use QuickSet to enter the AO map settings as shown in *Figure D.9*.

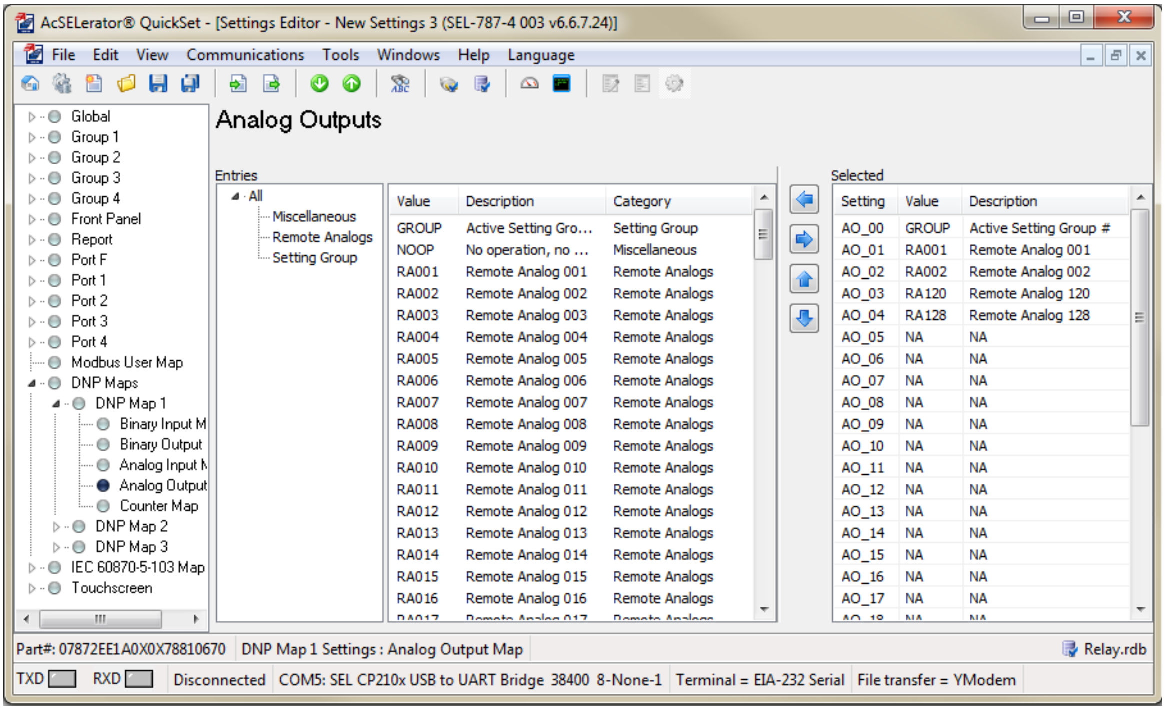

Figure D.9 Analog Output Map Entry in QuickSet

The **SET DNP *x* CO_00 <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 DNP *x* BO_00 TERSE <Enter>** to change the binary output Map *x* as shown in *Figure D.10*. You may populate the custom BO map with any of the 32 remote bits (RB01–RB32). You can define bit pairs in BO maps by including a colon (:) between the bit labels.

```
=>>SET DNP 1 BO_00 TERSE <Enter>
Binary Output Map

DNP Binary Output Label Name (23 characters)
BO_00    := NA
? > RB01 <Enter>

DNP Binary Output Label Name (23 characters)
BO_01    := NA
? > RB02 <Enter>

DNP Binary Output Label Name (23 characters)
BO_02    := NA
? > RB03:RB04 <Enter>

DNP Binary Output Label Name (23 characters)
BO_03    := NA
? > RB05:RB06 <Enter>

DNP Binary Output Label Name (23 characters)
BO_04    := NA
? > end <Enter>

=>>
```

Figure D.10 Sample Custom DNP3 BO Map Settings

You can also use QuickSet to enter the BO map settings as shown in the screen capture in *Figure D.11*.

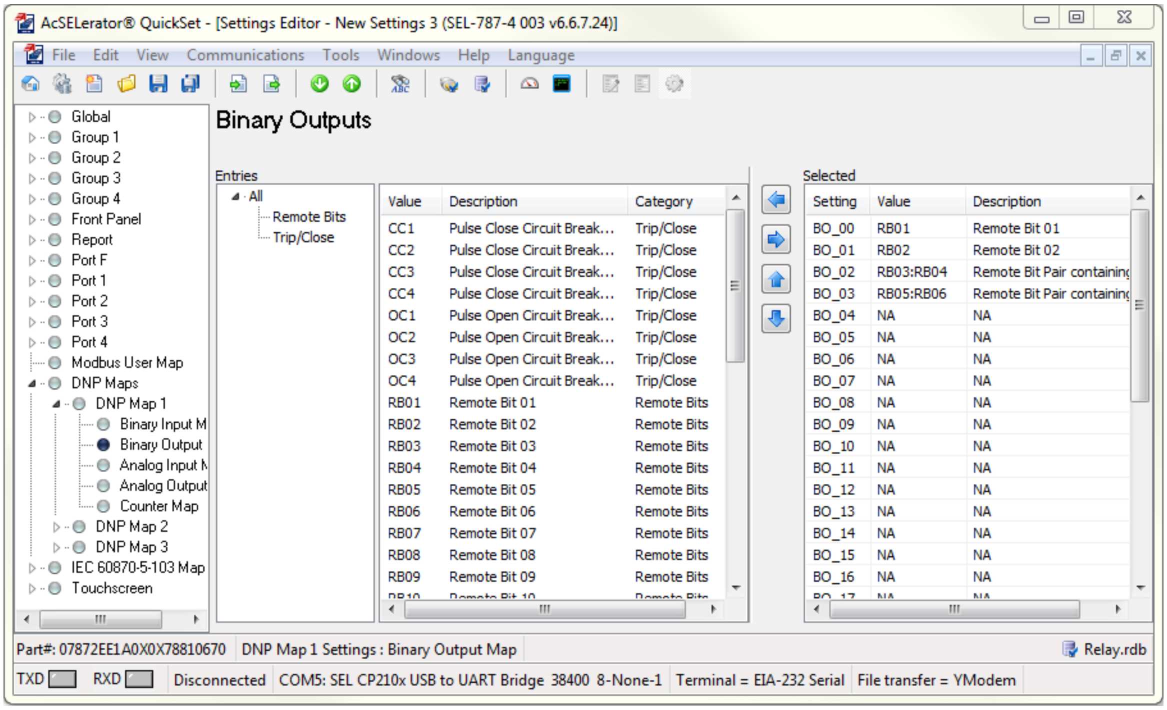

Figure D.11 Binary Output Map Entry in QuickSet

The binary input (BI) maps are modified in a similar manner, but pairs are not allowed.

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Appendix E
Modbus Communications

Overview

This appendix describes the Modbus RTU communications features supported by the SEL-787 Transformer Protection Relay. Complete specifications for the Modbus protocol are available from the Modbus user's group website at www.modbus.org.

Enable the Modbus TCP protocol with the optional Ethernet port settings. The SEL-787 supports as many as two Modbus TCP sessions. The TCP port number for each session is selected with the Ethernet port settings. The default 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 by using the same function codes and data maps as Modbus RTU.

Enable Modbus RTU protocol with the serial port settings. When Modbus RTU protocol is enabled, the relay switches the port to Modbus RTU protocol and deactivates the ASCII protocol.

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.

The SEL-787 Modbus communication allows a Modbus master device to do the following:

- ➤ Acquire metering, monitoring, and event data from the relay.
- ➤ Control SEL-787 output contacts.
- ➤ Read the SEL-787 self-test status and learn the present condition of all the relay protection elements.

Communications Protocol

Modbus Queries

Modbus RTU master devices initiate all exchanges by sending a query. The query consists of the fields shown in *Table E.1*.

Table E.1 Modbus Query Fields (Sheet 1 of 2)

Field	Number of Bytes
Slave Device Address	1 byte
Function Code	1 byte

Table E.1 Modbus Query Fields (Sheet 2 of 2)

Field	Number of Bytes
Data Region	0–251 bytes
Cyclical Redundancy Check (CRC)	2 bytes

The SEL-787 SLAVEID setting defines the device address. Set this value to a unique number for each device on the Modbus network. For Modbus communication to operate properly, no two slave devices may have the same address.

The cyclical redundancy check detects errors in the received data. If an error is detected, the relay discards the packet.

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 cyclical redundancy check value.

Supported Modbus Function Codes

The SEL-787 supports the Modbus function codes shown in *Table E.2*.

Table E.2 SEL-787 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
60h	Read Parameter Information
61h	Read Parameter Text
62h	Read Enumeration Text
7Dh	Encapsulate Modbus Packet With Control
7Eh	NOP (can only be used with the 7Dh function)

Modbus Exception Responses

The SEL-787 sends an exception code under the conditions described in *Table E.3*.

Table E.3 SEL-787 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 (i.e., cannot write to a read-only register, cannot write because the settings are locked, etc.).
3	Illegal Data Value	The received command contains a value that is out of range.
4	Device Error	The SEL-787 is in the wrong state for the function a query specifies. This also stands for Service Failure for DeviceNet interface applications. The relay is unable to perform the action specified by a query (i.e., cannot write to a read-only register, cannot write because settings are locked, 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 E.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.

Cyclical Redundancy Check

The SEL-787 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 response. When the master device receives the response, it recalculates the CRC. If the calculated CRC matches the CRC sent by the SEL-787, 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.

01h Read Discrete Output Coil Status Command

Use function code 01h to read the On/Off status of the selected bits (coils) (see the map shown in *Table E.14*). You can read the status of as many as 2000 bits per query, using the fields shown in *Table E.4*. Note that the SEL-787 coil addresses start at 0 (e.g., Coil 1 is located at address zero). 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 E.4 01h Read Discrete Output Coil Status Command (Sheet 1 of 2)

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

Table E.4 01h Read Discrete Output Coil Status Command (Sheet 2 of 2)

Bytes	Field
A successful response from the slave has 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-787 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 E.14* includes the coil number and lists all possible coils (identified as Outputs and Remote bits) available in the device. Note that the command depends on the device hardware configuration; the device responds only to installed cards.

The relay responses to errors in the query are shown in *Table E.5*.

Table E.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 E.6*. You can read the status of as many as 2000 bits per query. Note that input addresses start at 0 (e.g., Input 1 is located at address zero). 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 E.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 has 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 1 is TLED_06 and Input 8 is ENABLED). Input addresses start at 0000 (i.e., Input 1 is located at Input Address 0000). *Table E.7* includes the coil address in decimal and lists all possible inputs (Relay Word bits) available in the device. Note that the command depends on the device hardware configuration; the device responds only to installed cards.

Table E.7 02h SEL-787 Inputs

Coil Address (Decimal)	Function Code Supported	Coil Description[a]
0–7	2	Relay Element Status Row 0
8–15	2	Relay Element Status Row 1
16–23	2	Relay Element Status Row 2
•	•	•
•	•	•
•	•	•
1904–1911	2	Relay Element Status Row 238
1912–1919	2	Relay Element Status Row 239
1920–1927	2	Relay Element Status Row 240

[a] The input numbers are assigned from the right-most input to the left-most input in the relay row as shown in the following example for Row 0.
Address 7 = ENABLED
Address 6 = TRIP_LED
Address 5 = TLED_01
Address 4 = TLED_02
Address 3 = TLED_03
Address 2 = TLED_04
Address 1 = TLED_05
Address 0 = TLED_06

The relay responses to errors in the query are shown in *Table E.8*.

Table E.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 E.34*. You can read a maximum of 125 registers at once with this function code. Most masters use 4X references with this function code. If you are accustomed to 4X references with this function code, for five-digit addressing, add 40001 to the standard database address.

Table E.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 E.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 has 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 E.10*.

Table E.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 E.34*. You can read a maximum of 125 registers at once with this function code. Most masters use 3X references with this function code. If you are accustomed to 3X references with this function code, for five-digit addressing, add 30001 to the standard database address.

Table E.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 has 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 E.12*.

Table E.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. In *Table E.13*, the command response is identical to the command request.

Table E.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 E.14 lists the coil numbers supported by the SEL-787. The physical coils (coils 0–26) are self-resetting. Pulsing a Set remote bit (decimal address 59 through 90) causes the remote bit to be cleared at the end of the pulse.

Table E.14 01h, 05h SEL-787 Output (Sheet 1 of 3)

Coil Address (Decimal)	Function Code Supported	Coil Description
0	01, 05	Pulse OUT101 1 second
1	01, 05	Pulse OUT102 1 second
2	01, 05	Pulse OUT103 1 second
3	01, 05	Pulse OUT301 1 second
4	01, 05	Pulse OUT302 1 second
5	01, 05	Pulse OUT303 1 second
6	01, 05	Pulse OUT304 1 second
7	01, 05	Pulse OUT305 1 second
8	01, 05	Pulse OUT306 1 second
9	01, 05	Pulse OUT307 1 second
10	01, 05	Pulse OUT308 1 second
11	01, 05	Pulse OUT401 1 second
12	01, 05	Pulse OUT402 1 second
13	01, 05	Pulse OUT403 1 second
14	01, 05	Pulse OUT404 1 second
15	01, 05	Pulse OUT405 1 second
16	01, 05	Pulse OUT406 1 second
17	01, 05	Pulse OUT407 1 second
18	01, 05	Pulse OUT408 1 second

Table E.14 01h, 05h SEL-787 Output (Sheet 2 of 3)

Coil Address (Decimal)	Function Code Supported	Coil Description
19	01, 05	Pulse OUT501 1 second
20	01, 05	Pulse OUT502 1 second
21	01, 05	Pulse OUT503 1 second
22	01, 05	Pulse OUT504 1 second
23	01, 05	Pulse OUT505 1 second
24	01, 05	Pulse OUT506 1 second
25	01, 05	Pulse OUT507 1 second
26	01, 05	Pulse OUT508 1 second
27	01, 05	RB01
28	01, 05	RB02
29	01, 05	RB03
30	01, 05	RB04
31	01, 05	RB05
32	01, 05	RB06
33	01, 05	RB07
34	01, 05	RB08
35	01, 05	RB09
36	01, 05	RB10
37	01, 05	RB11
38	01, 05	RB12
39	01, 05	RB13
40	01, 05	RB14
41	01, 05	RB15
42	01, 05	RB16
43	01, 05	RB17
44	01, 05	RB18
45	01, 05	RB19
46	01, 05	RB20
47	01, 05	RB21
48	01, 05	RB22
49	01, 05	RB23
50	01, 05	RB24
51	01, 05	RB25
52	01, 05	RB26
53	01, 05	RB27
54	01, 05	RB28
55	01, 05	RB29
56	01, 05	RB30
57	01, 05	RB31
58	01, 05	RB32
59	01, 05	Pulse RB01[a]
60	01, 05	Pulse RB02[a]
61	01, 05	Pulse RB03[a]
62	01, 05	Pulse RB04[a]

Table E.14 01h, 05h SEL-787 Output (Sheet 3 of 3)

Coil Address (Decimal)	Function Code Supported	Coil Description
63	01, 05	Pulse RB05[a]
64	01, 05	Pulse RB06[a]
65	01, 05	Pulse RB07[a]
66	01, 05	Pulse RB08[a]
67	01, 05	Pulse RB09[a]
68	01, 05	Pulse RB10[a]
69	01, 05	Pulse RB11[a]
70	01, 05	Pulse RB12[a]
71	01, 05	Pulse RB13[a]
72	01, 05	Pulse RB14[a]
73	01, 05	Pulse RB15[a]
74	01, 05	Pulse RB16[a]
75	01, 05	Pulse RB17[a]
76	01, 05	Pulse RB18[a]
77	01, 05	Pulse RB19[a]
78	01, 05	Pulse RB20[a]
79	01, 05	Pulse RB21[a]
80	01, 05	Pulse RB22[a]
81	01, 05	Pulse RB23[a]
82	01, 05	Pulse RB24[a]
83	01, 05	Pulse RB25[a]
84	01, 05	Pulse RB26[a]
85	01, 05	Pulse RB27[a]
86	01, 05	Pulse RB28[a]
87	01, 05	Pulse RB29[a]
88	01, 05	Pulse RB30[a]
89	01, 05	Pulse RB31[a]
90	01, 05	Pulse RB32[a]

[a] Pulsing a Set remote bit causes the remote bit to be cleared at the end of the pulse (1 SELOGIC processing interval).

Coil addresses start at 0000 (i.e., Coil 1 is located at Coil address 0000). If the device is disabled it responds with Error Code 4 (Device Error). In addition to Error Code 4, the device responses to errors in the query are shown in *Table E.15*.

Table E.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-787 uses this function to allow a Modbus master to write directly to a database register. Refer to the Modbus Register Map in *Table E.34* for a list of registers that can be written by using this function code. If you are accustomed to 4X references with this function code, for six-digit addressing, add 400001 to the standard database addresses.

NOTE: When setting EN_LRC := Y (see Table 9.6), the Relay Word bit LOCAL supervises CCn and OCn (n = 1–4), 89CC2Pm and 89OC2Pm (m = 1–16), and 89CC3Pnm and 89OC3Pnm (m = 1–2, n = L or E). To set the binaries, the relay should be in remote control mode (i.e., LOCAL = 0). The Relay Word bit LOCAL is determined by the LOCAL SELogic control equation (see Table 9.6).

In *Table E.16*, the command response is identical to the command required by the master.

Table E.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 E.17*.

Table E.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-787 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 E.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 has 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 E.19*.

Table E.19 Responses to 08h Loopback Diagnostic Query Errors

Error	Error Code Returned	Communication Counter Increments
Illegal subfunction code	Illegal Data Value (03h)	Invalid 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, as many as 100 per operation. If you are accustomed to 4X references with the function code, for six-digit addressing, simply add 400001 to the standard database addresses.

Table E.20 10h Preset Multiple Registers Command

Bytes	Field
Queries from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (10h)
2 bytes	Starting Address
2 bytes	Number of Registers to Write
1 byte	Number of Bytes of Data (*n*)
n bytes	Data
2 bytes	CRC-16
A successful response from the slave has 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 E.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

60h Read Parameter Information Command

The SEL-787 uses this function to allow a Modbus master to read parameter information from the relay. One parameter (setting) is read in each query.

Table E.22 60h Read Parameter Information Command

Bytes	Field
Queries from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (60h)
2 bytes	Parameter Number
2 bytes	CRC-16
A successful response from the slave has the following format:	
1 byte	Slave Address
1 byte	Function Code (60h)
2 bytes	Parameter Number
1 byte	Parameter Descriptor
1 byte	Parameter Conversion
2 bytes	Parameter Minimum Settable Value
2 bytes	Parameter Maximum Settable Value
2 bytes	Parameter Default Value
2 bytes	CRC-16

The Parameter Descriptor field is defined in *Table E.23*.

Table E.23 60h Read Parameter Descriptor Field Definition

Bit	Name	Description
0	RO: Read-only	1 when the setting is read-only
1	H: Hidden	1 when the setting is hidden
2	DBL: 32-bit	1 when the following setting is a fractional value of this setting
3	RA: RAM-only	1 when the setting is not saved in nonvolatile memory
4	RR: Read-only if running	1 when the setting is read-only if in running/operational state
5‘	P: Power Cycle or Reset	1 when the setting change requires a power cycle or reset
6	0	Reserved
7	Extend	Reserved to extend the descriptor table

The Parameter Conversion field is defined in *Table E.24*.

Table E.24 60h Read Parameter Conversion Field Definition (Sheet 1 of 2)

Conversion Value	Type	Multiplier	Divisor	Offset	Base
0	Boolean	1	1	0	1
1	Unsigned Integer	1	1	0	1
2	Unsigned Integer	1	10	0	1
3	Unsigned Integer	1	100	0	1
4	Unsigned Integer	1	1000	0	1
5	Hexadecimal	1	1	0	1
6	Integer	1	1	0	1
7	Integer	1	10	0	1

Table E.24 60h Read Parameter Conversion Field Definition (Sheet 2 of 2)

Conversion Value	Type	Multiplier	Divisor	Offset	Base
8	Integer	1	100	0	1
9	Integer	1	1000	0	1
10	Enumeration	1	1	0	1
11	Bit Enumeration	1	1	0	1

Use *Table E.25* to calculate the actual (not scaled) value of the parameter (setting):

$$\text{value} = \frac{(\text{ParameterValue} + \text{Offset}) \bullet \text{ Multiplier} \bullet \text{ Base}}{\text{Divisor}} \qquad \textbf{Equation E.1}$$

Use *Table E.25* to calculate the scaled setting value:

$$\text{value} = \frac{\text{value} \bullet \text{ Divisor}}{\text{Multiplier} \bullet \text{ Base}} - \text{Offset} \qquad \textbf{Equation E.2}$$

The relay response to errors in the query are shown *Table E.25*.

Table E.25 Responses to 60h Read Parameter Information Query Errors

Error	Error Code Returned	Communication Counter Increments
Illegal parameter to read	Illegal Address (02h)	Invalid Address

61h Read Parameter Text Command

The SEL-787 uses this function to allow a Modbus master to read parameter text from the relay. One parameter text (setting name) is read in each query.

Table E.26 61h Read Parameter Text Command

Bytes	Field
Queries from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (61h)
2 bytes	Parameter Number
2 bytes	CRC-16
A successful response from the slave has the following format:	
1 byte	Slave Address
1 byte	Function Code (61h)
2 bytes	Parameter Number
16 bytes	Parameter Text (setting name)
4 bytes	Parameter Units (e.g., amperes)
2 bytes	CRC-16

The relay responses to errors in the query are shown in *Table E.27*.

Table E.27 61h Read Parameter Text Query Error Messages

Error	Error Code Returned	Communication Counter Increments
Illegal parameter to read	Illegal Address (02h)	Invalid Address

62h Read Enumeration Text Command

The SEL-787 uses this function to allow a Modbus master to read parameter enumeration or bit enumeration values (setting lists) from the relay. One parameter enumeration is read in each query.

Table E.28 62h Read Enumeration Text Command

Bytes	Field
Queries from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (62h)
2 bytes	Parameter Number
1 byte	Enumeration Index
2 bytes	CRC-16
A successful response from the slave has the following format:	
1 byte	Slave Address
1 byte	Function Code (62h)
2 bytes	Parameter Number
1 byte	Enumeration Index
16 bytes	Enumeration Text
2 bytes	CRC-16

The relay responses to errors in the query are shown in *Table E.29*.

Table E.29 61h Read Parameter Enumeration Text Query Error Messages

Error	Error Code Returned	Communication Counter Increments
Illegal parameter to read	Illegal Address (02h)	Invalid Address
Illegal enumeration in index	Illegal Data Value (03h)	Illegal Register

7Dh Encapsulated Packet With Control Command

The SEL-787 uses this function to allow a Modbus master to perform control operations and another Modbus function with one query. The Device Net card transmits this command periodically to achieve high-speed I/O processing and establish a heartbeat between the DeviceNet card and the main board.

Table E.30 7Dh Encapsulated Packet With Control Command (Sheet 1 of 2)

Bytes	Field
Queries from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (7Dh)
2 bytes	Control Command (same as write to 2000h)
1 byte	Embedded Modbus Function

Table E.30 7Dh Encapsulated Packet With Control Command (Sheet 2 of 2)

Bytes	Field
n bytes	Optional Data to Support Modbus Function (0–250)
2 bytes	CRC-16
A successful response from the slave has the following format:	
1 byte	Slave Address
1 byte	Function Code (7Dh)
2 bytes	Status Information (Register 2100h or 2101h based on Bit 3 in Control Command Word)
1 byte	Embedded Modbus Function
n bytes	Optional data to support the Modbus function (0–250)
2 bytes	CRC-16

Table E.31 shows the format of the relay responses to errors in the query.

Table E.31 7Dh Encapsulated Packet Query Errors

Bytes	Field
Queries from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (7Dh)
2 bytes	Status Information (Register 2100h or 2101h based on Bit 3 in Control Command Word)
1 byte	Modbus Function with Error Flag
1 bytes	Function Error Code[a]
2 bytes	CRC-16

[a] If the embedded function code is invalid, then an illegal function code is returned here and the illegal function counter is incremented. This error code is returned by the embedded function for all valid embedded functions.

7Eh NOP Command

This function code has no operation. This allows a Modbus master to perform a control operation without any other Modbus command. This is only used inside of the 7Dh when no regular Modbus query is required.

Table E.32 7Eh NOP Command

Bytes	Field
An example of a 7D message response using 7E has the following format:	
1 byte	Slave Address
1 byte	Function Code (7Dh)
2 bytes	Status Information
1 byte	Function Code (7Eh)
2 bytes	CRC-16

Reading Parameter Information and Value Using Modbus

Through use of Modbus commands, you can read the present value of a parameter as well as parameter name, units, low limit, high limit, scale, and even the enumeration string (if the parameter is an enumeration type). This means that you can use a general user interface to retrieve and display specific parameter details from the relay. Use the **60h**, **61h**, and **62h** commands to retrieve parameter information, and use the **03** command to retrieve values.

Controlling Output Contacts Using Modbus

The SEL-787 includes registers for controlling some of the outputs. See LOGIC COMMAND (2000h), RESET COMMAND (2001h), and registers in the Reset Settings region for the control features supported by the relay. 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.

User-Defined Modbus Data Region and SET M Command

The SEL-787 Modbus Register Map defines an area of 125 contiguous addresses whose contents are defined by 125 user-settable addresses. This feature allows you to take 125 discrete values from anywhere in the Modbus Register Map and place them in contiguous registers that you can then read in a single command. SEL ASCII command **SET M** provides a convenient method to define the user map addresses. The user map can also be defined by writing to user map registers MOD_001 to MOD_125.

To use the user-defined data region, follow the steps listed below.

Step 1. Define the list of desired quantities (as many as 125). Arrange the quantities in any order that is convenient for you to use.

Step 2. Refer to *Table E.33* for a list of the Modbus label for each quantity. For more information on the Modbus labels, refer to the respective register in the Modbus map (*Table E.34*).

Step 3. Execute **SET M** command from the command line to map user registers 001 to 125 (MOD_001 to MOD_125) using the labels in *Table E.33*.

Note that this step can also be performed using Modbus protocol. Use Modbus Function Code 06h to write to registers MOD_001 through MOD_125.

Step 4. Use Modbus function code 03h or 04h to read the desired quantities from addresses 126 through 250 (user map values).

Table E.33 Modbus Register Labels for Use With SET M Command (Sheet 1 of 6)

Register Address	Label
251–260	Reserved
261	RSTDAT
262–269	Reserved
270	SEC
271	MIN
272	HOUR
273	DAY
274	MONTH
275	YEAR
276–279	Reserved
280	FPGA
281	GPSB
282	HMI
283	RAM
284	ROM
285	CR_RAM
286	NON_VOL
287	CLKSTS
288	CID_FILE
289	RTD
290	P0P9PS
291	P1P2PS
292	P1P5PS
293	P1P8PS
294	P2P5PS
295	P3P3PS
296	P3P75PS
297	P5PS
298	N1P25PS
299	N5PS
300	CLKBAT
301	CARDC
302	CARDD
303	CARDE
304	CARDZ
305	IAW1STS
306	IBW1STS
307	ICW1STS
308	IAW2STS
309	IBW2STS
310	ICW2STS
311	IAW3STS
312	IBW3STS
313	ICW3STS
314	IAW4STS
315	IBW4STS
316	ICW4STS
317	INSTS
318	VASTS
319	VBSTS
320	VCSTS
321	VSSTS
322	RLYSTS
323	SER_NUMH
324	SER_NUML
325–329	Reserved
330	IAW1_MAG
331	IAW1_ANG
332	IBW1_MAG
333	IBW1_ANG
334	ICW1_MAG
335	ICW1_ANG
336	IGW1_MAG
337	IGW1_ANG
338	I1W1_MAG
339	I1W1_ANG
340	3I2W1MAG
341	3I2W1ANG
342	IAW2_MAG
343	IAW2_ANG
344	IBW2_MAG
345	IBW2_ANG
346	ICW2_MAG
347	ICW2_ANG
348	IGW2_MAG
349	IGW2_ANG
350	I1W2_MAG
351	I1W2_ANG
352	3I2W2MAG
353	3I2W2ANG
354	IAW3_MAG
355	IAW3_ANG
356	IBW3_MAG
357	IBW3_ANG
358	ICW3_MAG
359	ICW3_ANG
360	IGW3_MAG
361	IGW3_ANG
362	I1W3_MAG
363	I1W3_ANG
364	3I2W3MAG
365	3I2W3ANG
366	IAW4_MAG
367	IAW4_ANG
368	IBW4_MAG
369	IBW4_ANG
370	ICW4_MAG
371	ICW4_ANG
372	IGW4_MAG
373	IGW4_ANG
374	I1W4_MAG
375	I1W4_ANG
376	3I2W4MAG
377	3I2W4ANG
378	IAW12MAG
379	IAW12ANG
380	IBW12MAG
381	IBW12ANG
382	ICW12MAG
383	ICW12ANG
384	IGW12MAG
385	IGW12ANG
386	I1W12MAG
387	I1W12ANG
388	3I2W12MG
389	3I2W12AG
390	IAW34MAG
391	IAW34ANG
392	IBW34MAG
393	IBW34ANG
394	ICW34MAG
395	ICW34ANG
396	IGW34MAG
397	IGW34ANG
398	I1W34MAG
399	I1W34ANG
400	3I2W34MG
401	3I2W34AG
402	IN_MAG
403	IN_ANG
404–409	Reserved
410	VAB_MAG
411	VAB_ANG
412	VBC_MAG
413	VBC_ANG
414	VCA_MAG
415	VCA_ANG
416	VA_MAG
417	VA_ANG
418	VB_MAG
419	VB_ANG
420	VC_MAG
421	VC_ANG
422	VG_MAG
423	VG_ANG
424	V1_MAG
425	V1_ANG
426	3V2_MAG
427	3V2_ANG
428	VS_MAG
429	VS_ANG
430	VDC
431	PA
432	QA
433	SA
434	PB
435	QB
436	SB
437	PC
438	QC
439	SC
440	P
441	Q
442	S
443	PF
444	VHZ
445	FREQ
446	FREQS
447	PFA
448	PFB
449	PFC
450	MWHPH
451	MWHPL
452	MWHNH
453	MWHNL
454	MVARHPH
455	MVARHPL
456	MVARHNH
457	MVARHNL
458	ENRGY_S
459	ENRGYMN
460	ENRGY_H
461	ENRGY_D
462	ENRGYMO
463	ENRGY_Y
464–469	Reserved
470	IAD
471	IBD
472	ICD
473	IGD
474	3I2D
475	IAPD
476	IBPD
477	ICPD
478	IGPD
479	3I2PD

Table E.33 Modbus Register Labels for Use With SET M Command (Sheet 2 of 6)

Register Address	Label
480	PDEM_R_S
481	PDEM_RMN
482	PDEM_R_H
483	PDEM_R_D
484	PDEM_RMO
485	PDEM_R_Y
486-489	Reserved
490	IAW1_THD
491	IBW1_THD
492	ICW1_THD
493	IAW2_THD
494	IBW2_THD
495	ICW2_THD
496	IAW3_THD
497	IBW3_THD
498	ICW3_THD
499	IAW4_THD
500	IBW4_THD
501	ICW4_THD
502	IN_THD
503	VA_THD
504	VB_THD
505	VC_THD
506	VAB_THD
507	VBC_THD
508	VCA_THD
509	Reserved
510	RTDAMB
511	RTDOTHMX
512	RTD1
513	RTD2
514	RTD3
515	RTD4
516	RTD5
517	RTD6
518	RTD7
519	RTD8
520	RTD9
521	RTD10
522	RTD11
523	RTD12
524	AI501MXH
525	AI501MXL
526	AI501MNH
527	AI501MNL
528	AI502MXH
529	AI502MXL
530	AI502MNH
531	AI502MNL
532	AI503MXH
533	AI503MXL
534	AI503MNH
535	AI503MNL
536	AI504MXH
537	AI504MXL
538	AI504MNH
539	AI504MNL
540	IAW1RMS
541	IBW1RMS
542	ICW1RMS
543	IAW2RMS
544	IBW2RMS
545	ICW2RMS
546	IAW3RMS
547	IBW3RMS
548	ICW3RMS
549	IAW4RMS
550	IBW4RMS
551	ICW4RMS
552	INRMS
553	VARMS
554	VBRMS
555	VCRMS
556	VABRMS
557	VBCRMS
558	VCARMS
559	VSRMS
560-569	Reserved
570	INTTW1
571	EXTTW1
572	INTIAW1
573	INTIBW1
574	INTICW1
575	EXTIAW1
576	EXTIBW1
577	EXTICW1
578	WEARAW1
579	WEARBW1
580	WEARCW1
581	BM_R_S_1
582	BM_R_MN1
583	BM_R_H_1
584	BM_R_D_1
585	BM_R_MO1
586	BM_R_Y_1
587	INTTW2
588	EXTTW2
589	INTIAW2
590	INTIBW2
591	INTICW2
592	EXTIAW2
593	EXTIBW2
594	EXTICW2
595	WEARAW2
596	WEARBW2
597	WEARCW2
598	BM_R_S_2
599	BM_R_MN2
600	BM_R_H_2
601	BM_R_D_2
602	BM_R_MO2
603	BM_R_Y_2
604	INTTW3
605	EXTTW3
606	INTIAW3
607	INTIBW3
608	INTICW3
609	EXTIAW3
610	EXTIBW3
611	EXTICW3
612	WEARAW3
613	WEARBW3
614	WEARCW3
615	BM_R_S_3
616	BM_R_MN3
617	BM_R_H_3
618	BM_R_D_3
619	BM_R_MO3
620	BM_R_Y_3
621	INTTW4
622	EXTTW4
623	INTIAW4
624	INTIBW4
625	INTICW4
626	EXTIAW4
627	EXTIBW4
628	EXTICW4
629	WEARAW4
630	WEARBW4
631	WEARCW4
632	BM_R_S_4
633	BM_R_MN4
634	BM_R_H_4
635	BM_R_D_4
636	BM_R_MO4
637	BM_R_Y_4
638-639	Reserved
640	IAW1MX
641	IAW1MN
642	IBW1MX
643	IBW1MN
644	ICW1MX
645	ICW1MN
646	IGW1MX
647	IGW1MN
648	IAW2MX
649	IAW2MN
650	IBW2MX
651	IBW2MN
652	ICW2MX
653	ICW2MN
654	IGW2MX
655	IGW2MN
656	IAW3MX
657	IAW3MN
658	IBW3MX
659	IBW3MN
660	ICW3MX
661	ICW3MN
662	IGW3MX
663	IGW3MN
664	IAW4MX
665	IAW4MN
666	IBW4MX
667	IBW4MN
668	ICW4MX
669	ICW4MN
670	IGW4MX
671	IGW4MN
672	INMX
673	INMN
674	VABMX[a]
675	VABMN[a]
676	VBCMX[a]
677	VBCMN[a]
678	VCAMX[a]
679	VCAMN[a]
680	KW3PMX
681	KW3PMN
682	KVAR3PMX
683	KVAR3PMN
684	KVA3PMX
685	KVA3PMN
686	FREQMX
687	FREQMN

Table E.33 Modbus Register Labels for Use With SET M Command (Sheet 3 of 6)

Register Address	Label	Register Address	Label	Register Address	Label	Register Address	Label
688	IAW23MAG	742	AI304MXH	803	MV02L	852	MV27H
689	IAW23ANG	743	AI304MXL	804	MV03H	853	MV27L
690	IBW23MAG	744	AI304MNH	805	MV03L	854	MV28H
691	IBW23ANG	745	AI304MNL	806	MV04H	855	MV28L
692	ICW23MAG	746–749	Reserved	807	MV04L	856	MV29H
693	ICW23ANG	750	AI401MXH	808	MV05H	857	MV29L
694	IGW23MAG	751	AI401MXL	809	MV05L	858	MV30H
695	IGW23ANG	752	AI401MNH	810	MV06H	859	MV30L
696	I1W23ANG	753	AI401MNL	811	MV06L	860	MV31H
697	I1W23ANG	754	AI402MXH	812	MV07H	861	MV31L
698	3I2W23MG	755	AI402MXL	813	MV07L	862	MV32H
699	3I2W23AG	756	AI402MNH	814	MV08H	863	MV32L
700	RTD1MX	757	AI402MNL	815	MV08L	864–869	Reserved
701	RTD1MN	758	AI403MXH	816	MV09H	870	SC01
702	RTD2MX	759	AI403MXL	817	MV09L	871	SC02
703	RTD2MN	760	AI403MNH	818	MV10H	872	SC03
704	RTD3MX	761	AI403MNL	819	MV10L	873	SC04
705	RTD3MN	762	AI403MXH	820	MV11H	874	SC05
706	RTD4MX	763	AI403MXL	821	MV11L	875	SC06
707	RTD4MN	764	AI404MNH	822	MV12H	876	SC07
708	RTD5MX	765	AI404MNL	823	MV12L	877	SC08
709	RTD5MN	766–769	Reserved	824	MV13H	878	SC09
710	RTD6MX	770	MXMN_R_S	825	MV13L	879	SC10
711	RTD6MN	771	MXMN_RMN	826	MV14H	880	SC11
712	RTD7MX	772	MXMN_R_H	827	MV14L	881	SC12
713	RTD7MN	773	MXMN_R_D	828	MV15H	882	SC13
714	RTD8MX	774	MXMN_RMO	829	MV15L	883	SC14
715	RTD8MN	775	MXMN_R_Y	830	MV16H	884	SC15
716	RTD9MX	776–779	Reserved	831	MV16L	885	SC16
717	RTD9MN	780	AI301H	832	MV17H	886	SC17
718	RTD10MX	781	AI301L	833	MV17L	887	SC18
719	RTD10MN	782	AI302H	834	MV18H	888	SC19
720	RTD11MX	783	AI302L	835	MV18L	889	SC20
721	RTD11MN	784	AI303H	836	MV19H	890	SC21
722	RTD12MX	785	AI303L	837	MV19L	891	SC22
723	RTD12MN	786	AI304H	838	MV20H	892	SC23
724–729	Reserved	787	AI304L	839	MV20L	893	SC24
730	AI301MXH	788	AI401H	840	MV21H	894	SC25
731	AI301MXL	789	AI401L	841	MV21L	895	SC26
732	AI301MNH	790	AI402H	842	MV22H	896	SC27
733	AI301MNL	791	AI402L	843	MV22L	897	SC28
734	AI302MXH	792	AI403H	844	MV23H	898	SC29
735	AI302MXL	793	AI403L	845	MV23L	899	SC30
736	AI302MNH	794	AI404H	846	MV24H	900	SC31
737	AI302MNL	795	AI404L	847	MV24L	901	SC32
738	AI303MXH	796–799	Reserved	848	MV25H	902	AI501H
739	AI303MXL	800	MV01H	849	MV25L	903	AI501L
740	AI303MNH	801	MV01L	850	MV26H	904	AI502H
741	AI303MNL	802	MV02H	851	MV26L	905	AI502L

Table E.33 Modbus Register Labels for Use With SET M Command (Sheet 4 of 6)

Register Address	Label	Register Address	Label	Register Address	Label	Register Address	Label
906	AI503H	964	RA023_H	1013	RA047_L	1062	RA072_H
907	AI503L	965	RA023_L	1014	RA048_H	1063	RA072_L
908	AI504H	966	RA024_H	1015	RA048_L	1064	RA073_H
909	AI504L	967	RA024_L	1016	RA049_H	1065	RA073_L
910–919	Reserved	968	RA025_H	1017	RA049_L	1066	RA074_H
920	RA001_H	969	RA025_L	1018	RA050_H	1067	RA074_L
921	RA001_L	970	RA026_H	1019	RA050_L	1068	RA075_H
922	RA002_H	971	RA026_L	1020	RA051_H	1069	RA075_L
923	RA002_L	972	RA027_H	1021	RA051_L	1070	RA076_H
924	RA003_H	973	RA027_L	1022	RA052_H	1071	RA076_L
925	RA003_L	974	RA028_H	1023	RA052_L	1072	RA077_H
926	RA004_H	975	RA028_L	1024	RA053_H	1073	RA077_L
927	RA004_L	976	RA029_H	1025	RA053_L	1074	RA078_H
928	RA005_H	977	RA029_L	1026	RA054_H	1075	RA078_L
929	RA005_L	978	RA030_H	1027	RA054_L	1076	RA079_H
930	RA006_H	979	RA030_L	1028	RA055_H	1077	RA079_L
931	RA006_L	980	RA031_H	1029	RA055_L	1078	RA080_H
932	RA007_H	981	RA031_L	1030	RA056_H	1079	RA080_L
933	RA007_L	982	RA032_H	1031	RA056_L	1080	RA081_H
934	RA008_H	983	RA032_L	1032	RA057_H	1081	RA081_L
935	RA008_L	984	RA033_H	1033	RA057_L	1082	RA082_H
936	RA009_H	985	RA033_L	1034	RA058_H	1083	RA082_L
937	RA009_L	986	RA034_H	1035	RA058_L	1084	RA083_H
938	RA010_H	987	RA034_L	1036	RA059_H	1085	RA083_L
939	RA010_L	988	RA035_H	1037	RA059_L	1086	RA084_H
940	RA011_H	989	RA035_L	1038	RA060_H	1087	RA084_L
941	RA011_L	990	RA036_H	1039	RA060_L	1088	RA085_H
942	RA012_H	991	RA036_L	1040	RA061_H	1089	RA085_L
943	RA012_L	992	RA037_H	1041	RA061_L	1090	RA086_H
944	RA013_H	993	RA037_L	1042	RA062_H	1091	RA086_L
945	RA013_L	994	RA038_H	1043	RA062_L	1092	RA087_H
946	RA014_H	995	RA038_L	1044	RA063_H	1093	RA087_L
947	RA014_L	996	RA039_H	1045	RA063_L	1094	RA088_H
948	RA015_H	997	RA039_L	1046	RA064_H	1095	RA088_L
949	RA015_L	998	RA040_H	1047	RA064_L	1096	RA089_H
950	RA016_H	999	RA040_L	1048	RA065_H	1097	RA089_L
951	RA016_L	1000	RA041_H	1049	RA065_L	1098	RA090_H
952	RA017_H	1001	RA041_L	1050	RA066_H	1099	RA090_L
953	RA017_L	1002	RA042_H	1051	RA066_L	1100	RA091_H
954	RA018_H	1003	RA042_L	1052	RA067_H	1101	RA091_L
955	RA018_L	1004	RA043_H	1053	RA067_L	1102	RA092_H
956	RA019_H	1005	RA043_L	1054	RA068_H	1103	RA092_L
957	RA019_L	1006	RA044_H	1055	RA068_L	1104	RA093_H
958	RA020_H	1007	RA044_L	1056	RA069_H	1105	RA093_L
959	RA020_L	1008	RA045_H	1057	RA069_L	1106	RA094_H
960	RA021_H	1009	RA045_L	1058	RA070_H	1107	RA094_L
961	RA021_L	1010	RA046_H	1059	RA070_L	1108	RA095_H
962	RA022_H	1011	RA046_L	1060	RA071_H	1109	RA095_L
963	RA022_L	1012	RA047_H	1061	RA071_L	1110	RA096_H

Table E.33 Modbus Register Labels for Use With SET M Command (Sheet 5 of 6)

Register Address	Label	Register Address	Label	Register Address	Label	Register Address	Label
1111	RA096_L	1160	RA121_H	1212	EVE_MAXA	1280	ROW_30
1112	RA097_H	1161	RA121_L	1213	EVE_MAXO	1281	ROW_31
1113	RA097_L	1162	RA122_H	1214–1219	Reserved	1282	ROW_32
1114	RA098_H	1163	RA122_L	1220	TRIP_LO	1283	ROW_33
1115	RA098_L	1164	RA123_H	1221	TRIP_HI	1284	ROW_34
1116	RA099_H	1165	RA123_L	1222	WARN_LO	1285	ROW_35
1117	RA099_L	1166	RA124_H	1223	WARN_HI	1286	ROW_36
1118	RA100_H	1167	RA124_L	1224–1229	Reserved	1287	ROW_37
1119	RA100_L	1168	RA125_H	1230	NUMRCV	1288	ROW_38
1120	RA101_H	1169	RA125_L	1231	NUMOTH	1289	ROW_39
1121	RA101_L	1170	RA126_H	1232	INVADR	1290	ROW_40
1122	RA102_H	1171	RA126_L	1233	BADCRC	1291	ROW_41
1123	RA102_L	1172	RA127_H	1234	UARTERR	1292	ROW_42
1124	RA103_H	1173	RA127_L	1235	ILLFUNC	1293	ROW_43
1125	RA103_L	1174	RA128_H	1236	ILLREG	1294	ROW_44
1126	RA104_H	1175	RA128_L	1237	ILLWR	1295	ROW_45
1127	RA104_L	1176–1179	Reserved	1238	BADPKTF	1296	ROW_46
1128	RA105_H	1180	NUMEVE	1239	BADPKTL	1297	ROW_47
1129	RA105_L	1181	EVESEL	1240–1249	Reserved	1298	ROW_48
1130	RA106_H	1182	EVE_S	1250	ROW_0	1299	ROW_49
1131	RA106_L	1183	EVEMN	1251	ROW_1	1300	ROW_50
1132	RA107_H	1184	EVE_H	1252	ROW_2	1301	ROW_51
1133	RA107_L	1185	EVE_D	1253	ROW_3	1302	ROW_52
1134	RA108_H	1186	EVEMO	1254	ROW_4	1303	ROW_53
1135	RA108_L	1187	EVE_Y	1255	ROW_5	1304	ROW_54
1136	RA109_H	1188	EVE_TYPE	1256	ROW_6	1305	ROW_55
1137	RA109_L	1189	EVE_TRGT	1257	ROW_7	1306	ROW_56
1138	RA110_H	1190	EVE_IAW1	1258	ROW_8	1307	ROW_57
1139	RA110_L	1191	EVE_IBW1	1259	ROW_9	1308	ROW_58
1140	RA111_H	1192	EVE_ICW1	1260	ROW_10	1309	ROW_59
1141	RA111_L	1193	EVE_IGW1	1261	ROW_11	1310	ROW_60
1142	RA112_H	1194	EVE_IAW2	1262	ROW_12	1311	ROW_61
1143	RA112_L	1195	EVE_IBW2	1263	ROW_13	1312	ROW_62
1144	RA113_H	1196	EVE_ICW2	1264	ROW_14	1313	ROW_63
1145	RA113_L	1197	EVE_IGW2	1265	ROW_15	1314	ROW_64
1146	RA114_H	1198	EVE_IAW3	1266	ROW_16	1315	ROW_65
1147	RA114_L	1199	EVE_IBW3	1267	ROW_17	1316	ROW_66
1148	RA115_H	1200	EVE_ICW3	1268	ROW_18	1317	ROW_67
1149	RA115_L	1201	EVE_IGW3	1269	ROW_19	1318	ROW_68
1150	RA116_H	1202	EVE_IAW4	1270	ROW_20	1319	ROW_69
1151	RA116_L	1203	EVE_IBW4	1271	ROW_21	1320	ROW_70
1152	RA117_H	1204	EVE_ICW4	1272	ROW_22	1321	ROW_71
1153	RA117_L	1205	EVE_IGW4	1273	ROW_23	1322	ROW_72
1154	RA118_H	1206	EVE_IN	1274	ROW_24	1323	ROW_73
1155	RA118_L	1207	EVE_VAB	1275	ROW_25	1324	ROW_74
1156	RA119_H	1208	EVE_VBC	1276	ROW_26	1325	ROW_75
1157	RA119_L	1209	EVE_VCA	1277	ROW_27	1326	ROW_76
1158	RA120_H	1210	EVE_DY	1278	ROW_28	1327	ROW_77
1159	RA120_L	1211	EVE_FREQ	1279	ROW_29	1328	ROW_78

Table E.33 Modbus Register Labels for Use With SET M Command (Sheet 6 of 6)

Register Address	Label
1329	ROW_79
1330	ROW_80
1331	ROW_81
1332	ROW_82
1333	ROW_83
1334	ROW_84
1335	ROW_85
1336	ROW_86
1337	ROW_87
1338	ROW_88
1339	ROW_89
1340	ROW_90
1341	ROW_91
1342	ROW_92
1343	ROW_93
1344	ROW_94
1345	ROW_95
1346	ROW_96
1347	ROW_97
1348	ROW_98
1349	ROW_99
1350	ROW_100
1351	ROW_101
1352	ROW_102
1353	ROW_103
1354	ROW_104
1355	ROW_105
1356	ROW_106
1357	ROW_107
1358	ROW_108
1359	ROW_109
1360	ROW_110
1361	ROW_111
1362	ROW_112
1363	ROW_113
1364	ROW_114
1365	ROW_115
1366	ROW_116
1367	ROW_117
1368	ROW_118
1369	ROW_119
1370	ROW_120
1371	ROW_121
1372	ROW_122
1373	ROW_123
1374	ROW_124
1375	ROW_125
1376	ROW_126
1377	ROW_127
1378	ROW_128
1379	ROW_129
1380	ROW_130
1381	ROW_131
1382	ROW_132
1383	ROW_133
1384	ROW_134
1385	ROW_135
1386	ROW_136
1387	ROW_137
1388	ROW_138
1389	ROW_139
1390	ROW_140
1391	ROW_141
1392	ROW_142
1393	ROW_143
1394	ROW_144
1395	ROW_145
1396	ROW_146
1397	NA
1398	ROW_147
1399	ROW_148
1400	ROW_149
1401	ROW_150
1402	ROW_151
1403	ROW_152
1404	ROW_153
1405	ROW_154
1406	ROW_155
1407	ROW_156
1408	ROW_157
1409	ROW_158
1410	ROW_159
1411	ROW_160
1412	ROW_161
1413	ROW_162
1414	ROW_163
1415	ROW_164
1416	ROW_165
1417	ROW_166
1418	ROW_167
1419	ROW_168
1420	ROW_169
1421	ROW_170
1422	ROW_171
1423	ROW_172
1424	ROW_173
1425	ROW_174
1426	ROW_175
1427	ROW_176
1428	ROW_177
1429	ROW_178
1430	ROW_179
1431	ROW_180
1432	ROW_181
1433	ROW_182
1434	ROW_183
1435	ROW_184
1436	ROW_185
1437	ROW_186
1438	ROW_187
1439	ROW_188
1440	ROW_189
1441	ROW_190
1442	ROW_191
1443	ROW_192
1444	ROW_193
1445	ROW_194
1446	ROW_195
1447	ROW_196
1448	ROW_197
1449	ROW_198
1450	ROW_199
1451	ROW_200
1452	ROW_201
1453	ROW_202
1454	ROW_203
1455	ROW_204
1456	ROW_205
1457	ROW_206
1458	ROW_207
1459	ROW_208
1460	ROW_209
1461	ROW_210
1462	ROW_211
1463	ROW_212
1464	ROW_213
1465	ROW_214
1466	ROW_215
1467	ROW_216
1468	ROW_217
1469	ROW_218
1470	ROW_219
1471	ROW_220
1472	ROW_221
1473	ROW_222
1474	ROW_223
1475	ROW_224
1476	ROW_225
1477	ROW_226
1478	ROW_227
1479	ROW_228
1480	ROW_229
1481	ROW_230
1482	ROW_231
1483	ROW_232
1484	ROW_233
1485	ROW_234
1486	ROW_235
1487	ROW_236
1488	ROW_237
1489	ROW_238
1490	ROW_239
1491	ROW_240
1492–1499	Reserved

[a] Registers report the corresponding phase-to-phase values when the setting DELTA_Y = DELTA and the phase-to-neutral values when the setting DELTA_Y = WYE.

Reading History Data Using Modbus

Through use of the Modbus Register Map (*Table E.34*), you can download a complete history of the last fifty events via Modbus. The history contains the date and time stamp, type of event that triggered the report, currents, and voltages at the time of the event. Please refer to the Historical Data section in the map.

To use Modbus to download history data, write the event number (1–50) to the EVENT LOG SEL register at address 1181 (when a zero is written to the register, the relay will return event number one). Then read the history of the specific event number you requested from the registers shown in the Historical Data section of the Modbus Register Map (*Table E.34*). After a power cycle, the history data registers will show the history data corresponding to the latest event. This information updates dynamically; whenever there is a new event, the history data registers update automatically with new event data. If specific event number data have been retrieved using a write to the EVENT LOG SEL register, the event data registers will return that specific event history. These registers will return to the free running latest event history data mode when a zero is written to the event selection register from a prior nonzero selection.

Modbus Register Map

NOTE: Certain Modbus quantities are reported as 32-bit numbers; however, Modbus registers are only 16-bit. This results in displaying the Modbus quantities in a LOW and HIGH register. To determine the 32-bit number, concatenate the LOW register to the end of the HIGH register. For example, if the HIGH register value is 0x5ADC and the LOW register value is 0xF43B, the resulting 32-bit value is 0x5ADCF43B.

Table E.34 lists the data available in the Modbus interface and its description, range, and scaling information. The table also shows the parameter number for access using the DeviceNet interface. The DeviceNet parameter number is obtained by adding 100 to the Modbus register address.

Table E.34 Modbus Map[a] (Sheet 1 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
0 (R)	Reserved[d]		0	100	1		
User Map Register							
1 (R/W)	USER REG #1		280	1499	330	1	101
	•						
	•						
	•						
125 (R/W)	USER REG #125		280	1499	1397	1	225
User Map Reg Val							
126–250 (R)	USER REG#1 VAL– USER REG#125 VAL		0	65535	0	1	226–350
251–260 (R)	Reserved[d]		0	0	0	10	351–260
Reset Settings							
261 (R/W)	RESET DATA Bit 0 = TRIP RESET Bit 1 = Reserved[d] Bit 2 = RESET STAT DATA Bit 3 = RESET HIST DATA		0	2047	0	1	361

Table E.34 Modbus Map[a] (Sheet 2 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
	Bit 4 = RESET COMM CNTR Bit 5 = Reserved[d] Bit 6 = RST ENRGY DATA Bit 7 = RST MX/MN DATA Bit 8 = RST DEMAND Bit 9 = RST PEAK DEMAND Bit 10 = RST BKMON DATA Bit 11–Bit 15 = Reserved[d]						
262–269 (R)	Reserved[d]		0	0	0	1	362–369
Date/Time Set							
270 (R/W)	SET SEC		0	5999	0	0.01	370
271 (R/W)	SET MIN		0	59	0	1	371
272 (R/W)	SET HOUR		0	23	0	1	372
273 (R/W)	SET DAY		1	31	1	1	373
274 (R/W)	SET MONTH		1	12	1	1	374
275 (R/W)	SET YEAR		2000	9999	2000	1	375
276–279 (R)	Reserved[d]		0	0	0	1	376–379
Device Status 0 = OK 1 = WARN 2 = FAIL							
280 (R)	FPGA STATUS		0	2	0	1	380
281 (R)	GPSB STATUS		0	2	0	1	381
282 (R)	HMI STATUS		0	2	0	1	382
283 (R)	RAM STATUS		0	2	0	1	383
284 (R)	ROM STATUS		0	2	0	1	384
285 (R)	CR_RAM STATUS		0	2	0	1	385
286 (R)	NON_VOL STATUS		0	2	0	1	386
287 (R)	CLOCK STATUS		0	2	0	1	387
288 (R)	CID FILE STATUS		0	2	0	1	388
289 (R)	RTD STATUS		0	2	0	1	389
290 (R)	+0.9V STATUS		0	2	0	1	390
291 (R)	+1.2V STATUS		0	2	0	1	391
292 (R)	+1.5V STATUS		0	2	0	1	392
293 (R)	+1.8V STATUS		0	2	0	1	393
294 (R)	+2.5V STATUS		0	2	0	1	394
295 (R)	+3.3V STATUS		0	2	0	1	395
296 (R)	+3.75V STATUS		0	2	0	1	396
297 (R)	+5.0V STATUS		0	2	0	1	397
298 (R)	-1.25V STATUS		0	2	0	1	398
299 (R)	-5.0V STATUS		0	2	0	1	399
300 (R)	CLK_BAT STATUS		0	2	0	1	400
301 (R)	CARD C STATUS		0	2	0	1	401
302 (R)	CARD D STATUS		0	2	0	1	402
303 (R)	CARD E STATUS		0	2	0	1	403
304 (R)	CARD Z STATUS		0	2	0	1	404
305 (R)	IAW1 STATUS		0	2	0	1	405

Table E.34 Modbus Map[a] (Sheet 3 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
306 (R)	IBW1 STATUS		0	2	0	1	406
307 (R)	ICW1 STATUS		0	2	0	1	407
308 (R)	IAW2 STATUS		0	2	0	1	408
309 (R)	IBW2 STATUS		0	2	0	1	409
310 (R)	ICW2 STATUS		0	2	0	1	410
311 (R)	IAW3 STATUS		0	2	0	1	411
312 (R)	IBW3 STATUS		0	2	0	1	412
313 (R)	ICW3 STATUS		0	2	0	1	413
314 (R)	IAW4 STATUS		0	2	0	1	414
315 (R)	IBW4 STATUS		0	2	0	1	415
316 (R)	ICW4 STATUS		0	2	0	1	416
317 (R)	IN STATUS		0	2	0	1	417
318 (R)	VA STATUS		0	2	0	1	418
319 (R)	VB STATUS		0	2	0	1	419
320 (R)	VC STATUS		0	2	0	1	420
321 (R)	VS STATUS		0	2	0	1	421
322 (R)	RELAY STATUS		0	1	0	1	422
323 (R)	SERIAL NUMBER H		0	65535	0	1	423
324 (R)	SERIAL NUMBER L		0	65535	0	1	424
325–329 (R)	Reserved[d]		0	0	0	1	425–429
Current Data							
330 (R)	IAW1 CURRENT	A	0	65535	0	1	430
331 (R)	IAW1 ANGLE	deg	–1800	1800	0	0.1	431
332 (R)	IBW1 CURRENT	A	0	65535	0	1	432
333 (R)	IBW1 ANGLE	deg	–1800	1800	0	0.1	433
334 (R)	ICW1 CURRENT	A	0	65535	0	1	434
335 (R)	ICW1 ANGLE	deg	–1800	1800	0	0.1	435
336 (R)	IGW1 CURRENT	A	0	65535	0	1	436
337 (R)	IGW1 ANGLE	deg	–1800	1800	0	0.1	437
338 (R)	I1W1 PSEQ CURR	A	0	65535	0	1	438
339 (R)	I1W1 PSEQ ANGLE	deg	–1800	1800	0	0.1	439
340 (R)	3I2W1 NSEQ CURR	A	0	65535	0	1	440
341 (R)	3I2W1 NSEQ ANGLE	deg	–1800	1800	0	0.1	441
342 (R)	IAW2 CURRENT	A	0	65535	0	1	442
343 (R)	IAW2 ANGLE	deg	–1800	1800	0	0.1	443
344 (R)	IBW2 CURRENT	A	0	65535	0	1	444
345 (R)	IBW2 ANGLE	deg	–1800	1800	0	0.1	445
346 (R)	ICW2 CURRENT	A	0	65535	0	1	446
347 (R)	ICW2 ANGLE	deg	–1800	1800	0	0.1	447
348 (R)	IGW2 CURRENT	A	0	65535	0	1	448
349 (R)	IGW2 ANGLE	deg	–1800	1800	0	0.1	449
350 (R)	I1W2 PSEQ CURR	A	0	65535	0	1	450

Table E.34 Modbus Map[a] (Sheet 4 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
351 (R)	I1W2 PSEQ ANGLE	deg	–1800	1800	0	0.1	451
352 (R)	3I2W2 NSEQ CURR	A	0	65535	0	1	452
353 (R)	3I2W2 NSEQ ANGLE	deg	–1800	1800	0	0.1	453
354 (R)	IAW3 CURRENT	A	0	65535	0	1	454
355 (R)	IAW3 ANGLE	deg	–1800	1800	0	0.1	455
356 (R)	IBW3 CURRENT	A	0	65535	0	1	456
357 (R)	IBW3 ANGLE	deg	–1800	1800	0	0.1	457
358 (R)	ICW3 CURRENT	A	0	65535	0	1	458
359 (R)	ICW3 ANGLE	deg	–1800	1800	0	0.1	459
360 (R)	IGW3 CURRENT	A	0	65535	0	1	460
361 (R)	IGW3 ANGLE	deg	–1800	1800	0	0.1	461
362 (R)	I1W3 PSEQ CURR	A	0	65535	0	1	462
363 (R)	I1W3 PSEQ ANGLE	deg	–1800	1800	0	0.1	463
364 (R)	3I2W3 NSEQ CURR	A	0	65535	0	1	464
365 (R)	3I2W3 NSEQ ANGLE	deg	–1800	1800	0	0.1	465
366 (R)	IAW4 CURRENT	A	0	65535	0	1	466
367 (R)	IAW4 ANGLE	deg	–1800	1800	0	0.1	467
368 (R)	IBW4 CURRENT	A	0	65535	0	1	468
369 (R)	IBW4 ANGLE	deg	–1800	1800	0	0.1	469
370 (R)	ICW4 CURRENT	A	0	65535	0	1	470
371 (R)	ICW4 ANGLE	deg	–1800	1800	0	0.1	471
372 (R)	IGW4 CURRENT	A	0	65535	0	1	472
373 (R)	IGW4 ANGLE	deg	–1800	1800	0	0.1	473
374 (R)	I1W4 PSEQ CURR	A	0	65535	0	1	474
375 (R)	I1W4 PSEQ ANGLE	deg	–1800	1800	0	0.1	475
376 (R)	3I2W4 NSEQ CURR	A	0	65535	0	1	476
377 (R)	3I2W4 NSEQ ANGLE	deg	–1800	1800	0	0.1	477
378 (R)	IAW12 CURRENT	A	0	65535	0	1	478
379 (R)	IAW12 ANGLE	deg	–1800	1800	0	0.1	479
380 (R)	IBW12 CURRENT	A	0	65535	0	1	480
381 (R)	IBW12 ANGLE	deg	–1800	1800	0	0.1	481
382 (R)	ICW12 CURRENT	A	0	65535	0	1	482
383 (R)	ICW12 ANGLE	deg	–1800	1800	0	0.1	483
384 (R)	IGW12 CURRENT	A	0	65535	0	1	484
385 (R)	IGW12 ANGLE	deg	–1800	1800	0	0.1	485
386 (R)	I1W12 PSEQ CURR	A	0	65535	0	1	486
387 (R)	I1W12 PSEQ ANGLE	deg	–1800	1800	0	0.1	487
388 (R)	3I2W12 NSEQ CURR	A	0	65535	0	1	488
389 (R)	3I2W12 NSEQ ANG	deg	–1800	1800	0	0.1	489
390 (R)	IAW34 CURRENT	A	0	65535	0	1	490
391 (R)	IAW34 ANGLE	deg	–1800	1800	0	0.1	491
392 (R)	IBW34 CURRENT	A	0	65535	0	1	492

Table E.34 Modbus Map[a] (Sheet 5 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
393 (R)	IBW34 ANGLE	deg	–1800	1800	0	0.1	493
394 (R)	ICW34 CURRENT	A	0	65535	0	1	494
395 (R)	ICW34 ANGLE	deg	–1800	1800	0	0.1	495
396 (R)	IGW34 CURRENT	A	0	65535	0	1	496
397 (R)	IGW34 ANGLE	deg	–1800	1800	0	0.1	497
398 (R)	I1W34 PSEQ CURR	A	0	65535	0	1	498
399 (R)	I1W34 PSEQ ANGLE	deg	–1800	1800	0	0.1	499
400 (R)	3I2W34 NSEQ CURR	A	0	65535	0	1	500
401 (R)	3I2W34 NSEQ ANG	deg	–1800	1800	0	0.1	501
402 (R)	IN CURRENT	A	0	65535	0	1	502
403 (R)	IN ANGLE	deg	–1800	1800	0	0.1	503
404 (R)	IOP1 OPERATE	pu	0	65535	0	0.01	504
405 (R)	IOP2 OPERATE	pu	0	65535	0	0.01	505
406 (R)	IOP3 OPERATE	pu	0	65535	0	0.01	506
407 (R)	IRT1 RESTRAINT	pu	0	65535	0	0.01	507
408 (R)	IRT2 RESTRAINT	pu	0	65535	0	0.01	508
409 (R)	IRT3 RESTRAINT	pu	0	65535	0	0.01	509
Voltage Data							
410 (R)	VAB	kV	0	65535	0	0.01	510
411 (R)	VAB ANGLE	deg	–1800	1800	0	0.1	511
412 (R)	VBC	kV	0	65535	0	0.01	512
413 (R)	VBC ANGLE	deg	–1800	1800	0	0.1	513
414 (R)	VCA	kV	0	65535	0	0.01	514
415 (R)	VCA ANGLE	deg	–1800	1800	0	0.1	515
416 (R)	VAN	kV	0	65535	0	0.01	516
417 (R)	VAN ANGLE	deg	–1800	1800	0	0.1	517
418 (R)	VBN	kV	0	65535	0	0.01	518
419 (R)	VBN ANGLE	deg	–1800	1800	0	0.1	519
420 (R)	VCN	kV	0	65535	0	0.01	520
421 (R)	VCN ANGLE	deg	–1800	1800	0	0.1	521
422 (R)	VG	kV	0	65535	0	0.01	522
423 (R)	VG ANGLE	deg	–1800	1800	0	0.1	523
424 (R)	V1	kV	0	65535	0	0.01	524
425 (R)	V1 ANGLE	deg	–1800	1800	0	0.1	525
426 (R)	3V2	kV	0	65535	0	0.01	526
427 (R)	3V2 ANGLE	deg	–1800	1800	0	0.1	527
428 (R)	VSN	kV	0	65535	0	0.01	528
429 (R)	VSN ANGLE	deg	0	65535	0	1	529
430 (R)	VDC	V	0	65535	0	0.1	530
Power Data							
431 (R)	A REAL POWER	MW	–32768	32767	0	0.01	531
432 (R)	A REACTIVE POWER	MVAR	–32768	32767	0	0.01	532

Table E.34 Modbus Map[a] (Sheet 6 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
433 (R)	A APPARENT POWER	MVA	–32768	32767	0	0.01	533
434 (R)	B REAL POWER	MW	–32768	32767	0	0.01	534
435 (R)	B REACTIVE POWER	MVAR	–32768	32767	0	0.01	535
436 (R)	B APPARENT POWER	MVA	–32768	32767	0	0.01	536
437 (R)	C REAL POWER	MW	–32768	32767	0	0.01	537
438 (R)	C REACTIVE POWER	MVAR	–32768	32767	0	0.01	538
439 (R)	C APPARENT POWER	MVA	–32768	32767	0	0.01	539
440 (R)	REAL POWER	MW	–32768	32767	0	0.01	540
441 (R)	REACTIVE POWER	MVAR	–32768	32767	0	0.01	541
442 (R)	APPARENT POWER	MVA	–32768	32767	0	0.01	542
443 (R)	POWER FACTOR		–100	100	0	0.01	543
444 (R)	VOLTS PER HERTZ	%	0	1000	0	0.1	544
445 (R)	FREQUENCY	Hz	1500	7000	6000	0.01	545
446 (R)	SYNC FREQUENCY	Hz	1500	7000	6000	0.01	546
447 (R)	A POWER FACTOR		–100	100	0	0.01	547
448 (R)	B POWER FACTOR		–100	100	0	0.01	548
449 (R)	C POWER FACTOR		–100	100	0	0.01	549
Energy Data							
450 (R)	MWHP HI	MWhr	0	65535	0	0.001	550
451 (R)	MWHP LO	MWhr	0	65535	0	0.001	551
452 (R)	MWHN HI	MWhr	0	65535	0	0.001	552
453 (R)	MWHN LO	MWhr	0	65535	0	0.001	553
454 (R)	MVARHP HI	MVRh	0	65535	0	0.001	554
455 (R)	MVARHP LO	MVRh	0	65535	0	0.001	555
456 (R)	MVARHN HI	MVRh	0	65535	0	0.001	556
457 (R)	MVARHN LO	MVRh	0	65535	0	0.001	557
458 (R)	LAST RST TIME-ss		0	5999	0	0.01	558
459 (R)	LAST RST TIME-mm		0	59	0	1	559
460 (R)	LAST RST TIME-hh		0	23	0	1	560
461 (R)	LAST RST DATE-dd		1	31	1	1	561
462 (R)	LAST RST DATE-mm		1	12	1	1	562
463 (R)	LAST RST DATE-yy		2000	9999	2000	1	563
464–469 (R)	Reserved[d]		0	0	0	1	564–569
Demand Data							
470 (R)	IA DEMAND	A	0	65535	0	1	570
471 (R)	IB DEMAND	A	0	65535	0	1	571
472 (R)	IC DEMAND	A	0	65535	0	1	572
473 (R)	IG DEMAND	A	0	65535	0	1	573
474 (R)	3I2 DEMAND	A	0	65535	0	1	574
475 (R)	IA PEAK DEMAND	A	0	65535	0	1	575
476 (R)	IB PEAK DEMAND	A	0	65535	0	1	576
477 (R)	IC PEAK DEMAND	A	0	65535	0	1	577

Table E.34 Modbus Map[a] (Sheet 7 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
478 (R)	IG PEAK DEMAND	A	0	65535	0	1	578
479 (R)	3I2 PEAK DEMAND	A	0	65535	0	1	579
480 (R)	PEAKD RST TIM-ss		0	5999	0	0.01	580
481 (R)	PEAKD RST TIM-mm		0	59	0	1	581
482 (R)	PEAKD RST TIM-hh		0	23	0	1	582
483 (R)	PEAKD RST DAT-dd		1	31	1	1	583
484 (R)	PEAKD RST DAT-mm		1	12	1	1	584
485 (R)	PEAKD RST DAT-yy		2000	9999	2000	1	585
486–489 (R)	Reserved[d]		0	0	0	1	586–589
Harmonic Data							
490 (R)	IAW1 THD	%	0	65535	0	0.01	590
491 (R)	IBW1 THD	%	0	65535	0	0.01	591
492 (R)	ICW1 THD	%	0	65535	0	0.01	592
493 (R)	IAW2 THD	%	0	65535	0	0.01	593
494 (R)	IBW2 THD	%	0	65535	0	0.01	594
495 (R)	ICW2 THD	%	0	65535	0	0.01	595
496 (R)	IAW3 THD	%	0	65535	0	0.01	596
497 (R)	IBW3 THD	%	0	65535	0	0.01	597
498 (R)	ICW3 THD	%	0	65535	0	0.01	598
499 (R)	IAW4 THD	%	0	65535	0	0.01	599
500 (R)	IBW4 THD	%	0	65535	0	0.01	600
501 (R)	ICW4 THD	%	0	65535	0	0.01	601
502 (R)	VA THD	%	0	65535	0	0.01	602
503 (R)	VB THD	%	0	65535	0	0.01	603
504 (R)	VC THD	%	0	65535	0	0.01	604
505 (R)	VAB THD	%	0	65535	0	0.01	605
506 (R)	VBC THD	%	0	65535	0	0.01	606
507 (R)	VCA THD	%	0	65535	0	0.01	607
508–509 (R)	Reserved[d]		0	0	0	1	608–609
RTD Data							
510 (R)	MAX AMBIENT RTD 7FFFh = Open 8000h = Short 7FFCh = Comm Fail 7FF8h = Stat Fail 7FFEh = Fail 7FF0h = NA	degC	–32768	32767	0	1	610
511 (R)	MAX OTHER RTD	degC	–32768	32767	0	1	611
512 (R)	RTD1	degC	–32768	32767	0	1	612
513 (R)	RTD2	degC	–32768	32767	0	1	613
514 (R)	RTD3	degC	–32768	32767	0	1	614
515 (R)	RTD4	degC	–32768	32767	0	1	615
516 (R)	RTD5	degC	–32768	32767	0	1	616
517 (R)	RTD6	degC	–32768	32767	0	1	617

Table E.34 Modbus Map[a] (Sheet 8 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
518 (R)	RTD7	degC	–32768	32767	0	1	618
519 (R)	RTD8	degC	–32768	32767	0	1	619
520 (R)	RTD9	degC	–32768	32767	0	1	620
521 (R)	RTD10	degC	–32768	32767	0	1	621
522 (R)	RTD11	degC	–32768	32767	0	1	622
523 (R)	RTD12	degC	–32768	32767	0	1	623
Max/Min AI5 Data							
524 (R)	AI501 MX – HI	EU	–32768	32767	0	0.001	624
525 (R)	AI501 MX – LO	EU	–32768	32767	0	0.001	625
526 (R)	AI501 MN – HI	EU	–32768	32767	0	0.001	626
527 (R)	AI501 MN – LO	EU	–32768	32767	0	0.001	627
528 (R)	AI502 MX – HI	EU	–32768	32767	0	0.001	628
529 (R)	AI502 MX – LO	EU	–32768	32767	0	0.001	629
530 (R)	AI502 MN – HI	EU	–32768	32767	0	0.001	630
531 (R)	AI502 MN – LO	EU	–32768	32767	0	0.001	631
532 (R)	AI503 MX – HI	EU	–32768	32767	0	0.001	632
533 (R)	AI503 MX – LO	EU	–32768	32767	0	0.001	633
534 (R)	AI503 MN – HI	EU	–32768	32767	0	0.001	634
535 (R)	AI503 MN – LO	EU	–32768	32767	0	0.001	635
536 (R)	AI504 MX – HI	EU	–32768	32767	0	0.001	636
537 (R)	AI504 MX – LO	EU	–32768	32767	0	0.001	637
538 (R)	AI504 MN – HI	EU	–32768	32767	0	0.001	638
539 (R)	AI504 MN – LO	EU	–32768	32767	0	0.001	639
RMS Data							
540 (R)	IAW1 RMS	A	0	65535	0	1	640
541 (R)	IBW1 RMS	A	0	65535	0	1	641
542 (R)	ICW1 RMS	A	0	65535	0	1	642
543 (R)	IAW2 RMS	A	0	65535	0	1	643
544 (R)	IBW2 RMS	A	0	65535	0	1	644
545 (R)	ICW2 RMS	A	0	65535	0	1	645
546 (R)	IAW3 RMS	A	0	65535	0	1	646
547 (R)	IBW3 RMS	A	0	65535	0	1	647
548 (R)	ICW3 RMS	A	0	65535	0	1	648
549 (R)	IAW4 RMS	A	0	65535	0	1	649
550 (R)	IBW4 RMS	A	0	65535	0	1	650
551 (R)	ICW4 RMS	A	0	65535	0	1	651
552 (R)	IN RMS	A	0	65535	0	1	652
553 (R)	VA RMS	kV	0	65535	0	0.01	653
554 (R)	VB RMS	kV	0	65535	0	0.01	654
555 (R)	VC RMS	kV	0	65535	0	0.01	655
556 (R)	VAB RMS	kV	0	65535	0	0.01	656
557 (R)	VBC RMS	kV	0	65535	0	0.01	657

Table E.34 Modbus Map[a] (Sheet 9 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
558 (R)	VCA RMS	kV	0	65535	0	0.01	658
559 (R)	VS RMS	kV	0	65535	0	0.01	659
560–569 (R)	Reserved[d]		0	0	0	1	660–669
Breaker Monitor							
570 (R)	RELAY TRIP1 CNT		0	65535	0	1	670
571 (R)	EXTRN TRIP1 CNT		0	65535	0	1	671
572 (R)	RELAY TRIP1 IA	kA	0	65535	0	1	672
573 (R)	RELAY TRIP1 IB	kA	0	65535	0	1	673
574 (R)	RELAY TRIP1 IC	kA	0	65535	0	1	674
575 (R)	EXTRN TRIP1 IA	kA	0	65535	0	1	675
576 (R)	EXTRN TRIP1 IB	kA	0	65535	0	1	676
577 (R)	EXTRN TRIP1 IC	kA	0	65535	0	1	677
578 (R)	BRK1 WEAR POLE A	%	0	100	0	1	678
579 (R)	BRK1 WEAR POLE B	%	0	100	0	1	679
580 (R)	BRK1 WEAR POLE C	%	0	100	0	1	680
581 (R)	BRK 1 RST TIM-ss		0	5999	0	0.01	681
582 (R)	BRK 1 RST TIM-mm		0	59	0	1	682
583 (R)	BRK 1 RST TIM-hh		0	23	0	1	683
584 (R)	BRK 1 RST DAT-dd		1	31	1	1	684
585 (R)	BRK 1 RST DAT-mm		1	12	1	1	685
586 (R)	BRK 1 RST DAT-yy		2000	9999	2000	1	686
587 (R)	RELAY TRIP2 CNT		0	65535	0	1	687
588 (R)	EXTRN TRIP2 CNT		0	65535	0	1	688
589 (R)	RELAY TRIP2 IA	kA	0	65535	0	1	689
590 (R)	RELAY TRIP2 IB	kA	0	65535	0	1	690
591 (R)	RELAY TRIP2 IC	kA	0	65535	0	1	691
592 (R)	EXTRN TRIP2 IA	kA	0	65535	0	1	692
593 (R)	EXTRN TRIP2 IB	kA	0	65535	0	1	693
594 (R)	EXTRN TRIP2 IC	kA	0	65535	0	1	694
595 (R)	BRK2 WEAR POLE A	%	0	100	0	1	695
596 (R)	BRK2 WEAR POLE B	%	0	100	0	1	696
597 (R)	BRK2 WEAR POLE C	%	0	100	0	1	697
598 (R)	BRK 2 RST TIM-ss		0	5999	0	0.01	698
599 (R)	BRK 2 RST TIM-mm		0	59	0	1	699
600 (R)	BRK 2 RST TIM-hh		0	23	0	1	700
601 (R)	BRK 2 RST DAT-dd		1	31	1	1	701
602 (R)	BRK 2 RST DAT-mm		1	12	1	1	702
603 (R)	BRK 2 RST DAT-yy		2000	9999	2000	1	703
604 (R)	RELAY TRIP3 CNT		0	65535	0	1	704
605 (R)	EXTRN TRIP3 CNT		0	65535	0	1	705
606 (R)	RELAY TRIP3 IA	kA	0	65535	0	1	706
607 (R)	RELAY TRIP3 IB	kA	0	65535	0	1	707

Table E.34 Modbus Map[a] (Sheet 10 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
608 (R)	RELAY TRIP3 IC	kA	0	65535	0	1	708
609 (R)	EXTRN TRIP3 IA	kA	0	65535	0	1	709
610 (R)	EXTRN TRIP3 IB	kA	0	65535	0	1	710
611 (R)	EXTRN TRIP3 IC	kA	0	65535	0	1	711
612 (R)	BRK3 WEAR POLE A	%	0	100	0	1	712
613 (R)	BRK3 WEAR POLE B	%	0	100	0	1	713
614 (R)	BRK3 WEAR POLE C	%	0	100	0	1	714
615 (R)	BRK 3 RST TIM-ss		0	5999	0	0.01	715
616 (R)	BRK 3 RST TIM-mm		0	59	0	1	716
617 (R)	BRK 3 RST TIM-hh		0	23	0	1	717
618 (R)	BRK 3 RST DAT-dd		1	31	1	1	718
619 (R)	BRK 3 RST DAT-mm		1	12	1	1	719
620 (R)	BRK 3 RST DAT-yy		2000	9999	2000	1	720
621 (R)	RELAY TRIP4 CNT		0	65535	0	1	721
622 (R)	EXTRN TRIP4 CNT		0	65535	0	1	722
623 (R)	RELAY TRIP4 IA	kA	0	65535	0	1	723
624 (R)	RELAY TRIP4 IB	kA	0	65535	0	1	724
625 (R)	RELAY TRIP4 IC	kA	0	65535	0	1	725
626 (R)	EXTRN TRIP4 IA	kA	0	65535	0	1	726
627 (R)	EXTRN TRIP4 IB	kA	0	65535	0	1	727
628 (R)	EXTRN TRIP4 IC	kA	0	65535	0	1	728
629 (R)	BRK4 WEAR POLE A	%	0	100	0	1	729
630 (R)	BRK4 WEAR POLE B	%	0	100	0	1	730
631 (R)	BRK4 WEAR POLE C	%	0	100	0	1	731
632 (R)	BRK 4 RST TIM-ss		0	5999	0	0.01	732
633 (R)	BRK 4 RST TIM-mm		0	59	0	1	733
634 (R)	BRK 4 RST TIM-hh		0	23	0	1	734
635 (R)	BRK 4 RST DAT-dd		1	31	1	1	735
636 (R)	BRK 4 RST DAT-mm		1	12	1	1	736
637 (R)	BRK 4 RST DAT-yy		2000	9999	2000	1	737
638–639 (R)	Reserved[d]		0	0	0	1	738–739
Max/Min MTR Data							
640 (R)	IAW1 MAX	A	0	65535	0	1	740
641 (R)	IAW1 MIN	A	0	65535	0	1	741
642 (R)	IBW1 MAX	A	0	65535	0	1	742
643 (R)	IBW1 MIN	A	0	65535	0	1	743
644 (R)	ICW1 MAX	A	0	65535	0	1	744
645 (R)	ICW1 MIN	A	0	65535	0	1	745
646 (R)	IGW1 MAX	A	0	65535	0	1	746
647 (R)	IGW1 MIN	A	0	65535	0	1	747
648 (R)	IAW2 MAX	A	0	65535	0	1	748
649 (R)	IAW2 MIN	A	0	65535	0	1	749

Table E.34 Modbus Map[a] (Sheet 11 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
650 (R)	IBW2 MAX	A	0	65535	0	1	750
651 (R)	IBW2 MIN	A	0	65535	0	1	751
652 (R)	ICW2 MAX	A	0	65535	0	1	752
653 (R)	ICW2 MIN	A	0	65535	0	1	753
654 (R)	IGW2 MAX	A	0	65535	0	1	754
655 (R)	IGW2 MIN	A	0	65535	0	1	755
656 (R)	IAW3 MAX	A	0	65535	0	1	756
657 (R)	IAW3 MIN	A	0	65535	0	1	757
658 (R)	IBW3 MAX	A	0	65535	0	1	758
659 (R)	IBW3 MIN	A	0	65535	0	1	759
660 (R)	ICW3 MAX	A	0	65535	0	1	760
661 (R)	ICW3 MIN	A	0	65535	0	1	761
662 (R)	IGW3 MAX	A	0	65535	0	1	762
663 (R)	IGW3 MIN	A	0	65535	0	1	763
664 (R)	IAW4 MAX	A	0	65535	0	1	764
665 (R)	IAW4 MIN	A	0	65535	0	1	765
666 (R)	IBW4 MAX	A	0	65535	0	1	766
667 (R)	IBW4 MIN	A	0	65535	0	1	767
668 (R)	ICW4 MAX	A	0	65535	0	1	768
669 (R)	ICW4 MIN	A	0	65535	0	1	769
670 (R)	IGW4 MAX	A	0	65535	0	1	770
671 (R)	IGW4 MIN	A	0	65535	0	1	771
672 (R)	IN MAX	A	0	65535	0	1	772
673 (R)	IN MIN	A	0	65535	0	1	773
674 (R)	VAB/VA MAX	kV	0	65535	0	0.01	774
675 (R)	VAB/VA MIN	kV	0	65535	0	0.01	775
676 (R)	VBC/VB MAX	kV	0	65535	0	0.01	776
677 (R)	VBC/VB MIN	kV	0	65535	0	0.01	777
678 (R)	VCA/VC MAX	kV	0	65535	0	0.01	778
679 (R)	VCA/VC MIN	kV	0	65535	0	0.01	779
680 (R)	KW3P MAX	MW	–32768	32767	0	0.01	780
681 (R)	KW3P MIN	MW	–32768	32767	0	0.01	781
682 (R)	KVAR3P MAX	MVAR	–32768	32767	0	0.01	782
683 (R)	KVAR3P MIN	MVAR	–32768	32767	0	0.01	783
684 (R)	KVA3P MAX	MVA	–32768	32767	0	0.01	784
685 (R)	KVA3P MIN	MVA	–32768	32767	0	0.01	785
686 (R)	FREQ MAX	Hz	0	65535	0	0.01	786
687 (R)	FREQ MIN	Hz	0	65535	0	0.01	787
688 (R)	IAW23 CURRENT	A	0	65535	0	1	788
689 (R)	IAW23 ANGLE	deg	–1800	1800	0	0.1	789
690 (R)	IBW23 CURRENT	A	0	65535	0	1	790
691 (R)	IBW23 ANGLE	deg	–1800	1800	0	0.1	790

Table E.34 Modbus Map[a] (Sheet 12 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
692 (R)	ICW23 CURRENT	A	0	65535	0	1	792
693 (R)	ICW23 ANGLE	deg	–1800	1800	0	0.1	793
694 (R)	IGW23 CURRENT	A	0	65535	0	1	794
695 (R)	IGW23 ANGLE	deg	–1800	1800	0	0.1	795
696 (R)	I1W23 PSEQ CURR	A	0	65535	0	1	796
697 (R)	I1W23 PSEQ ANGLE	deg	–1800	1800	0	0.1	797
698 (R)	3I2W23 NSEQ CURR	A	0	65535	0	1	798
699 (R)	3I2W23 NSEQ ANG	deg	–1800	1800	0	0.1	799
Max/Min RTD Data							
700 (R)	RTD1 MAX	degC	–32768	32767	0	1	800
701 (R)	RTD1 MIN	degC	–32768	32767	0	1	801
702 (R)	RTD2 MAX	degC	–32768	32767	0	1	802
703 (R)	RTD2 MIN	degC	–32768	32767	0	1	803
704 (R)	RTD3 MAX	degC	–32768	32767	0	1	804
705 (R)	RTD3 MIN	degC	–32768	32767	0	1	805
706 (R)	RTD4 MAX	degC	–32768	32767	0	1	806
707 (R)	RTD4 MIN	degC	–32768	32767	0	1	807
708 (R)	RTD5 MAX	degC	–32768	32767	0	1	808
709 (R)	RTD5 MIN	degC	–32768	32767	0	1	809
710 (R)	RTD6 MAX	degC	–32768	32767	0	1	810
711 (R)	RTD6 MIN	degC	–32768	32767	0	1	811
712 (R)	RTD7 MAX	degC	–32768	32767	0	1	812
713 (R)	RTD7 MIN	degC	–32768	32767	0	1	813
714 (R)	RTD8 MAX	degC	–32768	32767	0	1	814
715 (R)	RTD8 MIN	degC	–32768	32767	0	1	815
716 (R)	RTD9 MAX	degC	–32768	32767	0	1	816
717 (R)	RTD9 MIN	degC	–32768	32767	0	1	817
718 (R)	RTD10 MAX	degC	–32768	32767	0	1	818
719 (R)	RTD10 MIN	degC	–32768	32767	0	1	819
720 (R)	RTD11 MAX	degC	–32768	32767	0	1	820
721 (R)	RTD11 MIN	degC	–32768	32767	0	1	821
722 (R)	RTD12 MAX	degC	–32768	32767	0	1	822
723 (R)	RTD12 MIN	degC	–32768	32767	0	1	823
724–729 (R)	Reserved[d]		0	0	0	1	824–829
Max/Min AI3 Data							
730 (R)	AI301 MX–HI	EU	–32768	32767	0	0.001	830
731 (R)	AI301 MX–LO	EU	–32768	32767	0	0.001	831
732 (R)	AI301 MN–HI	EU	–32768	32767	0	0.001	832
733 (R)	AI301 MN–LO	EU	–32768	32767	0	0.001	833
734 (R)	AI302 MX–HI	EU	–32768	32767	0	0.001	834
735 (R)	AI302 MX–LO	EU	–32768	32767	0	0.001	835
736 (R)	AI302 MN–HI	EU	–32768	32767	0	0.001	836

Table E.34 Modbus Map[a] (Sheet 13 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
737 (R)	AI302 MN–LO	EU	–32768	32767	0	0.001	837
738 (R)	AI303 MX–HI	EU	–32768	32767	0	0.001	838
739 (R)	AI303 MX–LO	EU	–32768	32767	0	0.001	839
740 (R)	AI303 MN–HI	EU	–32768	32767	0	0.001	840
741 (R)	AI303 MN–LO	EU	–32768	32767	0	0.001	841
742 (R)	AI304 MX–HI	EU	–32768	32767	0	0.001	842
743 (R)	AI304 MX–LO	EU	–32768	32767	0	0.001	843
744 (R)	AI304 MN–HI	EU	–32768	32767	0	0.001	844
745 (R)	AI304 MN–LO	EU	–32768	32767	0	0.001	845
746–749 (R)	Reserved[d]		0	0	0	1	846–849
Max/Min AI4 Data							
750 (R)	AI401 MX–HI	EU	–32768	32767	0	0.001	850
751 (R)	AI401 MX–LO	EU	–32768	32767	0	0.001	851
752 (R)	AI401 MN–HI	EU	–32768	32767	0	0.001	852
753 (R)	AI401 MN–LO	EU	–32768	32767	0	0.001	853
754 (R)	AI402 MX–HI	EU	–32768	32767	0	0.001	854
755 (R)	AI402 MX–LO	EU	–32768	32767	0	0.001	855
756 (R)	AI402 MN–HI	EU	–32768	32767	0	0.001	856
757 (R)	AI402 MN–LO	EU	–32768	32767	0	0.001	857
758 (R)	AI403 MX–HI	EU	–32768	32767	0	0.001	858
759 (R)	AI403 MX–LO	EU	–32768	32767	0	0.001	859
760 (R)	AI403 MN–HI	EU	–32768	32767	0	0.001	860
761 (R)	AI403 MN–LO	EU	–32768	32767	0	0.001	861
762 (R)	AI404 MX–HI	EU	–32768	32767	0	0.001	862
763 (R)	AI404 MX–LO	EU	–32768	32767	0	0.001	863
764 (R)	AI404 MN–HI	EU	–32768	32767	0	0.001	864
765 (R)	AI404 MN–LO	EU	–32768	32767	0	0.001	865
766–769 (R)	Reserved[d]		0	0	0	1	866–869
Max/Min RST Data							
770 (R)	MX/MN RST TIM-ss		0	5999	0	0.01	870
771 (R)	MX/MN RST TIM-mm		0	59	0	1	871
772 (R)	MX/MN RST TIM-hh		0	23	0	1	872
773 (R)	MX/MN RST DAT-dd		1	31	1	1	873
774 (R)	MX/MN RST DAT-mm		1	12	1	1	874
775 (R)	MX/MN RST DAT-yy		2000	9999	2000	1	875
776–779 (R)	Reserved[d]		0	0	0	1	876–879
Analog Input Data							
780 (R)	AI301–HI	EU	–32768	32767	0	0.001	880
781 (R)	AI301–LO	EU	–32768	32767	0	0.001	881
782 (R)	AI302–HI	EU	–32768	32767	0	0.001	882
783 (R)	AI302–LO	EU	–32768	32767	0	0.001	883
784 (R)	AI303–HI	EU	–32768	32767	0	0.001	884

Table E.34 Modbus Map[a] (Sheet 14 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
785 (R)	AI303–LO	EU	–32768	32767	0	0.001	885
786 (R)	AI304–HI	EU	–32768	32767	0	0.001	886
787 (R)	AI304–LO	EU	–32768	32767	0	0.001	887
788 (R)	AI401–HI	EU	–32768	32767	0	0.001	888
789 (R)	AI401–LO	EU	–32768	32767	0	0.001	889
790 (R)	AI402–HI	EU	–32768	32767	0	0.001	890
791 (R)	AI402–LO	EU	–32768	32767	0	0.001	891
792 (R)	AI403–HI	EU	–32768	32767	0	0.001	892
793 (R)	AI403–LO	EU	–32768	32767	0	0.001	893
794 (R)	AI404–HI	EU	–32768	32767	0	0.001	894
795 (R)	AI404–LO	EU	–32768	32767	0	0.001	895
796–799 (R)	Reserved[d]		0	0	0	1	896–899
Math Variables							
800 (R)	MV01–HI		–32768	32767	0	0.01	900
801 (R)	MV01–LO		–32768	32767	0	0.01	901
802 (R)	MV02–HI		–32768	32767	0	0.01	902
803 (R)	MV02–LO		–32768	32767	0	0.01	903
804 (R)	MV03–HI		–32768	32767	0	0.01	904
805 (R)	MV03–LO		–32768	32767	0	0.01	905
806 (R)	MV04–HI		–32768	32767	0	0.01	906
807 (R)	MV04–LO		–32768	32767	0	0.01	907
808 (R)	MV05–HI		–32768	32767	0	0.01	908
809 (R)	MV05–LO		–32768	32767	0	0.01	909
810 (R)	MV06–HI		–32768	32767	0	0.01	910
811 (R)	MV06–LO		–32768	32767	0	0.01	911
812 (R)	MV07–HI		–32768	32767	0	0.01	912
813 (R)	MV07–LO		–32768	32767	0	0.01	913
814 (R)	MV08–HI		–32768	32767	0	0.01	914
815 (R)	MV08–LO		–32768	32767	0	0.01	915
816 (R)	MV09–HI		–32768	32767	0	0.01	916
817 (R)	MV09–LO		–32768	32767	0	0.01	917
818 (R)	MV10–HI		–32768	32767	0	0.01	918
819 (R)	MV10–LO		–32768	32767	0	0.01	919
820 (R)	MV11–HI		–32768	32767	0	0.01	920
821 (R)	MV11–LO		–32768	32767	0	0.01	921
822 (R)	MV12–HI		–32768	32767	0	0.01	922
823 (R)	MV12–LO		–32768	32767	0	0.01	923
824 (R)	MV13–HI		–32768	32767	0	0.01	924
825 (R)	MV13–LO		–32768	32767	0	0.01	925
826 (R)	MV14–HI		–32768	32767	0	0.01	926
827 (R)	MV14–LO		–32768	32767	0	0.01	927
828 (R)	MV15–HI		–32768	32767	0	0.01	928

Table E.34 Modbus Map[a] (Sheet 15 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
829 (R)	MV15–LO		–32768	32767	0	0.01	929
830 (R)	MV16–HI		–32768	32767	0	0.01	930
831 (R)	MV16–LO		–32768	32767	0	0.01	931
832 (R)	MV17–HI		–32768	32767	0	0.01	932
833 (R)	MV17–LO		–32768	32767	0	0.01	933
834 (R)	MV18–HI		–32768	32767	0	0.01	934
835 (R)	MV18–LO		–32768	32767	0	0.01	935
836 (R)	MV19–HI		–32768	32767	0	0.01	936
837 (R)	MV19–LO		–32768	32767	0	0.01	937
838 (R)	MV20–HI		–32768	32767	0	0.01	938
839 (R)	MV20–LO		–32768	32767	0	0.01	939
840 (R)	MV21–HI		–32768	32767	0	0.01	940
841 (R)	MV21–LO		–32768	32767	0	0.01	941
842 (R)	MV22–HI		–32768	32767	0	0.01	942
843 (R)	MV22–LO		–32768	32767	0	0.01	943
844 (R)	MV23–HI		–32768	32767	0	0.01	944
845 (R)	MV23–LO		–32768	32767	0	0.01	945
846 (R)	MV24–HI		–32768	32767	0	0.01	946
847 (R)	MV24–LO		–32768	32767	0	0.01	947
848 (R)	MV25–HI		–32768	32767	0	0.01	948
849 (R)	MV25–LO		–32768	32767	0	0.01	949
850 (R)	MV26–HI		–32768	32767	0	0.01	950
851 (R)	MV26–LO		–32768	32767	0	0.01	951
852 (R)	MV27–HI		–32768	32767	0	0.01	952
853 (R)	MV27–LO		–32768	32767	0	0.01	953
854 (R)	MV28–HI		–32768	32767	0	0.01	954
855 (R)	MV28–LO		–32768	32767	0	0.01	955
856 (R)	MV29–HI		–32768	32767	0	0.01	956
857 (R)	MV29–LO		–32768	32767	0	0.01	957
858 (R)	MV30–HI		–32768	32767	0	0.01	958
859 (R)	MV30–LO		–32768	32767	0	0.01	959
860 (R)	MV31–HI		–32768	32767	0	0.01	960
861 (R)	MV31–LO		–32768	32767	0	0.01	961
862 (R)	MV32–HI		–32768	32767	0	0.01	962
863 (R)	MV32–LO		–32768	32767	0	0.01	963
864–869 (R)	Reserved[d]		0	0	0	1	964–969
Device Counters							
870 (R)	COUNTER SC01		0	65000	0	1	970
	• • •						• • •
901 (R)	COUNTER SC32		0	65000	0	1	1001
Analog Input Data							

Table E.34 Modbus Map[a] (Sheet 16 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
902 (R)	AI501 – HI	EU	–32768	32767	0	0.001	1002
903 (R)	AI501 – LO	EU	–32768	32767	0	0.001	1003
904 (R)	AI502 – HI	EU	–32768	32767	0	0.001	1004
905 (R)	AI502 – LO	EU	–32768	32767	0	0.001	1005
906 (R)	AI503 – HI	EU	–32768	32767	0	0.001	1006
907 (R)	AI503 – LO	EU	–32768	32767	0	0.001	1007
908 (R)	AI504 – HI	EU	–32768	32767	0	0.001	1008
909 (R)	AI504 – LO	EU	–32768	32767	0	0.001	1009
910–919 (R)	Reserved[d]		0	0	0	1	1010–1019
Remote Analogs 1							
920 (R/W)	RA001 (0:UW)		–32768	32767	0	0.01	1020
921 (R/W)	RA001 (1:LW)		–32768	32767	0	0.01	1021
922 (R/W)	RA002 (0:UW)		–32768	32767	0	0.01	1022
923 (R/W)	RA002 (1:LW)		–32768	32767	0	0.01	1023
924 (R/W)	RA003 (0:UW)		–32768	32767	0	0.01	1024
925 (R/W)	RA003 (1:LW)		–32768	32767	0	0.01	1025
926 (R/W)	RA004 (0:UW)		–32768	32767	0	0.01	1026
927 (R/W)	RA004 (1:LW)		–32768	32767	0	0.01	1027
928 (R/W)	RA005 (0:UW)		–32768	32767	0	0.01	1028
929 (R/W)	RA005 (1:LW)		–32768	32767	0	0.01	1029
930 (R/W)	RA006 (0:UW)		–32768	32767	0	0.01	1030
931 (R/W)	RA006 (1:LW)		–32768	32767	0	0.01	1031
932 (R/W)	RA007 (0:UW)		–32768	32767	0	0.01	1032
933 (R/W)	RA007 (1:LW)		–32768	32767	0	0.01	1033
934 (R/W)	RA008 (0:UW)		–32768	32767	0	0.01	1034
935 (R/W)	RA008 (1:LW)		–32768	32767	0	0.01	1035
936 (R/W)	RA009 (0:UW)		–32768	32767	0	0.01	1036
937 (R/W)	RA009 (1:LW)		–32768	32767	0	0.01	1037
938 (R/W)	RA010 (0:UW)		–32768	32767	0	0.01	1038
939 (R/W)	RA010 (1:LW)		–32768	32767	0	0.01	1039
940 (R/W)	RA011 (0:UW)		–32768	32767	0	0.01	1040
941 (R/W)	RA011 (1:LW)		–32768	32767	0	0.01	1041
942 (R/W)	RA012 (0:UW)		–32768	32767	0	0.01	1042
943 (R/W)	RA012 (1:LW)		–32768	32767	0	0.01	1043
944 (R/W)	RA013 (0:UW)		–32768	32767	0	0.01	1044
945 (R/W)	RA013 (1:LW)		–32768	32767	0	0.01	1045
946 (R/W)	RA014 (0:UW)		–32768	32767	0	0.01	1046
947 (R/W)	RA014 (1:LW)		–32768	32767	0	0.01	1047
948 (R/W)	RA015 (0:UW)		–32768	32767	0	0.01	1048
949 (R/W)	RA015 (1:LW)		–32768	32767	0	0.01	1049
950 (R/W)	RA016 (0:UW)		–32768	32767	0	0.01	1050
951 (R/W)	RA016 (1:LW)		–32768	32767	0	0.01	1051

Table E.34 Modbus Map[a] (Sheet 17 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
952 (R/W)	RA017 (0:UW)		–32768	32767	0	0.01	1052
953 (R/W)	RA017 (1:LW)		–32768	32767	0	0.01	1053
954 (R/W)	RA018 (0:UW)		–32768	32767	0	0.01	1054
955 (R/W)	RA018 (1:LW)		–32768	32767	0	0.01	1055
956 (R/W)	RA019 (0:UW)		–32768	32767	0	0.01	1056
957 (R/W)	RA019 (1:LW)		–32768	32767	0	0.01	1057
958 (R/W)	RA020 (0:UW)		–32768	32767	0	0.01	1058
959 (R/W)	RA020 (1:LW)		–32768	32767	0	0.01	1059
960 (R/W)	RA021 (0:UW)		–32768	32767	0	0.01	1060
961 (R/W)	RA021 (1:LW)		–32768	32767	0	0.01	1061
962 (R/W)	RA022 (0:UW)		–32768	32767	0	0.01	1062
963 (R/W)	RA022 (1:LW)		–32768	32767	0	0.01	1063
964 (R/W)	RA023 (0:UW)		–32768	32767	0	0.01	1064
965 (R/W)	RA023 (1:LW)		–32768	32767	0	0.01	1065
966 (R/W)	RA024 (0:UW)		–32768	32767	0	0.01	1066
967 (R/W)	RA024 (1:LW)		–32768	32767	0	0.01	1067
968 (R/W)	RA025 (0:UW)		–32768	32767	0	0.01	1068
969 (R/W)	RA025 (1:LW)		–32768	32767	0	0.01	1069
970 (R/W)	RA026 (0:UW)		–32768	32767	0	0.01	1070
971 (R/W)	RA026 (1:LW)		–32768	32767	0	0.01	1071
972 (R/W)	RA027 (0:UW)		–32768	32767	0	0.01	1072
973 (R/W)	RA027 (1:LW)		–32768	32767	0	0.01	1073
974 (R/W)	RA028 (0:UW)		–32768	32767	0	0.01	1074
975 (R/W)	RA028 (1:LW)		–32768	32767	0	0.01	1075
976 (R/W)	RA029 (0:UW)		–32768	32767	0	0.01	1076
977 (R/W)	RA029 (1:LW)		–32768	32767	0	0.01	1077
978 (R/W)	RA030 (0:UW)		–32768	32767	0	0.01	1078
979 (R/W)	RA030 (1:LW)		–32768	32767	0	0.01	1079
980 (R/W)	RA031 (0:UW)		–32768	32767	0	0.01	1080
981 (R/W)	RA031 (1:LW)		–32768	32767	0	0.01	1081
982 (R/W)	RA032 (0:UW)		–32768	32767	0	0.01	1082
983 (R/W)	RA032 (1:LW)		–32768	32767	0	0.01	1083
984 (R/W)	RA033 (0:UW)		–32768	32767	0	0.01	1084
985 (R/W)	RA033 (1:LW)		–32768	32767	0	0.01	1085
986 (R/W)	RA034 (0:UW)		–32768	32767	0	0.01	1086
987 (R/W)	RA034 (1:LW)		–32768	32767	0	0.01	1087
988 (R/W)	RA035 (0:UW)		–32768	32767	0	0.01	1088
989 (R/W)	RA035 (1:LW)		–32768	32767	0	0.01	1089
990 (R/W)	RA036 (0:UW)		–32768	32767	0	0.01	1090
991 (R/W)	RA036 (1:LW)		–32768	32767	0	0.01	1091
992 (R/W)	RA037 (0:UW)		–32768	32767	0	0.01	1092
993 (R/W)	RA037 (1:LW)		–32768	32767	0	0.01	1093

Table E.34 Modbus Map[a] (Sheet 18 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
994 (R/W)	RA038 (0:UW)		–32768	32767	0	0.01	1094
995 (R/W)	RA038 (1:LW)		–32768	32767	0	0.01	1095
996 (R/W)	RA039 (0:UW)		–32768	32767	0	0.01	1096
997 (R/W)	RA039 (1:LW)		–32768	32767	0	0.01	1097
998 (R/W)	RA040 (0:UW)		–32768	32767	0	0.01	1098
999 (R/W)	RA040 (1:LW)		–32768	32767	0	0.01	1099
1000 (R/W)	RA041 (0:UW)		–32768	32767	0	0.01	1100
1001 (R/W)	RA041 (1:LW)		–32768	32767	0	0.01	1101
1002 (R/W)	RA042 (0:UW)		–32768	32767	0	0.01	1102
1003 (R/W)	RA042 (1:LW)		–32768	32767	0	0.01	1103
1004 (R/W)	RA043 (0:UW)		–32768	32767	0	0.01	1104
1005 (R/W)	RA043 (1:LW)		–32768	32767	0	0.01	1105
1006 (R/W)	RA044 (0:UW)		–32768	32767	0	0.01	1106
1007 (R/W)	RA044 (1:LW)		–32768	32767	0	0.01	1107
1008 (R/W)	RA045 (0:UW)		–32768	32767	0	0.01	1108
1009 (R/W)	RA045 (1:LW)		–32768	32767	0	0.01	1109
1010 (R/W)	RA046 (0:UW)		–32768	32767	0	0.01	1110
1011 (R/W)	RA046 (1:LW)		–32768	32767	0	0.01	1111
1012 (R/W)	RA047 (0:UW)		–32768	32767	0	0.01	1112
1013 (R/W)	RA047 (1:LW)		–32768	32767	0	0.01	1113
1014 (R/W)	RA048 (0:UW)		–32768	32767	0	0.01	1114
1015 (R/W)	RA048 (1:LW)		–32768	32767	0	0.01	1115
1016 (R/W)	RA049 (0:UW)		–32768	32767	0	0.01	1116
1017 (R/W)	RA049 (1:LW)		–32768	32767	0	0.01	1117
1018 (R/W)	RA050 (0:UW)		–32768	32767	0	0.01	1118
1019 (R/W)	RA050 (1:LW)		–32768	32767	0	0.01	1119
1020 (R/W)	RA051 (0:UW)		–32768	32767	0	0.01	1120
1021 (R/W)	RA051 (1:LW)		–32768	32767	0	0.01	1121
1022 (R/W)	RA052 (0:UW)		–32768	32767	0	0.01	1122
1023 (R/W)	RA052 (1:LW)		–32768	32767	0	0.01	1123
1024 (R/W)	RA053 (0:UW)		–32768	32767	0	0.01	1124
1025 (R/W)	RA053 (1:LW)		–32768	32767	0	0.01	1125
1026 (R/W)	RA054 (0:UW)		–32768	32767	0	0.01	1126
1027 (R/W)	RA054 (1:LW)		–32768	32767	0	0.01	1127
1028 (R/W)	RA055 (0:UW)		–32768	32767	0	0.01	1128
1029 (R/W)	RA055 (1:LW)		–32768	32767	0	0.01	1129
1030 (R/W)	RA056 (0:UW)		–32768	32767	0	0.01	1130
1031 (R/W)	RA056 (1:LW)		–32768	32767	0	0.01	1131
1032 (R/W)	RA057 (0:UW)		–32768	32767	0	0.01	1132
1033 (R/W)	RA057 (1:LW)		–32768	32767	0	0.01	1133
1034 (R/W)	RA058 (0:UW)		–32768	32767	0	0.01	1134
1035 (R/W)	RA058 (1:LW)		–32768	32767	0	0.01	1135

Table E.34 Modbus Map[a] (Sheet 19 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
1036 (R/W)	RA059 (0:UW)		–32768	32767	0	0.01	1136
1037 (R/W)	RA059 (1:LW)		–32768	32767	0	0.01	1137
1038 (R/W)	RA060 (0:UW)		–32768	32767	0	0.01	1138
1039 (R/W)	RA060 (1:LW)		–32768	32767	0	0.01	1139
1040 (R/W)	RA061 (0:UW)		–32768	32767	0	0.01	1140
1041 (R/W)	RA061 (1:LW)		–32768	32767	0	0.01	1141
1042 (R/W)	RA062 (0:UW)		–32768	32767	0	0.01	1142
1043 (R/W)	RA062 (1:LW)		–32768	32767	0	0.01	1143
1044 (R/W)	RA063 (0:UW)		–32768	32767	0	0.01	1144
1045 (R/W)	RA063 (1:LW)		–32768	32767	0	0.01	1145
1046 (R/W)	RA064 (0:UW)		–32768	32767	0	0.01	1146
1047 (R/W)	RA064 (1:LW)		–32768	32767	0	0.01	1147
Remote Analogs 2							
1048 (R/W)	RA065 (0:UW)		–32768	32767	0	0.01	1148
1049 (R/W)	RA065 (1:LW)		–32768	32767	0	0.01	1149
1050 (R/W)	RA066 (0:UW)		–32768	32767	0	0.01	1150
1051 (R/W)	RA066 (1:LW)		–32768	32767	0	0.01	1151
1052 (R/W)	RA067 (0:UW)		–32768	32767	0	0.01	1152
1053 (R/W)	RA067 (1:LW)		–32768	32767	0	0.01	1153
1054 (R/W)	RA068 (0:UW)		–32768	32767	0	0.01	1154
1055 (R/W)	RA068 (1:LW)		–32768	32767	0	0.01	1155
1056 (R/W)	RA069 (0:UW)		–32768	32767	0	0.01	1156
1057 (R/W)	RA069 (1:LW)		–32768	32767	0	0.01	1157
1058 (R/W)	RA070 (0:UW)		–32768	32767	0	0.01	1158
1059 (R/W)	RA070 (1:LW)		–32768	32767	0	0.01	1159
1060 (R/W)	RA071 (0:UW)		–32768	32767	0	0.01	1160
1061 (R/W)	RA071 (1:LW)		–32768	32767	0	0.01	1161
1062 (R/W)	RA072 (0:UW)		–32768	32767	0	0.01	1162
1063 (R/W)	RA072 (1:LW)		–32768	32767	0	0.01	1163
1064 (R/W)	RA073 (0:UW)		–32768	32767	0	0.01	1164
1065 (R/W)	RA073 (1:LW)		–32768	32767	0	0.01	1165
1066 (R/W)	RA074 (0:UW)		–32768	32767	0	0.01	1166
1067 (R/W)	RA074 (1:LW)		–32768	32767	0	0.01	1167
1068 (R/W)	RA075 (0:UW)		–32768	32767	0	0.01	1168
1069 (R/W)	RA075 (1:LW)		–32768	32767	0	0.01	1169
1070 (R/W)	RA076 (0:UW)		–32768	32767	0	0.01	1170
1071 (R/W)	RA076 (1:LW)		–32768	32767	0	0.01	1171
1072 (R/W)	RA077 (0:UW)		–32768	32767	0	0.01	1172
1073 (R/W)	RA077 (1:LW)		–32768	32767	0	0.01	1173
1074 (R/W)	RA078 (0:UW)		–32768	32767	0	0.01	1174
1075 (R/W)	RA078 (1:LW)		–32768	32767	0	0.01	1175
1076 (R/W)	RA079 (0:UW)		–32768	32767	0	0.01	1176

Table E.34 Modbus Map[a] (Sheet 20 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
1077 (R/W)	RA079 (1:LW)		–32768	32767	0	0.01	1177
1078 (R/W)	RA080 (0:UW)		–32768	32767	0	0.01	1178
1079 (R/W)	RA080 (1:LW)		–32768	32767	0	0.01	1179
1080 (R/W)	RA081 (0:UW)		–32768	32767	0	0.01	1180
1081 (R/W)	RA081 (1:LW)		–32768	32767	0	0.01	1181
1082 (R/W)	RA082 (0:UW)		–32768	32767	0	0.01	1182
1083 (R/W)	RA082 (1:LW)		–32768	32767	0	0.01	1183
1084 (R/W)	RA083 (0:UW)		–32768	32767	0	0.01	1184
1085 (R/W)	RA083 (1:LW)		–32768	32767	0	0.01	1185
1086 (R/W)	RA084 (0:UW)		–32768	32767	0	0.01	1186
1087 (R/W)	RA084 (1:LW)		–32768	32767	0	0.01	1187
1088 (R/W)	RA085 (0:UW)		–32768	32767	0	0.01	1188
1089 (R/W)	RA085 (1:LW)		–32768	32767	0	0.01	1189
1090 (R/W)	RA086 (0:UW)		–32768	32767	0	0.01	1190
1091 (R/W)	RA086 (1:LW)		–32768	32767	0	0.01	1191
1092 (R/W)	RA087 (0:UW)		–32768	32767	0	0.01	1192
1093 (R/W)	RA087 (1:LW)		–32768	32767	0	0.01	1193
1094 (R/W)	RA088 (0:UW)		–32768	32767	0	0.01	1194
1095 (R/W)	RA088 (1:LW)		–32768	32767	0	0.01	1195
1096 (R/W)	RA089 (0:UW)		–32768	32767	0	0.01	1196
1097 (R/W)	RA089 (1:LW)		–32768	32767	0	0.01	1197
1098 (R/W)	RA090 (0:UW)		–32768	32767	0	0.01	1198
1099 (R/W)	RA090 (1:LW)		–32768	32767	0	0.01	1199
1100 (R/W)	RA091 (0:UW)		–32768	32767	0	0.01	1200
1101 (R/W)	RA091 (1:LW)		–32768	32767	0	0.01	1201
1102 (R/W)	RA092 (0:UW)		–32768	32767	0	0.01	1202
1103 (R/W)	RA092 (1:LW)		–32768	32767	0	0.01	1203
1104 (R/W)	RA093 (0:UW)		–32768	32767	0	0.01	1204
1105 (R/W)	RA093 (1:LW)		–32768	32767	0	0.01	1205
1106 (R/W)	RA094 (0:UW)		–32768	32767	0	0.01	1206
1107 (R/W)	RA094 (1:LW)		–32768	32767	0	0.01	1207
1108 (R/W)	RA095 (0:UW)		–32768	32767	0	0.01	1208
1109 (R/W)	RA095 (1:LW)		–32768	32767	0	0.01	1209
1110 (R/W)	RA096 (0:UW)		–32768	32767	0	0.01	1210
1111 (R/W)	RA096 (1:LW)		–32768	32767	0	0.01	1211
1112 (R/W)	RA097 (0:UW)		–32768	32767	0	0.01	1212
1113 (R/W)	RA097 (1:LW)		–32768	32767	0	0.01	1213
1114 (R/W)	RA098 (0:UW)		–32768	32767	0	0.01	1214
1115 (R/W)	RA098 (1:LW)		–32768	32767	0	0.01	1215
1116 (R/W)	RA099 (0:UW)		–32768	32767	0	0.01	1216
1117 (R/W)	RA099 (1:LW)		–32768	32767	0	0.01	1217
1118 (R/W)	RA100 (0:UW)		–32768	32767	0	0.01	1218

Table E.34 Modbus Map[a] (Sheet 21 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
1119 (R/W)	RA100 (1:LW)		–32768	32767	0	0.01	1219
1120 (R/W)	RA101 (0:UW)		–32768	32767	0	0.01	1220
1121 (R/W)	RA101 (1:LW)		–32768	32767	0	0.01	1221
1122 (R/W)	RA102 (0:UW)		–32768	32767	0	0.01	1222
1123 (R/W)	RA102 (1:LW)		–32768	32767	0	0.01	1223
1124 (R/W)	RA103 (0:UW)		–32768	32767	0	0.01	1224
1125 (R/W)	RA103 (1:LW)		–32768	32767	0	0.01	1225
1126 (R/W)	RA104 (0:UW)		–32768	32767	0	0.01	1226
1127 (R/W)	RA104 (1:LW)		–32768	32767	0	0.01	1227
1128 (R/W)	RA105 (0:UW)		–32768	32767	0	0.01	1228
1129 (R/W)	RA105 (1:LW)		–32768	32767	0	0.01	1229
1130 (R/W)	RA106 (0:UW)		–32768	32767	0	0.01	1230
1131 (R/W)	RA106 (1:LW)		–32768	32767	0	0.01	1231
1132 (R/W)	RA107 (0:UW)		–32768	32767	0	0.01	1232
1133 (R/W)	RA107 (1:LW)		–32768	32767	0	0.01	1233
1134 (R/W)	RA108 (0:UW)		–32768	32767	0	0.01	1234
1135 (R/W)	RA108 (1:LW)		–32768	32767	0	0.01	1235
1136 (R/W)	RA109 (0:UW)		–32768	32767	0	0.01	1236
1137 (R/W)	RA109 (1:LW)		–32768	32767	0	0.01	1237
1138 (R/W)	RA110 (0:UW)		–32768	32767	0	0.01	1238
1139 (R/W)	RA110 (1:LW)		–32768	32767	0	0.01	1239
1140 (R/W)	RA111 (0:UW)		–32768	32767	0	0.01	1240
1141 (R/W)	RA111 (1:LW)		–32768	32767	0	0.01	1241
1142 (R/W)	RA112 (0:UW)		–32768	32767	0	0.01	1242
1143 (R/W)	RA112 (1:LW)		–32768	32767	0	0.01	1243
1144 (R/W)	RA113 (0:UW)		–32768	32767	0	0.01	1244
1145 (R/W)	RA113 (1:LW)		–32768	32767	0	0.01	1245
1146 (R/W)	RA114 (0:UW)		–32768	32767	0	0.01	1246
1147 (R/W)	RA114 (1:LW)		–32768	32767	0	0.01	1247
1148 (R/W)	RA115 (0:UW)		–32768	32767	0	0.01	1248
1149 (R/W)	RA115 (1:LW)		–32768	32767	0	0.01	1249
1150 (R/W)	RA116 (0:UW)		–32768	32767	0	0.01	1250
1151 (R/W)	RA116 (1:LW)		–32768	32767	0	0.01	1251
1152 (R/W)	RA117 (0:UW)		–32768	32767	0	0.01	1252
1153 (R/W)	RA117 (1:LW)		–32768	32767	0	0.01	1253
1154 (R/W)	RA118 (0:UW)		–32768	32767	0	0.01	1254
1155 (R/W)	RA118 (1:LW)		–32768	32767	0	0.01	1255
1156 (R/W)	RA119 (0:UW)		–32768	32767	0	0.01	1256
1157 (R/W)	RA119 (1:LW)		–32768	32767	0	0.01	1257
1158 (R/W)	RA120 (0:UW)		–32768	32767	0	0.01	1258
1159 (R/W)	RA120 (1:LW)		–32768	32767	0	0.01	1259
1160 (R/W)	RA121 (0:UW)		–32768	32767	0	0.01	1260

Table E.34 Modbus Map[a] (Sheet 22 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
1161 (R/W)	RA121 (1:LW)		–32768	32767	0	0.01	1261
1162 (R/W)	RA122 (0:UW)		–32768	32767	0	0.01	1262
1163 (R/W)	RA122 (1:LW)		–32768	32767	0	0.01	1263
1164 (R/W)	RA123 (0:UW)		–32768	32767	0	0.01	1264
1165 (R/W)	RA123 (1:LW)		–32768	32767	0	0.01	1265
1166 (R/W)	RA124 (0:UW)		–32768	32767	0	0.01	1266
1167 (R/W)	RA124 (1:LW)		–32768	32767	0	0.01	1267
1168 (R/W)	RA125 (0:UW)		–32768	32767	0	0.01	1268
1169 (R/W)	RA125 (1:LW)		–32768	32767	0	0.01	1269
1170 (R/W)	RA126 (0:UW)		–32768	32767	0	0.01	1270
1171 (R/W)	RA126 (1:LW)		–32768	32767	0	0.01	1271
1172 (R/W)	RA127 (0:UW)		–32768	32767	0	0.01	1272
1173 (R/W)	RA127 (1:LW)		–32768	32767	0	0.01	1273
1174 (R/W)	RA128 (0:UW)		–32768	32767	0	0.01	1274
1175 (R/W)	RA128 (1:LW)		–32768	32767	0	0.01	1275
1176–1179 (R)	Reserved[d]		0	0	0	1	1276–1279
Historical Data							
1180 (R)	NO. EVENT LOGS		0	50	0	1	1280
1181 (R/W)	EVENT LOG SEL.		0	50	0	1	1281
1182 (R)	EVENT TIME ss		0	5999	0	0.01	1282
1183 (R)	EVENT TIME mm		0	59	0	1	1283
1184 (R)	EVENT TIME hh		0	23	0	1	1284
1185 (R)	EVENT DAY dd		0	31	1	1	1285
1186 (R)	EVENT DAY mm		0	12	1	1	1286
1187 (R)	EVENT DAY yy		0	9999	2000	1	1287
1188 (R)	EVENT TYPE 0 = Reserved[d] 1 = DIFF 87 TRIP 2 = REF TRIP 3 = WDG1 PH 50 TRIP 4 = WDG1 GND 50 TRIP 5 = WDG1 50Q TRIP 6 = WDG2 PH 50 TRIP 7 = WDG2 GND 50 TRIP 8 = WDG2 50Q TRIP 9 = WDG3 A 50 TRIP 10 = WDG3 B 50 TRIP 11 = WDG3 C 50 TRIP 12 = WDG3 PH 50 TRIP 13 = WDG3 GND 50 TRIP 14 = WDG3 50Q TRIP 15 = WDG4 PH 50 TRIP 16 = WDG4 GND 50 TRIP 17 = WDG4 50Q TRIP 18 = NEUTRAL 50 TRIP 19 = WDG1 PH 51 TRIP 20 = WDG1 GND 51 TRIP 21 = WDG1 51Q TRIP		0	60	0	1	1288

Table E.34 Modbus Map[a] (Sheet 23 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
	22 = WDG2 PH 51 TRIP						
	23 = WDG2 GND 51 TRIP						
	24 = WDG2 51Q TRIP						
	25 = WDG3 A 51 TRIP						
	26 = WDG3 B 51 TRIP						
	27 = WDG3 C 51 TRIP						
	28 = WDG3 PH 51 TRIP						
	29 = WDG3 GND 51 TRIP						
	30 = WDG3 51Q TRIP						
	31 = WDG4 PH 51 TRIP						
	32 = WDG4 GND 51 TRIP						
	33 = WDG4 51Q TRIP						
	34 = WDG12 PH 51 TRIP						
	35 = WDG34 PH 51 TRIP						
	36 = WDG12 GND 51 TRP						
	37 = WDG34 GND 51 TRP						
	38 = NEUTRAL 51 TRIP						
	39 = POWERELEMNT TRIP						
	40 = UNDERVOLT TRIP						
	41 = OVERVOLT TRIP						
	42 = VOLT/HZ 24 TRIP						
	43 = FREQUENCY81 TRIP						
	44 = RTD TRIP						
	45 = RTD FAIL TRIP						
	46 = BKR FAILURE TRIP						
	47 = REMOTE TRIP						
	48 = COMMIDLELOSSTRIP						
	49 = TRIGGER						
	50 = ER TRIGGER						
	51 = TRIP						
	52 = WDG12 PH 50 TRIP						
	53 = WDG23 PH 50 TRIP						
	54 = WDG34 PH 50 TRIP						
	55 = WDG12 GND 50 TRP						
	56 = WDG23 GND 50 TRP						
	57 = WDG34 GND 50 TRP						
	58 = WDG23 PH 51 TRIP						
	59 = WDG23 GND 51 TRP						
	60 = DIFF 87Q TRIP						
1189 (R)	EVENT TARGETS		0	255	0	1	1289
	Bit 0 = TLED_06						
	Bit 1 = TLED_05						
	Bit 2 = TLED_04						
	Bit 3 = TLED_03						
	Bit 4 = TLED_02						
	Bit 5 = TLED_01						
	Bit 6 = TRIP_LED						
	Bit 7 = ENABLED						
1190 (R)	EVENT IAW1	A	0	65535	0	1	1290
1191 (R)	EVENT IBW1	A	0	65535	0	1	1291
1192 (R)	EVENT ICW1	A	0	65535	0	1	1292
1193 (R)	EVENT IGW1	A	0	65535	0	1	1293
1194 (R)	EVENT IAW2	A	0	65535	0	1	1294
1195 (R)	EVENT IBW2	A	0	65535	0	1	1295

Table E.34 Modbus Map[a] (Sheet 24 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
1196 (R)	EVENT ICW2	A	0	65535	0	1	1296
1197 (R)	EVENT IGW2	A	0	65535	0	1	1297
1198 (R)	EVENT IAW3	A	0	65535	0	1	1298
1199 (R)	EVENT IBW3	A	0	65535	0	1	1299
1200 (R)	EVENT ICW3	A	0	65535	0	1	1300
1201 (R)	EVENT IGW3	A	0	65535	0	1	1301
1202 (R)	EVENT IAW4	A	0	65535	0	1	1302
1203 (R)	EVENT IBW4	A	0	65535	0	1	1303
1204 (R)	EVENT ICW4	A	0	65535	0	1	1304
1205 (R)	EVENT IGW4	A	0	65535	0	1	1305
1206 (R)	EVENT IN	A	0	65535	0	1	1306
1207 (R)	EVENT VAB/VAN	kV	0	65535	0	0.01	1307
1208 (R)	EVENT VBC/VBN	kV	0	65535	0	0.01	1308
1209 (R)	EVENT VCA/VCN	kV	0	65535	0	0.01	1309
1210 (R)	EVENT DELTA/WYE 0 = DELTA 1 = WYE		0	1	0	1	1310
1211 (R)	EVENT FREQ	Hz	2000	7000	6000	0.01	1311
1212 (R)	EVNT MAX AMB RTD	degC	–32768	32767	0	1	1312
1213 (R)	EVNT MAX OTH RTD	degC	–32768	32767	0	1	1313
1214–1219 (R)	Reserved[d]		0	0	0	1	1314–1319
Trip/Warn Data							
The Trip/Warn Status register bits are momentarily set as long as a trip/warn condition exists (see *Table E.35* for the trigger conditions). When a trip event occurs, the elements are latched to the rising edge of the TRIP Relay Word bit and they are not cleared until a target reset is issued from any interface.							
1220 (R)	TRIP STATUS LO Bit 0 = WDG1+WDG2 50 PH Bit 1 = WDG1+WDG2 50 GND Bit 2 = WDG1+WDG2 50 NEQ Bit 3 = WDG1+WDG2 51 PH Bit 4 = WDG1+WDG2 51 GND Bit 5 = WDG1+WDG2 51 NEQ Bit 6 = WDG3+WDG4 50 PH Bit 7 = WDG3+WDG4 50 GND Bit 8 = WDG3+WDG4 50 NEQ Bit 9 = WDG3+WDG4 51 PH Bit 10 = WDG3+WDG4 51 GND Bit 11 = WDG3+WDG4 51 NEQ Bit 12 = NEUTRAL 50 Bit 13 = NEUTRAL 51 Bit 14 = RESTR DIFF 87R Bit 15 = UNRESTR DIFF 87U		0	65535	0	1	1320
1221 (R)	TRIP STATUS HI Bit 0 = UNDERVOLT 27P Bit 1 = OVERVOLT 59P Bit 2 = NSEQVOLT 59Q Bit 3 = POWER ELEMENTS Bit 4 = FREQUENCY 81 Bit 5 = VOLTS/HERTZ		0	65535	0	1	1321

Table E.34 Modbus Map[a] (Sheet 25 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
	Bit 6 = RESTRCTD EARTH Bit 7 = RTD TRIP Bit 8 = BREAKER FAIL Bit 9 = REMOTE TRIP Bit 10 = DIFF 87Q TRIP Bit 11 = RESERVED Bit 12 = RESERVED Bit 13 = RESERVED Bit 14 = RESERVED Bit 15 = TRIP						
1222 (R)	WARN STATUS LO Bit 0 = THR FAULT ALARM Bit 1 = DEMAND ALARM Bit 2 = RTD FAULT Bit 3 = CONFIG FAULT Bit 4 = COMM FAULT Bit 5 = COMM IDLE Bit 6 = COMM LOSS Bit 7 = DIFF ALARM 87A Bit 8 = 5TH HARMONIC ALM Bit 9 = RTD ALARM Bit 10 = LOSS OF POTNTIAL Bit 11 = AI HI/LO ALARM Bit 12 = RESERVED Bit 13 = HALARM Bit 14 = SALARM Bit 15 = WARNING		0	65535	0	1	1322
1223 (R)	WARN STATUS HI Bit 0–Bit 15 = Reserved[d]		0	65535	0	1	1323
1224–1229 (R)	Reserved[d]		0	0	0	1	1324–1329
Comm Counters							
1230 (R)	NUM MSG RCVD		0	65535	0	1	1330
1231 (R)	NUM OTHER MSG		0	65535	0	1	1331
1232 (R)	INVALID ADDR		0	65535	0	1	1332
1233 (R)	BAD CRC		0	65535	0	1	1333
1234 (R)	UART ERROR		0	65535	0	1	1334
1235 (R)	ILLEGAL FUNCTION		0	65535	0	1	1335
1236 (R)	ILLEGAL REGISTER		0	65535	0	1	1336
1237 (R)	ILLEGAL WRITE		0	65535	0	1	1337
1238 (R)	BAD PKT FORMAT		0	65535	0	1	1338
1239 (R)	BAD PKT LENGTH		0	65535	0	1	1339
1240–1249 (R)	Reserved[d]		0	0	0	1	1340–1349
Relay Elements							
1250–1396 (R)	ROW 0–ROW 146		0	255	0	1	1350–1496
1397 (R)	Reserved[d]		0	0	0	1	1497
1398–1491 (R)	ROW 147–ROW 240		0	255	0	1	1498–1591
1492–1499 (R)	Reserved[d]		0	0	0	1	1592–1599
Control I/O Commands							
2000H (Hex) (W)	LOGIC COMMAND		0	65535	0	na	

Table E.34 Modbus Map[a] (Sheet 26 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
	Bit 0 = Breaker1 Close Bit 1 = Breaker1 Open Bit 2 = Breaker2 Close Bit 3 = Return Status 0/1 Bit 4 = DN Aux 1 Cmd Bit 5 = DN Aux 2 Cmd Bit 6 = DN Aux 3 Cmd Bit 7 = DN Aux 4 Cmd Bit 8 = DN Aux 5 Cmd Bit 9 = DN Aux 6 Cmd Bit 10 = DN Aux 7 Cmd Bit 11 = DN Aux 8 Cmd Bit 12 = DN Aux 9 Cmd Bit 13 = DN Aux 10 Cmd Bit 14 = DN Aux 11 Cmd Bit 15 = Breaker2 Open						
2001H (W)	RESET COMMAND Bit 0 = Trip Reset Bit 1 = Set to Defaults Bit 2 = Reset Stat Data Bit 3 = Reset Hist Data Bit 4 = Reset Comm Cntr Bit 5 = Reserved[d] Bit 6 = Rst Enrgy Data Bit 7 = Rst Mx/Mn Data Bit 8 = Rst Demand Bit 9 = Rst Peak Demand Bit 10 = Rst Bkmon Data Bit 11 = Breaker3 Close Bit 12 = Breaker3 Open Bit 13 = Breaker4 Close Bit 14 = Breaker4 Open Bit 15 = Reserved[d]		0	255	0	na	
2002H (W)	LOGIC COMMAND Bit 0 = Close Three-Position In-Line Disconnect 1 Bit 1 = Open Three-Position In-Line Disconnect 1 Bit 2 = Close Three-Position Earthing Disconnect 1 Bit 3 = Open Three-Position Earthing Disconnect 1 Bit 4 = Close Three-Position In-Line Disconnect 2 Bit 5 = Open Three-Position In-Line Disconnect 2 Bit 6 = Close Three-Position Earthing Disconnect 2 Bit 7 = Open Three-Position Earthing Disconnect 2 Bit 8 = Close Two-Position Disconnect 1 Bit 9 = Open Two-Position Disconnect 1 Bit 10 = Close Two-Position Disconnect 2		0	255	0	na	

Table E.34 Modbus Map[a] (Sheet 27 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
	Bit 11 = Open Two-Position Disconnect 2						
	Bit 12 = Close Two-Position Disconnect 3						
	Bit 13 = Open Two-Position Disconnect 3						
	Bit 14 = Close Two-Position Disconnect 4						
	Bit 15 = Open Two-Position Disconnect 4						
2003H (W)	LOGIC COMMAND		0	255	0	na	
	Bit 0 = Close Two-Position Disconnect 5						
	Bit 1 = Open Two-Position Disconnect 5						
	Bit 2 = Close Two-Position Disconnect 6						
	Bit 3 = Open Two-Position Disconnect 6						
	Bit 4 = Close Two-Position Disconnect 7						
	Bit 5 = Open Two-Position Disconnect 7						
	Bit 6 = Close Two-Position Disconnect 8						
	Bit 7 = Open Two-Position Disconnect 8						
	Bit 8 = Close Two-Position Disconnect 9						
	Bit 9 = Open Two-Position Disconnect 9						
	Bit 10 = Close Two-Position Disconnect 10						
	Bit 11 = Open Two-Position Disconnect 10						
	Bit 12 = Close Two-Position Disconnect 11						
	Bit 13 = Open Two-Position Disconnect 11						
	Bit 14 = Close Two-Position Disconnect 12						
	Bit 15 = Open Two-Position Disconnect 12						
2004H (W)	LOGIC COMMAND		0	255	0	na	
	Bit 0 = Close Two-Position Disconnect 13						
	Bit 1 = Open Two-Position Disconnect 13						
	Bit 2 = Close Two-Position Disconnect 14						
	Bit 3 = Open Two-Position Disconnect 14						
	Bit 4 = Close Two-Position Disconnect 15						
	Bit 5 = Open Two-Position Disconnect 15						
	Bit 6 = Close Two-Position Disconnect 16						

Table E.34 Modbus Map[a] (Sheet 28 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
	Bit 7 = Open Two-Position Disconnect 16 Bit 8–Bit 15= Reserved[d]						
Relay Elements							
2100H (R)	FAST STATUS 0 Bit 0 = Faulted/Trip Bit 1 = Warning Bit 2 = IN101 Status Bit 3 = IN102 Status Bit 4 = IN401 Status Bit 5 = IN402 Status Bit 6 = IN403 Status Bit 7 = Reserved[d] Bit 8 = OUT101 Status Bit 9 = OUT102 Status Bit 10 = OUT401 Status Bit 11 = OUT402 Status Bit 12 = OUT403 Status Bit 13 = OUT404 Status Bit 14–Bit 15 = Reserved[d]		0	65535	0	na	
2101H (R)	FAST STATUS 1 Bit 0 = Enabled Bit 1 = Reserved[d] Bit 2 = IN404 Status Bit 3 = IN405 Status Bit 4 = IN406 Status Bit 5 = IN407 Status Bit 6 = IN408 Status Bit 7 = Reserved[d] Bit 8 = OUT405 Status Bit 9 = OUT406 Status Bit 10 = OUT407 Status Bit 11 = OUT408 Status Bit 12–Bit 15 = Reserved[d]		0	65535	0	na	
2102H (R)	TRIP STATUS LO					na	
2103H (R)	TRIP STATUS HI					na	
2104H (R)	WARN STATUS LO					na	
2105H (R)	WARN STATUS HI					na	
2106H (R)	AVERAGE CURRENT					na	
2107H (R)	IAW1 CURRENT					na	
2108H (R)	IBW1 CURRENT					na	
2109H (R)	ICW1 CURRENT					na	
210AH (R)	Reserved[d]					na	
210BH (R)	Reserved[d]					na	
210CH (R)	Reserved[d]					na	
210DH (R)	IGW1 CURRENT					na	
210EH (R)	IN1 CURRENT					na	
210FH (R)	Reserved[d]					na	
2110H (R)	FAST STATUS 2 Bit 0 = IN301 Status		0	65535	0	na	

Table E.34 Modbus Map[a] (Sheet 29 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
	Bit 1 = IN302 Status						
	Bit 2 = IN303 Status						
	Bit 3 = IN304 Status						
	Bit 4 = IN305 Status						
	Bit 5 = IN306 Status						
	Bit 6 = IN307 Status						
	Bit 7 = IN308 Status						
	Bit 8 = OUT301 Status						
	Bit 9 = OUT302 Status						
	Bit 10 = OUT303 Status						
	Bit 11 = OUT304 Status						
	Bit 12 = OUT305 Status						
	Bit 13 = OUT306 Status						
	Bit 14 = OUT307 Status						
	Bit 15 = OUT308 Status						
2111H (R)	FAST STATUS 3		0	65535	0	na	
	Bit 0–Bit 7 = Reserved[d]						
	Bit 8 = OUT501 Status						
	Bit 9 = OUT502 Status						
	Bit 10 = OUT503 Status						
	Bit 11 = OUT504 Status						
	Bit 12 = OUT505 Status						
	Bit 13 = OUT506 Status						
	Bit 14 = OUT507 Status						
	Bit 15 = OUT508 Status						
Par Group Indices							
3000H (R)	Reserved[d]		0	0	0	na	
3001H (R)	USER MAP REG		1	125	1	1	
3002H (R)	USER MAP REG VAL		126	250	126	1	
3003H (R)	RESERVED AREA1		251	260	251	1	
3004H (R)	RESET SETTINGS		261	269	261	1	
3005H (R)	DATE/TIME SET		270	279	270	1	
3006H (R)	DEVICE STATUS		280	329	280	1	
3007H (R)	CURRENT DATA		330	409	330	1	
3008H (R)	VOLTAGE DATA		410	439	410	1	
3009H (R)	POWER DATA		440	449	440	1	
300AH (R)	ENERGY DATA		450	469	450	1	
300BH (R)	DEMAND DATA		470	489	470	1	
300CH (R)	HARMONIC DATA		490	509	490	1	
300DH (R)	RTD DATA		510	523	510	1	
300EH (R)	MAX/MIN AI5 DATA		524	539	524	1	
300FH (R)	RMS DATA		540	569	540	1	
3010H (R)	BREAKER MONITOR		570	639	570	1	
3011H (R)	MAX/MIN MTR DATA		640	699	640	1	
3012H (R)	MAX/MIN RTD DATA		700	729	700	1	
3013H (R)	MAX/MIN AI3 DATA		730	749	730	1	
3014H (R)	MAX/MIN AI4 DATA		750	769	750	1	
3015H (R)	MAX/MIN RST DATA		770	779	770	1	

Table E.34 Modbus Map[a] (Sheet 30 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
3016H (R)	ANA INP DATA		780	799	780	1	
3017H (R)	MATH VARIABLES		800	869	800	1	
3018H (R)	DEVICE COUNTERS		870	901	870	1	
3019H (R)	ANA AI5 DATA		902	919	902	1	
301AH (R)	REMOTE ANALOGS1		920	1047	920	1	
301BH (R)	REMOTE ANALOGS2		1048	1179	1048	1	
301CH (R)	HISTORICAL DATA		1180	1219	1180	1	
301DH (R)	TRIP/WARN DATA		1220	1229	1220	1	
301EH (R)	COMMN COUNTERS		1230	1249	1230	1	
301FH (R)	RELAY ELEMENTS		1250	1491	1250	1	
Product Information							
4000H (R)	VENDOR CODE 865 = SEL		0	65535	865	na	
4001H (R)	PRODDUCT CODE		0	65535	108	na	
4002H (R/W)	ASA NUMBER LOW		0	65535		na	
4003H (R/W)	ASA NUMBER HIGH		0	65535		na	
4004H (R)	FIRMWARE REVISION		1	32639		na	
4005H (R)	NUM OF PAR		1	2000	1491	na	
4006H (R)	NUM OF PAR GROUP		1	100	70	na	
4007H (R/W)	MAC ID 64-99 = Swr Configurable		1	99	0	na	
4008H (R/W)	DN BAUD RATE 0 = 125 kbps 1 = 250 kbps 2 = 500 kbps 3 = AUTO 4-9 Swr Configurable		0	9	0	na	
4009H (R/W)	DN STATUS Bit 0 = Explicit Cnxn Bit 1 = I/O Cnxn Bit 2 = Explicit Fault Bit 3 = I/O Fault Bit 4 = I/O Idle Bit 5–Bit 15 = Reserved[d]		0	31	0	na	
400AH	Reserved[d]						
400BH (R)	CONFIG PAR CKSUM				0	na	
400CH (R)	LANGUAGE CODE 0 = English 1 = French 2 = Spanish (Mexican) 3 = Italian 4 = German 5 = Japanese 6 = Portuguese 7 = Mandarin Chinese 8 = Russian 9 = Dutch				0	na	
400DH (R)	FIRMWARE BUILD NUM		16400	16400	0	na	

Table E.34 Modbus Map[a] (Sheet 31 of 31)

Modbus Register Address[b]	Name/Enums	Units	Min	Max	Def	Multiplier[c]	DeviceNet Parameter Numbers
400EH	Reserved[d]						
400FH (R)	PRODUCT SUPPORT BITS Bit 0 = 2nd IO Card Installed Bits 1–15 = Reserved[d]					na	
4010H (R/W)	SETTINGS TIMEOUT	ms	500	65535	750	na	
4011H	Reserved[d]						
4012H	Reserved[d]						
4013H	Reserved[d]						
4014H (R)	CONFIGURED BIT Bit 0 = Unit Configured Bits 1–Bit 15 = Reserved[d]				0	na	
4015H (R)	Reserved[d]		0	0	0	na	
4016H (R)	ERROR REGISTER Bit 0 = Settings Read Error Bit 1 = Setting Write Error Bit 2 = Settings Update Error Bit 3 = Settings Resource Error Bit 4 = Settings Locked Bit 5 = Group Settings Error Bit 6 = Global Settings Error Bit 7 = Logic Settings Error Bit 8 = Report Settings Error Bit 9 = Front Panel Settings Error Bit 10 = Memory Not Available Bit 11 = Settings Prep Error Bit 12 = Setting Changes Disabled Bit 13 = Memory Diag Error Bit 14–Bit 15 = Reserved[d]		0	65535	0	na	
4017H (R)	ERROR ADDRESS		0	65535	0	na	
4018H (R)	Reserved[d]		0	0	0	na	
TO							
401FH (R)	Reserved[d]		0	0	0	na	

[a] All addresses in this table refer to the register addresses in the Modbus packet.
[b] Registers labeled (R/W) are read-write registers. Registers labeled (W) are write-only registers. Registers labeled (R) are read-only registers.
[c] Register Value • Multiplier = System Value as seen by the relay. For example, if Register 331 (IAW1 Angle) reads 300 in decimal, then the system value is 30 degrees (multiplier = 0.1).
[d] Reserved addresses return 0.

Table E.35 Trigger Conditions for the Trip/Warn Status Register Bits (Sheet 1 of 2)

Register #	Bit #	Description	Trigger Condition
1220	—	TRIP STATUS LO	—
	Bit 0	WDG1+WDG2 50 PH	50P11T OR 50P12T OR 50P13T OR 50P14T OR 50P21T OR 50P21T OR 50P23T OR 50P24T
	Bit 1	WDG1+WDG2 50 GND	50G11T OR 50G12T OR 50G21T OR 50G22T
	Bit 2	WDG1+WDG2 50 NEQ	50Q11T OR 50Q12T OR 50Q21T OR 50Q22T
	Bit 3	WDG1+WDG2 51 PH	51P1T OR 51P2T
	Bit 4	WDG1+WDG2 51 GND	51G1T OR 51G2T
	Bit 5	WDG1+WDG2 51 NEQ	51Q1T OR 51Q2T
	Bit 6	WDG3+WDG4 50 PH	50P31T OR 50P32T OR 50P33T OR 50P34T OR 50P41T OR 50P42T OR 50P43T OR 50P44T
	Bit 7	WDG3+WDG4 50 GND	50G31T OR 50G32T OR 50G41T OR 50G42T
	Bit 8	WDG3+WDG4 50 NEQ	50Q31T OR 50Q32T OR 50Q41T OR 50Q42T
	Bit 9	WDG3+WDG4 51 PH	51P3T OR 51P4T
	Bit 10	WDG3+WDG4 51 GND	51G3T OR 51G4T
	Bit 11	WDG3+WDG4 51 NEQ	51Q3T OR 51Q4T
	Bit 12	NEUTRAL 50	50N11T OR 50N12T
	Bit 13	NEUTRAL 51	51N1T
	Bit 14	RESTR DIFF 87R	87R
	Bit 15	UNRESTR DIFF 87U	87U
1221	—	TRIP STATUS HI	—
	Bit 0	UNDERVOLT 27P	27P1T OR 27P2T
	Bit 1	OVERVOLT 59P	59P1T OR 59P2T
	Bit 2	NSEQVOLT 59Q	59Q1T OR 59Q2T
	Bit 3	POWER ELEMENTS	3PWR1T OR 3PWR2T
	Bit 4	FREQUENCY 81	81D1T OR 81D2T OR 81D3T OR 81D4T
	Bit 5	VOLTS/HERTZ	24D1T OR 24C2T
	Bit 6	RESTRCTD EARTH	REF1P OR REF3AP OR REF3BP
	Bit 7	RTD TRIP	RTDT
	Bit 8	BREAKER FAIL	BFT1 OR BFT2 OR BFT3 OR BFT4
	Bit 9	REMOTE TRIP	REMTRIP
	Bit 10	RESERVED	—
	Bit 11	RESERVED	—
	Bit 12	RESERVED	—
	Bit 13	RESERVED	—
	Bit 14	RESERVED	—
	Bit 15	TRIP	TRIP

Table E.35 Trigger Conditions for the Trip/Warn Status Register Bits (Sheet 2 of 2)

Register #	Bit #	Description	Trigger Condition
1222	—	WARN STATUS LO	—
	Bit 0	THR FAULT ALARM	TFLTALA OR TFLTALB OR TFLTALC
	Bit 1	DEMAND ALARM	PHDEM OR 3I2DEM OR GNDEM
	Bit 2	RTD FAULT	RTDFLT
	Bit 3	CONFIG FAULT	ALARMCR
	Bit 4	COMM FAULT	COMMFLT
	Bit 5	COMM IDLE	COMMIDLE
	Bit 6	COMM LOSS	COMMLOSS
	Bit 7	DIFF ALARM 87A	87AT
	Bit 8	5TH HARMONIC ALM	TH5T
	Bit 9	RTD ALARM	RTDA
	Bit 10	LOSS OF POTNTIAL	LOP
	Bit 11	AI HI/LO ALARM	AILAL OR AIHAL
	Bit 12	RESERVED	—
	Bit 13	HALARM	HALARM
	Bit 14	SALARM	SALARM
	Bit 15	WARNING	WARNING
1223	—	WARN STATUS HI	—
	Bit 0–Bit 15	RESERVED	—

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Appendix F
EtherNet/IP Communications

Overview

EtherNet/IP, or Ethernet/Industrial Protocol, is an industrial protocol that uses standard Ethernet and TCP/IP technology to transport Common Industrial Protocol (CIP) packets.

The SEL-787 Transformer Protection Relay supports EtherNet/IP. This section discusses general specifications for EtherNet/IP implementation as well as the CIP data model, the allocation of the CIP connections, the EtherNet/IP Port 1 settings, and the Electronic Data Sheet (EDS) file in the SEL-787.

The SEL-787 supports two ways of exchanging data via EtherNet/IP.

- **Implicit Message Adapter.** The I/O data are mapped into Assembly object instances. The SEL-787 exchanges these I/O data via EtherNet/IP Implicit Class 1 connections with a remote EtherNet/IP Scanner device using UDP packets.
- **Explicit Message Server.** The I/O data are mapped into Assembly object instances. The SEL-787 responds to generic TCP EtherNet/IP Explicit message requests initiated by a remote EtherNet/IP Client device.

For more information on EtherNet/IP, visit www.odva.org.

Specifications

Table F.1 EtherNet/IP Specifications (Sheet 1 of 2)

EtherNet/IP Services
Implicit Message Adapter (Class 1) Explicit Message Server (Class 3 and unconnected)
CIP Model—Implemented Objects
Identity Object Message Router Object Assembly Object Connection Manager Object File Object TCP/IP Interface Object Ethernet Link Object Vendor Specific Object

Table F.1 EtherNet/IP Specifications (Sheet 2 of 2)

Implicit Message Adapter	
Number of Connections	As many as eight (two Class 1 connections and six Class 3/unconnected connections)
Class 1 Connection Types	Unicast Multicast
Class 1 Connection Transport Types	Exclusive Owner Input Only Listen Only
Class 1 Connection Trigger Types	Cyclic Change of State
Input Only Heartbeat Connection Point	238
Listen Only Heartbeat Connection Point	237

CIP Data Model

Profile

Table F.2 CIP Data Model Profile

Class Name	Class ID	Number of Instances
Identity Object	0x01	1
Message Router Object	0x02	1
Assembly Object	0x04	Determined by the user/based on the application
Connection Manager Object	0x06	1
File Object	0x37	2
TCP/IP Interface Object	0xF5	1
Ethernet Link Object	0xF6	See *Ethernet Link Object (0xF6)*
Vendor Specific Object	0x64	1

Identity Object (0x01)

Instances Implemented

The SEL-787 supports one instance (Instance ID = 1) of the Identity Object.

Table F.3 Identity Object List of Attributes

Attribute ID	Name	Access	Data Type	Default	Description
Class Attributes					
1	Revision	GET	UINT	1	The revision of this CIP Object
2	Max Instance	GET	UINT	1	The maximum Identity Object Instance ID
3	Number of Instances	GET	UINT	1	Total number of Identity Objects
4	Optional Attribute List	GET	[UINT, Array of UINT]	[1, [21]]	[Number of Optional Instance Attributes, List of Optional Instance Attributes]
6	Maximum ID Number Class Attributes	GET	UINT	7	Maximum Class Attribute ID
7	Maximum ID Number Instance Attributes	GET	UINT	21	Maximum Instance Attribute ID
Instance Attributes					
1	Vendor ID	GET	UINT	865	
2	Device Type	GET	UINT	0x2B	
3	Product Code	GET	UINT		The most significant byte is the Device Code (DEVCODE as found in the **ID** command of the SEL-787) and its least significant byte is the user-configurable Configuration ID as provided in the Ethernet port settings
4	[Major Revision, Minor Revision]	GET	[USINT, USINT]	[1,1]	
5	Status	GET	WORD		Refer to *Table F.4*
6	Serial Number	GET	UDINT		The low-order 32 bits of the MAC address of the Ethernet port
7	Product Name	GET	STRING		The existing default product name (the default RID string) of the SEL-787 plus the value of the user-configurable Configuration ID as provided in the Ethernet port settings. The general format is, “<Default RID>-<Configuration ID>”
21	Catalog Number	GET	STRING		The existing default product name (the default RID string) of the SEL-787 plus the value of the user-configurable Configuration ID as provided in the Ethernet port settings. The general format is, “<Default RID>-<Configuration ID>”

Table F.4 Status WORD Bits Descriptions

Bit Number[a]	Name	Description
0	Owned	TRUE, if at least one scanner has established an Exclusive Owner Class 1 connection to the SEL-787. FALSE, if the SEL-787 has no active Exclusive Owner connections to a scanner.
2	Configured	Always TRUE.
4 to 7	Extended Device Status	Hexadecimal value: 2: A Class 1 connection has timed out. 3: No Class 1 connection has been established. 6: At least one Class 1 connection is active. 7: In any other case.
11	Major Unrecoverable Fault	TRUE if the product is disabled due to an unrecoverable fault; otherwise, it is FALSE.

[a] The Status WORD bits not listed in this table are always set to FALSE.

Table F.5 Identity Object Supported Services

Service Code	Service Name	Class	Instance	Description
0x01	Get Attributes All	Yes	Yes	Returns a list of all of the values of the attributes.
0x05	Reset	No	Yes	Restarts the EtherNet/IP service in the SEL-787. Only reset type 0 is allowed.
0x0E	Get Attribute Single	Yes	Yes	Returns the value of a specific attribute.

Message Router Object (0x02)

Table F.6 Message Router Object List of Attributes (Sheet 1 of 2)

Attribute ID	Name	Access	Data Type	Default	Description
Class Attributes					
1	Revision	GET	UINT	1	The revision of this CIP Object
2	Max Instance	GET	UINT	1	The maximum Message Router Object Instance ID
3	Number of Instances	GET	UINT	1	Total number of Message Router Object Instances
4	Optional Attribute List	GET	[UINT, Array of UINT]	[3,[1,2,3]]	[Number of Optional Instance Attributes, List of Optional Instance Attributes]
5	Optional Service List	GET	[UINT, Array of UINT]	[1,[10]]	Number of Optional Service Codes followed by the List of Optional Service Codes
6	Maximum ID Number Class Attributes	GET	UINT	7	Maximum Class Attribute ID
7	Maximum ID Number Instance Attributes	GET	UINT	3	Maximum Instance Attribute ID

Table F.6 Message Router Object List of Attributes (Sheet 2 of 2)

Attribute ID	Name	Access	Data Type	Default	Description
Instance Attributes					
1	Class List	GET	[UINT, Array of UINT]		Implemented object list
2	Maximum Connections	GET	UINT		Maximum number of connections supported
3	Number of Connections	GET	UINT		Number of connections currently used

Table F.7 Message Router Supported Services

Service Code	Service Name	Class	Instance	Description
0x01	Get Attribute All	Yes	Yes	Returns a list of all of the attributes.
0x0E	Get Attribute Single	Yes	Yes	Returns the value of a specific attribute.
0x0A	Multiple Service Packet	No	Yes	

Assembly Object (0x04)

Instances Implemented

The SEL-787 settings define the number of Assembly Object Instances based on the number and type of connections configured and the data content of each instance. Each assembly is as large as 500 bytes in size. The SEL-787 supports a total of six assemblies (three Input Assemblies and three Output Assemblies).

Table F.8 Assembly Object List of Attributes (Sheet 1 of 2)

Attribute ID	Name	Access	Data Type	Default	Description
Class Attributes					
1	Revision	GET	UINT	2	The revision of this CIP Object
2	Max Instance	GET		Determined by the settings	The maximum Assembly Object Instance ID defined by the user
3	Number of Instances	GET		Determined by the settings	Total number of Assembly Object instances defined by the user
4	Optional Attribute List	GET	[UINT, Array of UINT]	[1,[4]]	[Number of Optional Instance Attributes, List of Optional Instance Attributes]
6	Maximum ID Number Class Attributes	GET	UINT	7	Maximum Class Attribute ID
7	Maximum ID Number Instance Attributes	GET	UINT	4	Maximum Instance Attribute ID
Instance Attributes					
1	Number of Members	GET	UINT		Number of Assembly Members defined by the user
2	Member List	GET	Array of [UINT, UINT, EPATH]		Only 500 bytes allowed

Table F.8 Assembly Object List of Attributes (Sheet 2 of 2)

Attribute ID	Name	Access	Data Type	Default	Description
3	Data	GET, SET	Array of Bytes		Data map defined with **SET E 1**, **2**, or **3**
4	Size	GET	UINT		Number of bytes in Instance Attribute 3

Table F.9 Assembly Object Supported Services

Service Code	Service Name	Class	Instance	Description
0x0E	Get Attribute Single	Yes	Yes	Returns the value of a specific attribute.
0x10	Set Attribute Single	No	Yes	Sets the value of a specific attribute.
0x18	Get Member	No	Yes	Returns the value of a member of the data attribute.
0x19	Set Member	No	Yes	Modifies the value of a member of the data attribute.

Connection Manager Object (0x06)

Table F.10 Connection Manager Object List of Attributes (Sheet 1 of 2)

Attribute ID	Name	Access	Data Type	Default	Description
Class Attributes					
1	Revision	GET	UINT	1	The revision of this CIP Object
2	Max Instance	GET	UINT		The maximum Connection Manager Object Instance ID
3	Number of Instances	GET	UINT		Total number of Connection Manager Object Instances
4	Optional Attribute List	GET	[UINT, Array of UINT]	[8,[1,2,3,4,5,6,7,8]]	[Number of Optional Instance Attributes, List of Optional Instance Attributes]
6	Maximum ID Number Class Attributes	GET	UINT	7	Maximum Class Attribute ID
7	Maximum ID Number Instance Attributes	GET	UINT	8	Maximum Instance Attribute ID
Instance Attributes					
1	Open Requests	GET/SET	UINT		Number of FWD Open service requests received
2	Open Format Rejects	GET/SET	UINT		Number of FWD Open service requests rejected because of bad format
3	Open Resource Rejects	GET/SET	UINT		Number of FWD Open service requests rejected because of lack of resources
4	Open Other Rejects	GET/SET	UINT		Number of FWD Open service requests rejected for reasons other than bad format or lack or resources
5	Close Requests	GET/SET	UINT		Number of FWD Close service requests received
6	Close Format Rejects	GET/SET	UINT		Number of FWD Close service requests rejected because of bad format

Table F.10 Connection Manager Object List of Attributes (Sheet 2 of 2)

Attribute ID	Name	Access	Data Type	Default	Description
7	Close Other Rejects	GET/SET	UINT		Number of FWD Open service requests rejected for reasons other than bad format
8	Connection Timeouts	GET/SET	UINT		Number of connection timeouts

Table F.11 Connection Manager Object Supported Services

Service Code	Service Name	Class	Instance	Description
0x01	Get Attribute All	Yes	Yes	Returns a list of all of the attributes.
0x0E	Get Attribute Single	Yes	Yes	Returns the value of a specific attribute.
0x10	Set Attribute Single	No	Yes	Sets the value of a specific attribute.
0x02	Set Attribute All	No	Yes	Sets the value of all attributes.
0x54	Forward Open	No	Yes	Establishes a CIP connection.
0x4E	Forward Close	No	Yes	Closes a CIP connection.
0x5B	Large Forward Open	No	Yes	Establishes a CIP connection that allows a large connection size.
0x5A	Get Connection Owner	No	Yes	Returns data about the connection that owns the object.

File Object (0x37)

The File Object stores the EDS and icon files. The EDS file is generated by the SEL-787 based on the EtherNet/IP Port 1 settings and the SET E 1, 2, or 3 settings. The relay can retrieve the file using the File Object services. You cannot write an EDS file to the relay using the File Object services.

The SEL-787 implements two instances of the File Object:

- ➤ Instance 0xC8 returns an uncompressed version of the EDS file with an embedded icon.
- ➤ Instance 0xC9 returns a compressed version of the icon file.

Table F.12 File Object List of Attributes (Sheet 1 of 2)

Attribute ID	Name	Access	Data Type	Default	Description
Class Attributes					
1	Revision	GET	UINT	1	The revision of this CIP Object
2	Max Instance	GET	UINT	201	
3	Number of Instances	GET	UINT	2	
6	Maximum ID Number Class Attributes	GET	UINT	32	Maximum Class Attribute ID
7	Maximum ID Number Instance Attributes	GET	UINT	11	Maximum Instance Attribute ID
32	Directory	GET	[UINT, STRINGI, STRINGI] [UINT, STRINGI, STRINGI]	[0xC8,(ENG)‘EDS and Icon Files’, (ENG)‘EDS.txt’] [0xC9, (ENG)‘Related EDS and Icon Files’, (ENG)‘EDSCollection.gz’]	List of all File Object instance and file names present in the SEL-787 and the associated instance numbers

Table F.12 File Object List of Attributes (Sheet 2 of 2)

Attribute ID	Name	Access	Data Type	Default	Description
0xC8 Instance Attributes					
1	State	GET	USINT	2	
2	Instance Name	GET	STRINGI	(ENG)‘EDS and Icon Files’	
3	File Format Version	GET	UINT	1	
4	File Name	GET	STRINGI	(ENG)‘EDS.txt’	
5	File Revision	GET	[USINT, USINT]		[Major EDS revision Ethernet port setting, Minor EDS revision Ethernet port setting]
6	File Size	GET	UDINT		Size of the EDS file in bytes
7	File Checksum	GET	UINT		Checksum of the EDS file (2s complement of the 16-bit sum of all octets in the file)
8	Invocation Method	GET	USINT	255	
9	File Save Parameters	GET	USINT	0	
10	File Access Rule	GET	USINT	1	
11	File Encoding Format	GET	USINT	0	
0xC9 Instance Attributes					
1	State	GET	USINT	2	
2	Instance Name	GET	STRINGI	(ENG)‘Related EDS and Icon Files’	
3	File Format Version	GET	UINT	1	
4	File Name	GET	STRINGI	(ENG)‘EDSCollection.gz’	
5	File Revision	GET	[USINT, USINT]	[1,1]	[Major Revision, Minor Revision]
6	File Size	GET	UDINT		Size of the loaded file in bytes
7	File Checksum	GET	UINT		Checksum of the EDSCollection file (2s complement of the 16-bit sum of all octets in the file)
8	Invocation Method	GET	USINT	255	
9	File Save Parameters	GET	USINT	0	
10	File Access Rule	GET	USINT	1	
11	File Encoding Format	GET	USINT	1	

Table F.13 File Object Supported Services

Service Code	Service Name	Class	Instance	Description
0x0E	Get Attribute Single	Yes	Yes	Returns the value of a specific attribute.
0x4B	Initiate Upload	No	Yes	
0x4F	Upload Transfer	No	Yes	

TCP/IP Interface Object (0xF5)

Instances Implemented

The number of instances of the TCP/IP Interface Object is always 1, regardless of whether the CPU card contains a single Ethernet port or a dual Ethernet port.

Table F.14 TCP/IP Interface Object List of Attributes (Sheet 1 of 2)

Attribute ID	Name	Access	Data Type	Default	Description
Class Attributes					
1	Revision	GET	UINT	4	The revision of this CIP Object
2	Max Instance	GET	UINT	1	The maximum TCP/IP Object Instance ID
3	Number of Instances	GET	UINT	1	Total number of TCP/IP Object Instances
4	Optional Attribute List	GET	[UINT, Array of UINT]	[4,[8,9,16,17]]	[Number of Optional Instance Attributes, List of Optional Instance Attributes]
6	Maximum ID Number Class Attributes	GET	UINT	7	Maximum Class Attribute ID
7	Maximum ID Number Instance Attributes	GET	UINT	17	Maximum Instance Attribute ID
Instance Attributes					
1	Status	GET	DWORD	2	
2	Configuration Capability	GET	DWORD	32	Any change in the configuration will be updated when the server is restarted.
3	Configuration Control	GET	DWORD	0	IP addresses must be configured statically. DHCP and DNS are not supported.
4	Physical Link Object	GET	[UINT, EPATH]		[Path size, Path to the corresponding Ethernet link object instance] For a dual Ethernet port CPU card, the value is 00 00 (path size of 0). For a single Ethernet port CPU card, the value is 02 00 20 F6 24 01, where 02 00 is the path size (number of 16-bit words), 20 is the 8-bit class segment type, F6 is the Ethernet Link Object class, 24 is the 8-bit instance segment type, and 01 is Instance 1.
5	Interface Configuration	GET	[UDINT, UDINT, UDINT, UDINT, UDINT, STRING]		[IP address, Network mask, Gateway address, 0, 0, null]
6	Host Name	GET	STRING		When converted to ASCII, this displays, “[Product Name]-[Serial Number]”. This attribute cannot be set by the scanner.
8	TTL Value	GET/SET	USINT	1	The scanner can set this attribute.

Table F.14 TCP/IP Interface Object List of Attributes (Sheet 2 of 2)

Attribute ID	Name	Access	Data Type	Default	Description
9	Mcast Config	GET/SET	[USINT, USINT, UINT, UDINT]	[Alloc control, Reserved, Num Mcast, Mcast Start Address]	The scanner can set this attribute only if the control is 01 00. 1st and 2nd Byte: This represents the control. When the value is 00 00, the scanner cannot change the number of multicast connections nor the Mcast Start Address. To change these, all eight bytes must be written at once, e.g., 01 00 *xx xx yy yy yy yy*. 3rd and 4th Byte: Number of multicast connections supported by the product in little endian order. 02 00 is the default value. The maximum number of multicast connections supported is 2. 5th–8th Byte: Mcast Start Address according to the default algorithm specified in Section 3-5.3 of Volume 2 of the standard.
13	Encapsulation Inactivity Timeout	GET/SET	UINT	120	The scanner can set this value.
16	Active TCP Connections	GET	UINT	1	
17	Non-CIP Encapsulation Messages per Second	GET	UDINT	0	

Table F.15 TCP/IP Interface Object Supported Services

Service Code	Service Name	Class	Instance	Description
0x01	Get Attribute All	Yes	Yes	Returns a list of all of the attributes.
0x0E	Get Attribute Single	Yes	Yes	Returns the value of a specific attribute.
0x10	Set Attribute Single	No	Yes	Sets the value of a specific attribute.

Ethernet Link Object (0xF6)

Instances Implemented

The number of instances of the Ethernet Link Object depends on whether the CPU card contains a single Ethernet port or a dual Ethernet port. The value will be 1 for a single Ethernet port and 2 for a dual Ethernet port.

Table F.16 Ethernet Link Object List of Attributes (Sheet 1 of 2)

Attribute ID	Name	Access	Data Type	Default	Description
Class Attributes					
1	Revision	GET	UINT	4	The revision of this CIP Object
2	Max Instance	GET	UINT		The maximum Ethernet Link Object Instance ID
3	Number of Instances	GET	UINT		Total number of Ethernet Link Object Instances
4	Optional Attribute List	GET	[UINT, Array of UINT]	[1,[10]]	[Number of Optional Instance Attributes, List of Optional Instance Attributes]

Table F.16 Ethernet Link Object List of Attributes (Sheet 2 of 2)

Attribute ID	Name	Access	Data Type	Default	Description
6	Maximum ID Number Class Attributes	GET	UINT	7	Maximum Class Attribute ID
7	Maximum ID Number Instance Attributes	GET	UINT	11	Maximum Instance Attribute ID
Instance Attributes					
1	Interface Speed	GET	UINT		Speed (MBPS) in use on the corresponding interface
2	Interface Flags	GET	DWORD		See *Table F.17*
3	Physical Address	GET	USINT[6]		MAC address of the corresponding interface
10	Interface Label	GET	STRING		SEL-787 interface name, e.g., “PORT 1”
11	Interface Capability	GET	[DWORD, USINT]		[Capability bits, Array Element Count]

Table F.17 Interface Flags Bits Descriptions

Bit Number	Name	Description
0	Link Status	0: The Ethernet interface link is inactive. 1: The link is active.
1	Half/Full Duplex	0: The interface is running half duplex. 1: The interface is running full duplex.
2–4	Negotiation Status	Octal unsigned value: 0: Auto negotiation in progress. 1: Auto negotiation and speed detection failed. Using default values. 2: Auto negotiation failed, but detected speed. 3: Successfully negotiated speed and duplex. 4: Auto negotiation not attempted.
5	Manual Setting Requires Reset	Set to 1.

Table F.18 Ethernet Link Object Supported Services

Service Code	Service Name	Class	Instance	Description
0x01	Get Attribute All	Yes	Yes	Returns a list of all of the attributes.
0x0E	Get Attribute Single	Yes	Yes	Returns the value of a specific attribute.

Vendor Specific Object (0x64)

Instances Implemented

The SEL-787 supports one instance (Instance ID = 1) of the Vendor Specific Object.

Table F.19 Vendor Specific Object List of Attributes

Attribute ID	Name	Access	Data Type	Default	Description
Class Attributes					
1	Revision	GET	UINT	1	The revision of this CIP Object
2	Max Instance	GET	UINT	1	The maximum Vendor Specific Object Instance ID
3	Number of Instances	GET	UINT	1	Total number of Vendor Specific Object Instances
Instance Attributes					
100	Enabled[a]	GET	BOOL		Relay Enabled Status
101	Trip	GET	BOOL		Protection Trip

[a] This attribute reflects the value of the Relay Word bit indicating Enabled status of the SEL-787.

Table F.20 Vendor Specific Object Supported Services

Service Code	Service Name	Class	Instance	Description
0x01	Get Attribute All	Yes	Yes	Returns a list of all of the attributes.
0x0E	Get Attribute Single	Yes	Yes	Returns the value of a specific attribute.

CIP Connections and Corresponding Assembly Maps

The SEL-787 supports as many as eight simultaneous CIP connections. Of the eight simultaneous connections, as many as two can be Class 1 (I/O) connections and as many as six can be a combination of Class 3 messages and Unconnected Message Manager (UCMM) messages. The SEL-787 creates Class 3 connections internally when the EtherNet/IP scanner makes the appropriate connection.

When configuring EtherNet/IP (EIP) on Port 1, you can create as many as six Class 1 (I/O) connection configurations. Of these six, only two can be used simultaneously. Of the six available connection configurations, as many as three can be Exclusive Owner connection configurations. The remaining connection configurations must be Input Only connection configurations.

An Exclusive Owner connection configuration contains both a Target to Originator (T->O, data flows from the SEL-787 to the scanner) connection and an Originator to Target (O->T, data flows from the scanner to the SEL-787) connection. An Input Only connection configuration contains a (T->O) connection only. For every distinct (T->O) connection, the SEL-787 automatically creates a Listen Only connection configuration. Listen Only connection configurations do not count against the six Class 1 (I/O) connection configurations. For the SEL-787, the types of supported connections are shown in *Table F.21*.

The flow of data is represented via assemblies. Input Assemblies 100, 102, and 104 are always associated with (T->O) connections, and Output Assemblies 101, 103, and 105 are always associated with (O->T) connections. Note that these output assemblies can also be associated with (T->O) connections. The Input Assemblies can contain both binary input (from *Table L.1*) and analog input (from *Table M.1*) data. The Output Assemblies can contain both binary output and analog output data. Input Assembly 100 and Output Assembly 101 consist of data that can be chosen by setting the EtherNet/IP Assembly Map 1 settings using the **SET E 1** command. Similarly, Input Assembly 102 and Output Assembly 103 consist of data that can be chosen by setting the EtherNet/IP Assembly Map 2 settings using the **SET E 2** command. Input Assembly 104 and Output Assembly 105 consist of data that can be chosen by setting the EtherNet/IP Assembly Map 3 settings using the **SET E 3** command. Each of these assembly maps contains 100 binary input points, 100 analog input points, 32 binary output points, and 32 analog output points. It is important to note that the binary output points can take on the value of any remote bit (SET/CLEAR) or any 89OC/89CC bit (SET by the scanner and pulsed by the SEL-787 outside of the EIP library) within the SEL-787. The OC and CC bits are also allowed (SET by the scanner and pulsed by the SEL-787 outside of the EIP library). The analog output points can take on the value of NOOP (writing to this point reports no errors and modifies no internal values). All the remote analogs and the active settings group are controllable.

The SEL-787 uses both the EIP settings on Port 1 and the configured assembly maps to create the Electronic Data Sheet (EDS) file. Only the SEL-787 can create and modify the EDS file. Refer to *Electronic Data Sheet File* for more information.

Table F.21 Class 1 Connection Support

Class 1 Connections	Supported Connections
Input Only	Point-to-point Point to-multicast Multicast-to-point Multicast-to-multicast
Listen Only	Point-to-point Point to-multicast Multicast-to-point Multicast-to-multicast
Exclusive Owner	Point-to-point Point to-multicast Multicast-to-point Multicast-to-multicast

EtherNet/IP Settings

Table F.22 shows the EtherNet/IP Port 1 settings in the SEL-787.

Table F.22 Port 1 EtherNet/IP Protocol Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE ETHERNET/IP	Y, N	EEIP := N
CONFIGURATION ID	0–255	CONFIGID := 0
MAJOR EDS REVISION	1–255	MAJOREDS := 1
MINOR EDS REVISION	1–255	MINOREDS := 1
NUMBER OF IP ADDRESSES FOR EIP SCANNER	OFF, 1–8	NUMIP := 1
IP ADDRESS *zzz.yyy.xxx.www*	*zzz*: 1–126, 128–223 *yyy*: 0–255 *xxx*: 0–255 *www*: 0–255	EIPIP1 := 192.168.1.151 EIPIP2 := 192.168.1.152 EIPIP3 := 192.168.1.153 EIPIP4 := 192.168.1.154 EIPIP5 := 192.168.1.155 EIPIP6 := 192.168.1.156 EIPIP7 := 192.168.1.157 EIPIP8 := 192.168.1.158
NUMBER OF I/O CONNECTIONS	1–6	NUMCONN := 1
APPLICATION TYPE[a]	EXCLUSIVE_OWNER, INPUT_ONLY	APPTYP*n* := INPUT_ONLY
INPUT ASSEMBLY[a]	IA1, IA2, IA3, OA1, OA2, OA3	INASSM*n* := IA1
OUTPUT ASSEMBLY[a]	OA1, OA2, OA3	OUTASSM*n* := OA1

[a] n = 1 to 3.

Electronic Data Sheet File

EtherNet/IP uses an EDS file to define the interface between the EIP library and the scanner. The scanner uses this information to determine what objects, attributes, and services are supported by the SEL-787.

In the SEL-787, the EDS file consists of the following sections:

- *File Description Section, [File]*
- *Device Description Section, [Device]*
- *Device Classification Section, [Device Classification]*
- *Parameters Section, [Params]*
- *Assembly Section, [Assembly]*
- *Connections Section, [Connection Manager]*
- *Vendor Specific Object Section*
- *Capacity Section, [Capacity]*
- *Ethernet Link Class, [Ethernet Link Class]*

File Description Section, [File]

The File Description Section of the EDS file contains the entries listed in *Table F.23*.

Table F.23 File Description Section Entries

Name	Keyword	Value
File Description Text	DescText	Contains the product specific name <Prod Name> as specified by the product. It is of the format “<Prod Name> EtherNet/IP Adapter EDS File”.
File Creation Date	CreateDate	UTC date value that is hard-coded to match the R-release date of the firmware.
File Creation Time	CreateTime	UTC time value that is hard-coded to match the R-release time of the firmware.
Last Modification Date	ModDate	UTC data value that is determined when the EDS file is generated.
Last Modification Time	ModTime	UTC time value that is determined when the EDS file is generated.
EDS Revision	Revision	The format is MAJOREDS.MINOREDS, where MAJOREDS and MINOREDS are populated by the correspondingly named parameters in the Port 1 settings.

Device Description Section, [Device]

The Device Description Section of the EDS file contains the entries listed in *Table F.24*.

Table F.24 Device Description Section Entries (Sheet 1 of 2)

Name	Keyword	Value
Vendor ID	VendCode	SEL Vendor ID number, 865
Vendor Name	VendName	“Schweitzer Engineering Laboratories”
Device Type	ProdType	43
Device Type String	ProdTypeStr	“Generic Device Type”
Product Code	ProdCode	The number derived from the Device Code (DEVCODE as found in the **ID** command of the SEL-787) and Configuration ID as provided in the Ethernet port settings
Major Revision	MajRev	The Major Revision is assigned internally by the SEL-787
Minor Revision	MinRev	The Minor Revision is assigned internally by the SEL-787
Product Name	ProdName	Takes on the existing default product name (the default RID string in a two-line display model or the default STRING RID in a touch-screen display model) of the SEL-787 plus the value of the user-configurable Configuration ID as provided in the Port 1 settings. The general format is “<Default RID>-<Configuration ID>”.

Table F.24 Device Description Section Entries (Sheet 2 of 2)

Name	Keyword	Value
Catalog Number	Catalog	Takes on the existing default product name (the default RID string in a two-line display model or the default STRING RID in a touch-screen display model) of the SEL-787 plus the value of the user-configurable Configuration ID as provided in the Port 1 settings. The general format is "<Default RID>-<Configuration ID>".
Icon File Name	Icon	SEL787.ICO
Icon Contents	IconContents	Uncompressed content of characters

Device Classification Section, [Device Classification]

The Device Classification Section of the EDS file contains the entry listed in *Table F.25*.

Table F.25 Device Classification Section Entry

Name	Keyword	Value
Device Classification	Class1	"EtherNetIP"

Parameters Section, [Params]

Each parameter entry is named as *ParamN,* where *N* is a sequential number starting from 1 and ending at the maximum number of parameter object instances as defined in the corresponding assembly map.

All parameters of the EDS file are defined for *ParamN* in *Table F.26*.

Table F.26 Parameters of the EDS File (Sheet 1 of 2)

Label	Value
Reserved	0
Path Size, Path	Left empty
Descriptor	0x0000
Data Type	Digitals: BOOL (0xC1) 1 Byte (0 or 1) Analogs: SINT (0xC2) Signed 1 Byte Integer, USINT (0xC6) Unsigned 1 Byte Integer, INT (0xC3) Signed 2 Byte Integer, UINT (0xC7) Unsigned 2 Byte Integer, DINT (0xC4) Signed 4 Byte Integer, UDINT (0xC8) Unsigned 4 Byte Integer, REAL (0xCA) 4 Byte Float, LREAL (0xCB) 8 Byte Float, LINT (0xC5) Signed 8 Byte Integer, or ULINT (0xC9) Unsigned 8 Byte Integer
Data Size (Bytes)	See previous
Name	Takes on the label name as defined in the corresponding assembly map. Names are unique.
Units	The value is "" for digitals. The value is determined internally by the SEL-787 for analogs.
Help String	""
Min, max, default data values	It is 0,1,0 for digitals and ,,0, for analogs

Table F.26 Parameters of the EDS File (Sheet 2 of 2)

Label	Value
Mult, div, base, offset scaling	It is ,,,, for all instances
Mult, div, base, offset links	It is ,,,, for all instances
Decimal places	0

RPI Parameter

The Requested Packet Interval (RPI) parameter entry falls immediately after the last parameter object instance as defined previously. This RPI parameter entry, Param(N+1), follows the structure detailed in *Table F.27*.

Table F.27 RPI Parameter Structure

Label	Value
Reserved	0
Path Size, Path	,,
Descriptor	0x0004
Data Type	0xC8
Data Size (Bytes)	4
Name	“RPI Range”
Units	“ms”
Help String	“This parameter limits the range of the RPI value”
Min, max, default data values	100000,,1000000
Mult, div, base, offset scaling	1,1000,1,0
Mult, div, base, offset links	,,,,
Decimal Places	1

Assembly Section, [Assembly]

The Assembly Section of the EDS file contains the entries listed in *Table F.28* for all of the available assemblies in the product.

Table F.28 Assembly Section Entries

Label	Value
Name	*Name* reflects the name of the Assembly type and instance, e.g., Input Assembly 1, Output Assembly 1, Input Assembly 2, etc.
Path	Set to “20 04 24 *InstID* 30 03” where *InstID* is the hexadecimal representation of the Assembly instance ID number.
Size	*Size_Bytes* reflects the total size in bytes of the mapped parameters in the Assembly instance.
Descriptor	0x0000
Reserved	Left empty

Table F.28 Assembly Section Entries

Label	Value
Member Size	Each mapped parameter in the corresponding Assembly instance is included in the EDS file using the following format: Member Size, Member Reference, Member Size, Member Reference, ... Member Size, Member Reference *MemberSize* reflects the data size for each parameter mapped in the corresponding Assembly instance in bits.
Member Reference	*MemberReference* reflects the name of each parameter entry "ParamN" (where N is the parameter instance) mapped in the corresponding Assembly instance.

Connections Section, [Connection Manager]

The Connections Section of the EDS file contains the entries listed in *Table F.29*, *Table F.30*, and *Table F.31*.

Table F.29 Input Only Connection Entries

Field	Value
Trigger and transport	0x02030002
Connection parameters	0x44640305
O->T RPI	Left empty
O->T size	0
O->T format	Left empty
T->O RPI	Set to "*ParamN*" where *N* is the parameter entry that defines the RPI for the device.
T->O size	Left empty
T->O format	*Input_Assem* is set to "*AssemN*" where *N* is the configured input assembly for the connection point.
Connection name string	*Connection_Name* contains "INPUT ONLY" as part of the string. All names are enumerated, e.g., "INPUT ONLY 1", etc.
Help string	""
Path	Set to "20 04 2C EE 2C *In*" where *In* is the hexadecimal representation of the configured input assembly instance ID number.

Table F.30 Listen Only Connection Entries (Sheet 1 of 2)

Field	Value
Trigger and transport	0x01030002
Connection parameters	0x44640305
O->T RPI	Left empty
O->T size	0
O->T format	Left empty

Table F.30 Listen Only Connection Entries (Sheet 2 of 2)

Field	Value
T->O RPI	Set to "*ParamN*" where N is the parameter entry that defines the RPI for the device.
T->O size	Left empty
T->O format	*Input_Assem* is set to "AssemN" where N is the configured input assembly for the connection point.
Connection name string	*Connection_Name* contains "LISTEN ONLY" as part of the string. All names shall be enumerated, e.g., "LISTEN ONLY 1", etc.
Help string	""
Path	Set to "20 04 2C ED 2C *In*" where *In* is the hexadecimal representation of the configured input assembly instance ID number.

Table F.31 Exclusive Owner Connection Entries

Field	Value
Trigger and transport	0x04030002
Connection parameters	0x44640405
O->T RPI	Set to *"ParamN"* where N is the parameter entry that defines the RPI for the device.
O->T size	Left empty
O->T format	*Output_Assem* is set to *"AssemN"* where N is the configured output assembly for the connection point.
T->O RPI	Set to *"ParamN"* where N is the parameter entry that defines the RPI for the device.
T->O size	Left empty
T->O format	*Input_Assem* is set to *"AssemN"* where N is the configured input assembly for the connection point.
Connection name string	*Connection_Name* contains "EXCLUSIVE OWNER" as part of the string. All names are enumerated, e.g., "EXCLUSIVE OWNER 1", etc.
Help string	""
Path	"20 04 2C *Out* 2C *In*" where *Out* is the hexadecimal representation of the configured output assembly instance ID number and *In* is the hexadecimal representation of the configured input assembly instance ID number.

Vendor Specific Object Section

The Vendor Specific Object Section of the EDS file contains the entries listed in *Table F.32*.

Table F.32 Vendor Specific Object Section Entries (Sheet 1 of 2)

Label	Value
Revision	1
Maximum Instance Number	1
Number of Static Instances	1

Table F.32 Vendor Specific Object Section Entries (Sheet 2 of 2)

Label	Value
Maximum Number of Dynamic Instances	0
Object Name	“Relay Status”
Object Class Code	0x64

Capacity Section, [Capacity]

The Capacity Section of the EDS file contains the entries listed in *Table F.33*.

Table F.33 Capacity Section Entries

Keyword	Value
MaxIOConnections	2
MaxMsgConnections	6

Ethernet Link Class, [Ethernet Link Class]

The Ethernet Link Class Section of the EDS file contains the entries listed in *Table F.34*.

Table F.34 Ethernet Link Class Entries

Keyword	Value
Revision	4
Object_Name	"Ethernet Link Object"
Object_Class_Code	0xF6
MaxInst	It is 2 if a dual Ethernet port CPU card is used. It is 1 if a single Ethernet port CPU card is used.
Number_Of_Static_ Instances	It is 2 if a dual Ethernet port CPU card is used. It is 1 if a single Ethernet port CPU card is used.
Max_Number_Of_ Dynamic_Instances	0
InterfaceLabel1	It is “PORT 1” if a single Ethernet port CPU card is used. It is “PORT 1A” if a dual Ethernet port CPU card is used.
InterfaceLabel2	Does not exist if a single Ethernet port CPU card is used. It is “PORT 1B” if a dual Ethernet port CPU card is used.

Appendix G
IEC 61850 Communications

Features

NOTE: The SEL-787 Relay ships with a default CID file installed that supports basic IEC 61850 functionality. A new CID file should be loaded if a change in the relay configuration is required. If an invalid CID file is transferred, the relay will reject the file and revert to the previous valid CID file.

The SEL-787 Relay uses Ethernet and IEC 61850 to support the following features:

- **SCADA**—Connect as many as seven simultaneous IEC 61850 MMS client sessions. The SEL-787 also supports as many as seven buffered and seven unbuffered report control blocks. See *Table G.38* for Logical Node mapping that enables SCADA control via a Manufacturing Message Specification (MMS) browser. Controls support the Direct Normal Security and Enhanced Security (Direct or Select Before Operate) control models.
- **Peer-to-Peer Real-Time Status and Control**—Use GOOSE with as many as 64 incoming (receive) and 8 outgoing (transmit) messages. Virtual bits (VB001–VB128) and Remote Analogs (RA001–RA128) can be mapped from incoming GOOSE messages.
- **Configuration**—Use FTP client software or ACSELERATOR Architect SEL-5032 Software to transfer the Substation Configuration Language (SCL) Configured IED Description (CID) file to the relay.
- **Commissioning and Troubleshooting**—Use software such as AX-S4 from Sisco, Inc., to browse the relay logical nodes and verify functionality.

This appendix presents the information you need to use the IEC 61850 features of the SEL-787:

- *IEC 61850 Introduction*
- *IEC 61850 Operation*
- *Simulation Mode*
- *IEC 61850 Mode/Behavior*
- *IEC 61850 Configuration*
- *Logical Nodes*
- *Protocol Implementation Conformance Statement*
- *ACSI Conformance Statements*

IEC 61850 Introduction

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 G.1*.

These parts were first published between 2001 and 2004, and they are often referred to as IEC 61850 Edition 1 (Ed1). Selected parts of these standards were released in 2011 and tagged as Edition 2 (Ed2). The SEL-787 Relay is compliant with Ed2.

It is possible and even likely, that an installation can have a mixture of devices that conform to either Ed1 or Ed2. The standard supports backwards compatibility, i.e., Ed2 devices can send and receive messages to and from Ed1 devices. However, there are important considerations to be made when adding Ed2 devices to an existing Ed1 system. Please refer to *Potential Client and Automation Application Issues With Edition 2 Upgrades on page G.89* for more information.

Table G.1 IEC 61850 Document Set (Sheet 1 of 2)

IEC 61850 Sections	Definitions
IEC 61850-1	Introduction and overview
IEC 61850-2	Glossary
IEC 61850-3	General requirements
IEC 61850-4	System and project management
IEC 61850-5	Communications requirements
IEC 61850-6	Configuration description language for substation IEDs
IEC 61850-7-1	Basic communications structure for substations and feeder equipment—Principles and models
IEC 61850-7-2	Basic communications structure for substations and feeder equipment—Abstract Communication Service Interface (ACSI)
IEC 61850-7-3	Basic communications structure for substations and feeder equipment—Common data classes
IEC 61850-7-4	Basic communications structure for substations and feeder equipment—Compatible logical node (LN) classes and data classes

Table G.1 IEC 61850 Document Set (Sheet 2 of 2)

IEC 61850 Sections	Definitions
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 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 are available as options in the SEL-787. In addition to IEC 61850, the Ethernet port provides support protocols and data exchange, including FTP and Telnet. Access the SEL-787 Port 1 settings to configure all of the Ethernet settings, including IEC 61850 enable settings.

The SEL-787 Ethernet port supports IEC 61850 services, including transport of logical node objects, over TCP/IP. The Ethernet port can coordinate a maximum of seven concurrent IEC 61850 MMS sessions.

Object Models

The IEC 61850 standard relies heavily on the Abstract Communication Service Interface (ACSI) model to define a set of service and the responses to those services. In terms of network behavior, abstract modeling enables all IEDs to act identically. You can use these abstract models 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 Local Nodes.

UCA2 uses 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 can contain many functions such as protection, metering, and control. Multiple logical nodes represent the functions in multifunction devices.

You can organize logical nodes 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. 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 G.2* shows how the Phase A current expressed as MMXUAphsA$cVal is broken down into its component parts.

Table G.2 Example IEC 61850 Descriptor Components

Components		Description
MMXU	Logical Node	Polyphase measurement unit
A	Data Object	Phase-to-ground amperes
PhsA	Sub-Data Object	A-phase
cVal	Data Attribute	Complex value

Data Mapping

Device data are mapped to IEC 61850 logical nodes (LN) according to rules defined by SEL. Refer to IEC 61850-5:2013(E) and IEC 61850-7-4:2010(E) for the mandatory content and usage of these LNs. The SEL-787 logical nodes are grouped under Logical Devices for organization based on function. See *Table G.3* for descriptions of the Logical Devices in an SEL-787. See *Logical Nodes on page G.28* for a description of the LNs that make up these Logical Devices.

Table G.3 SEL-787 Logical Devices

Logical Device	Description
ANN	Annunciator elements—alarms, status values
CFG	Configuration elements—datasets and report control blocks
CON	Control elements—Remote bits
MET	Metering or Measurement elements—currents, voltages, power, etc.
PRO	Protection elements—protection functions and breaker control

Functional Naming

NOTE: Functional naming is not supported by all MMS clients and GOOSE subscribers. Verify support for this feature before configuring functional names in a publishing IED.

Substation design typically starts with a one-line diagram and progresses down to the assignment of functions to IEDs. In this top-down approach, the functions are identified and named independently from the IEDs to which they are assigned.

Because a logical device is a grouping of logical nodes that perform a certain high-level function at a substation, the associated name often indicates the assigned function. The functional naming feature allows users to name a logical device based on the function it provides independent of the name of the IED to which the function is assigned. The alternative is product naming, which prepends the IED name to the logical device instance to create the logical device name. The functional name is used on the communications interface for all references to data in the logical device.

The SEL-787 supports functional naming of logical devices. You can add functional names in Architect for supported Edition 2 relays. To enable it in Architect, navigate to **Edit** > **Project Settings** and select the **Enable functional name editing on Server Model tab of supporting IEDs** check box, as shown in *Figure G.1*.

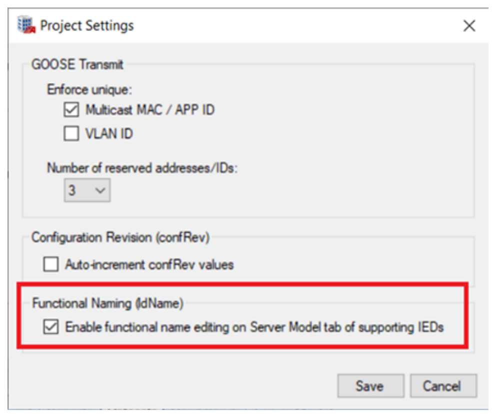

Figure G.1 Enable Functional Naming in Architect

To provide functional names to the logical devices, navigate to the Server Model tab for the IED. Because datasets and control blocks are in the CFG logical device, any functional name given to the CFG logical device instance is used in dataset references, control block references, and in published GOOSE messages, as shown in *Figure G.2*. The IED Server Model also allows the user to change the default logical node prefix and instance values.

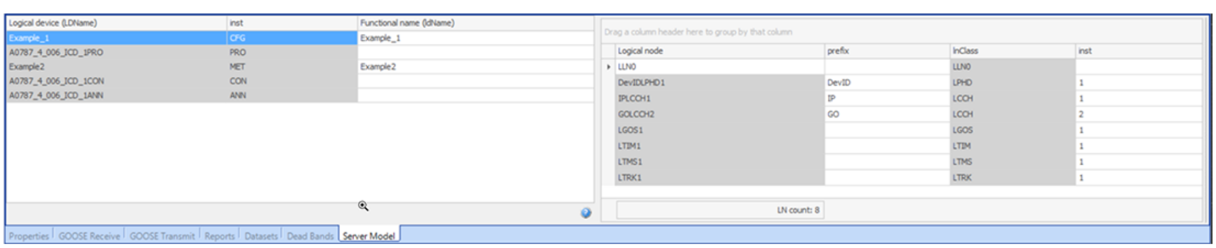

Figure G.2 Server Model View in Architect

MMS

Manufacturing Message 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 be 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. MMS associations are discussed within IEC 61850-8-1, Clause 10 of the Edition 1 standard.

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 Access Level 2 password of the SEL-787.

- 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.

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 devices to transfer data as files
- A hierarchical file structure for the device data

The SEL-787 supports MMS file transfer with or without authentication; the service is intended to support the following:

- CID file download and upload
- Settings Files download and upload
- Retrieval of events, and reports

MMS file services are enabled or disabled via Port 1 settings. See *Virtual File Interface on page 7.73* for details on the files available for MMS file services. For additional details, see *File Transfer Protocol (FTP) and MMS File Transfer on page 7.15*, *Retrieving COMTRADE Event Files on page 10.41*, and *Retrieving Event Reports Via Ethernet File Transfer on page 10.29*.

SCL Files

Substation Configuration Language (SCL) is an XML-based configuration language used to support the exchange of database configuration data between different tools, which may come from different manufacturers. There are four types of SCL files:

- IED Capability Description file (.ICD)
- System Specification Description (.SSD) file
- Substation Configuration Description file (.SCD)
- Configured IED Description file (.CID)

The ICD file described 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 necessary 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

IEC 61850 datasets are lists of references to DataObject attributes for the purpose of efficient observation and transmission of data. Architect ICD files come with predefined datasets that can be used to transfer data via GOOSE messages, or MMS reports. The datasets listed in *Figure G.1* are the defaults for an SEL-787 device. Datasets BRDSet01–BRDSet07 and URDSet01–URDSet07 are preconfigured with common FCDAs to be used for reporting. These datasets can be configured to represent the data you want to monitor. Dataset GPDSet01, which contains breaker status and control data attributes, is used in the default Goose Control Publication.

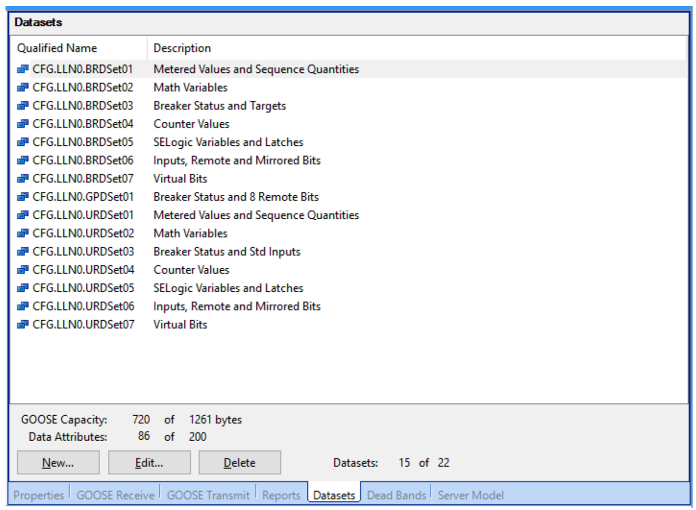

Figure G.3 SEL-787 Datasets

- GOOSE: You can use predefined or edited datasets, or create new datasets for outgoing GOOSE transmission.

NOTE: Do not edit the dataset names used in reports. Changing or deleting any of those dataset names will cause a failure in generating the corresponding report.

- Reports: Fourteen predefined datasets (BRDSet01–BRDSet07 and URDSet01–URDSet07) correspond to the default seven buffered and seven unbuffered reports, respectively. 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 dataset contains and so define what data an IEC 61850 client receives with a report.
- MMS: You can use predefined or edited datasets, or create new datasets to be monitored by MMS clients.

Reports

The SEL-787 supports buffered and unbuffered report control blocks in the report model as defined in IEC 61850-8-1:2011. The predefined reports shown in *Figure G.3* are available by default via IEC 61850. There are 14 report control blocks, seven buffered reports and seven unbuffered.

NOTE: When configuring buffered and unbuffered reports that contain analog values, only a change in the magnitudes value (mag or cVal data attributes) will trigger a data change report.

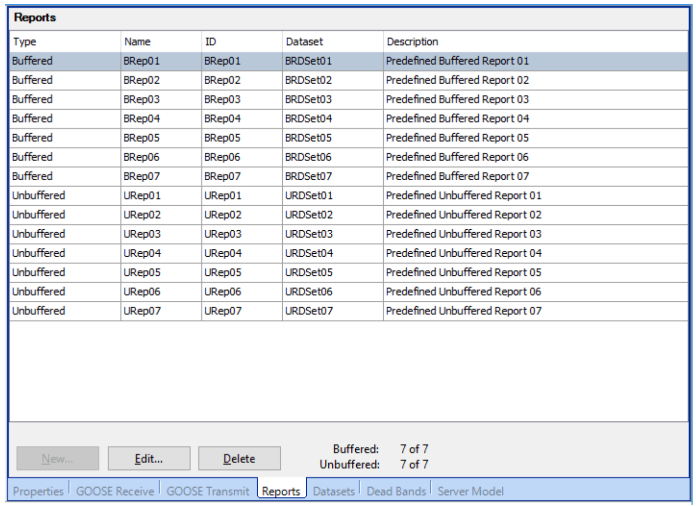

Figure G.4 SEL-787 Predefined Reports

For each report control block, there can be just one client association, i.e., only one client can be associated to a report control block (BRCB or URCB) at any given time. The number of reports (14) and the type of reports (buffered or unbuffered) cannot be changed. However, by using Architect, you can reallocate data within each report dataset to present different data attributes for each report beyond the predefined datasets. For buffered reports, connected clients can edit the report parameters shown in *Table G.4*.

Table G.4 Buffered Report Control Block Client Access

RCB Attribute	User changeable (Report Disabled)	User changeable (Report Enabled)	Default Values
RptId	YES		BRep01–BRep07
RptEna	YES	YES	FALSE
OptFlds	YES		seqNum timeStamp dataSet configRef reasonCode dataRef
BufTm	YES		500
TrgOp	YES		dchg qchg
IntgPd	YES		0
GI	YES[a b]	YES[a]	FALSE
PurgeBuf	YES[a]		FALSE
EntryId	YES		0

[a] Exhibits a pulse behavior. Write a one to issue the command. Once command is accepted returns to zero. Always read as zero.
[b] When disabled, a GI is processed and the report buffered if a buffer has been previously established. A buffer is established when the report is enabled for the first time.

Similarly, for unbuffered reports, connected clients can edit the report parameters shown in *Table G.5*.

Table G.5 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
OptFlds	YES		seqNum timeStamp dataSet configRef reasonCode dataRef
BufTm	YES		250
TrgOps	YES		dchg qchg
IntgPd	YES		0
GI		YES[a]	

[a] Exhibits a pulse behavior. Write a one to issue the command. Once command is accepted, returns to zero. Always read as zero.

For buffered reports, only one client can enable the RptEna attribute of the BRCB at a time resulting in a client association for that BRCB. Once enabled, the associated client has exclusive access to the BRCB until the connection is closed or the client disables the RptEna attribute. Once enabled, all unassociated clients have read only access to the BRCB.

For unbuffered reports, as many as seven clients can enable the RptEna attribute of the URCB at a time, resulting in multiple client associations for that URCB. Once enabled, each client has independent access to a copy of that URCB.

The Resv attribute is writable, however, the SEL-787 does not support reservations. Writing any field of the URCB causes the client to obtain its own copy of the URCB-in essence, acquiring a reservation.

Reports are serviced at a 2 Hz rate. The client can set the IntgPd to any value with a resolution of 1 ms. However, the integrity report is only sent when the period has been detected as having expired. The report service rate of 2 Hz results in a report being sent within 500 ms of expiration of the IntgPd. The new IntgPd begins at the time that the current report is serviced.

Supplemental Software

Examine the data structure and value of the supported IEC 61850 LNs with an MMS browser such as MMS Object Explorer and AX-S4 61850 from Sisco, Inc.

The settings necessary to browse an SEL-787 with an MMS browser are as follows:

OSI-PSEL (Presentation Selector)	00000001
OSI-SSEL (Session Selector)	0001
OSI-TSEL (Transport Selector)	0001

Time Stamps and Quality

In addition to the various data values, the two attributes quality and t (time stamp) are available at any time. The relay determines the time stamp when it detects a change in quality or data.

The relay applies a time stamp to all data and quality attributes (Boolean, Bstrings, Analogs, etc.) in the same fashion as when it detects a data or quality change. However, there is a difference in how the relay detects the change between the different attribute types. For points that are assigned as SER points, i.e., programmed in the SER report, the relay detects the change as the receipt of an SER record (which contains the SER time stamp) within the relay.

For all other Booleans or Bstrings, the relay detects the change via the scanner, which compares the last state against the previous state to detect the change. For analogs, the scanner looks at the amount of change relative to the deadband configured for the point to indicate a change and apply the time stamp. In all cases, the relay uses these time stamps for the reporting model.

LN data attributes mapped to points assigned to the SER report have 4 ms SER-accurate time stamps for data change events. To ensure that you get SER-quality time stamps for changes to certain points, you must include those points in the SER report. All other LN data attributes are scanned for data changes on a 1/2-second interval and have 1/2-second time-stamped accuracy. See *SER Trigger Lists on page 4.156* for information on programming the SER report.

The SEL-787 uses GOOSE quality attributes to indicate the quality of the data in its transmitted GOOSE messages. Under normal conditions, all attributes are zero, indicating good quality data. *Figure G.5* shows the GOOSE quality attributes available to devices that subscribe to GOOSE messages from SEL-787 datasets that contain them. Internal status indicators provide the information necessary for the device to set these attributes.

For example, if the device becomes disabled, as shown via status indications (e.g., an internal self-test failure), the SEL-787 sets the Validity attribute to invalid and the Failure attribute to TRUE. Note that the SEL-787 does not set any of the other quality attributes. These attributes always indicate FALSE (0). See the Architect online help for additional information on GOOSE Quality attributes.

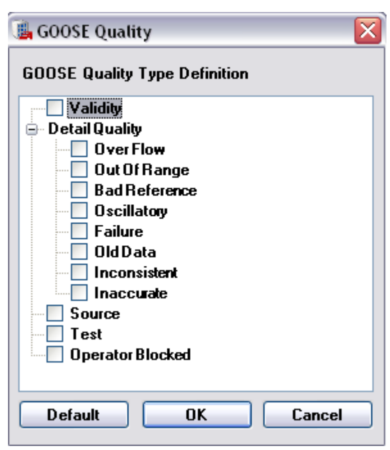

Figure G.5 Goose Quality

Control

IEC 61850 Controls

An IEC 61850 server may allow a client to manipulate data related to its outputs, external devices, or internal functions. This is accomplished by the IEC 61850 control model, which provides services to execute control commands. The control models are defined in IEC 61850-7-2 and the mapping to the MMS (Manufacturing Message Specification) application protocol is defined in IEC 61850-8-1. The former describes control functionality while the latter maps the IEC 61850 control primitives to MMS.

The SEL-787 Relay supports four different control models:

- Status Only
- Direct with Normal Security
- Direct with Enhanced Security
- SBO with Enhanced Security

The SEL-787 Relay supports the above control models for SPC and DPC controllable common data classes (CDCs) as defined in IEC 61850-8-1:2004. Other controllable CDCs defined in the standard are either unsupported or must be configured with the status-only control model. Supported CDCs include remote bits RBGGIO*n* in the CON Logical Device (LD), and breaker and disconnect controls *xx*XCBR*nn* and *xx*XSWI*nn* in the PRO LD. One control model must be selected during initial IED configuration in Architect and is applied throughout the CID file. This control model will apply to all controls in the IED.

Direct Control Models

The “Direct” control models provide the simplest means to initiate actions on the server. In these models, the client issues a control request via MMS, the server validates the request. Once validated, the server attempts to act upon the request. Note that if multiple clients are trying to perform control actions, the server will do nothing to prevent this.

SBO Control Model

The SBO control model supports the Select or SelectWithValue Service and can be used to prevent multiple clients from performing simultaneous control actions. In this mode, a client has to “reserve” the control object by sending a “select” control command. Once an object is selected, only the client that made the selection is allowed to perform control actions on it. If that client does not send a valid operate request for the object by the time the ten-second selection timer runs out, the object becomes available for selection again. The relay will support as many as ten pending control object selections at any time.

NOTE: When an IED is configured with the SBO with Enhanced Security control model, the sboTimeout attribute of the controllable CDCs in the CID file is set to ten seconds. The time-out is not configurable via Architect.

The attribute stSeld (selected status) of the controllable CDC is set to TRUE when a client successfully selects the control object. The attribute is reset to FALSE when either the control (operate) command is successfully executed, an error occurs, or no operate command is received within the select time-out period. The stSeld attribute may trigger a report just like any data attribute with trigger option.

Security in Control Models

“Security” in the control model context refers to additional supervision of the status value by the control object. The “enhanced security” models report additional error information on failed operations to the requesting client than the models with “normal security”. Enhanced security control models also

NOTE: The maximum time required for a control operation to be completed should be less than the configured time-out period to avoid erroneous command termination reports indicating failure.

provide a command termination report indicating if the control actually reached the new state as commanded within a configurable time-out period.

The time-out period between the execution of a control and the generation of a command termination report indicating failure has a default value of 1 s and is configurable via the CID file. This time-out is not configurable via Architect.

Optional Control Configurations

The SEL-787 supports the pulse configuration option specified in Clause 6.7 of IEC 61850-7-3. Contact the factory if this feature is necessary for your application.

Control Interlocking

The SEL-787 relay uses control interlocking to supervise the open and close control commands from MMS Clients. The relay accomplishes it by checking the CSWI logical node control object against an associated CILO logical node data object. The CILO logical node has two data objects: Enable Open (EnaOpn) and Enable Close (EnaCls). When the associated CILO logical node EnaCls and EnaOpn data objects are not asserted, the relay blocks the control operation and sends the AddCause "Blocked-by-interlocking" to the MMS Client.

Program SELOGIC settings SCBK1BO, SCBK2BO, SCBK3BO, and SCBK4BO to supervise opening and SCBK1BC, SCBK2BC, SCBK3BC, and SCBK4BC to supervise closing of the circuit breaker. For example, when SCBK1BO and SCBK1BC are asserted, the associated bits, BKENO1 of CILO EnaOpn and BKENC1 of CILO EnaCls, respectively, deassert, the relay blocks the control command of the circuit breaker. Use settings 89CB*km* and 89OB*km* (*k* = 2P, 3PL, or 3PE, *m* = switch number [1–16 if *k* = 2P; 1–2 if *k* = 3PL or 3PE]) to supervise closing and opening of the 2- or 3-position disconnect switches, respectively.

Figure G.6 shows how the relay responds to a CSWI logical node *write* command request from the MMS client when IEC 61850 control interlocking is applied.

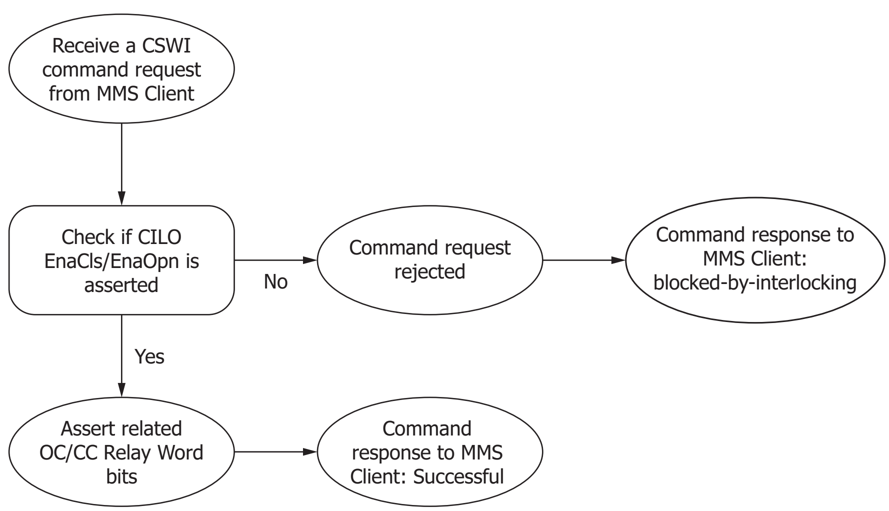

Figure G.6 CSWI Logical Node Direct Operate Command Request

Local/Remote Control Authority

Control commands at a substation originate from one of three levels: remote (network control center) level, station level, or bay level. Under certain operational conditions (e.g., during maintenance), it may be necessary to block control commands from one or more of these levels. The local/remote control feature allows users to enable or disable control authority at any of the three levels. The level at which a control command originates is determined by the value of the origin.orCat (originator category) attribute in the command.

The SEL-787 supports the local/remote control feature defined in IEC 61850-7-4. The feature is supported at the IED level with identical and configurable attributes in the LLN0 logical node in each logical device. *Table G.6* describes the attributes and their data sources.

Table G.6 Control Authority Attributes

Attribute	Data Source	Description
LLN0.Loc.stVal	LOC	Control authority at local (bay) level
LLN0.LocSta.stVal	LOCSTA	Control authority at station level
LLN0.MltLev.setVal	MLTLEV	Multilevel control authority

Using these three attributes, you can enable or disable control authority at any of the three switching levels, as shown in *Table G.7*.

Table G.7 Control Authority Settings

LLN0			orCat Value		
Loc.stVal	**LocSta.stVal**	**MltLev.setVal**	**Bay (1 or 4)**	**Station (2 or 5)**	**Remote (3 or 6)**
F	F	F	NA	NA	AA
F	F	T	AA	AA	AA
F	T	F	NA	AA	NA
T	X	X	AA[a]	NA	NA
F	T	T	AA	AA	NA

[a] Commands to CSWI logical nodes that control process level equipment (XCBR/XSWI) are not allowed.
T = True (asserted)
F = False (deasserted)
X = Do not care (true or false)
AA = Command is allowed
NA = Command is not allowed

By default, all three attributes are set to False, so only remote commands are allowed.

You can control the Relay Word bits LOC, LOCSTA, and MLTLEV through SELOGIC control equations. LOCSTA is set to True when the SELOGIC control equation SC850LS asserts and set to False when SC850LS deasserts. LOCSTA may also be controlled through MMS, but if it is set to True through SELOGIC control equations, it cannot be set to False through MMS.

In the SEL-787, you can place only the XCBR and XSWI logical nodes in local mode by asserting the LOCAL Relay Word bit. This blocks all control commands to the associated CSWI logical nodes.

Control Requests

IEC 61850 control services are implemented by reading and writing to pseudovariables in the relay in response to MMS requests. Similar to how client requests are generated and mapped to MMS read or write service requests, server actions are also mapped to internal commands, read and write actions and MMS information report messages. In the case of an unsuccessful control request, the relay will send the appropriate response PDU indicating that there was a problem and an MMS information report that contains more detailed information about the problem that occurred.

When writing controls, the client must select and write the entire Oper, SBOw, or Cancel structure to the relay. See *Figure G.7* for the attributes of the CON Logical Device and ST and CO functional constraints (FC) of LN RBGGIO1 used for controls of RB01 through RB08.

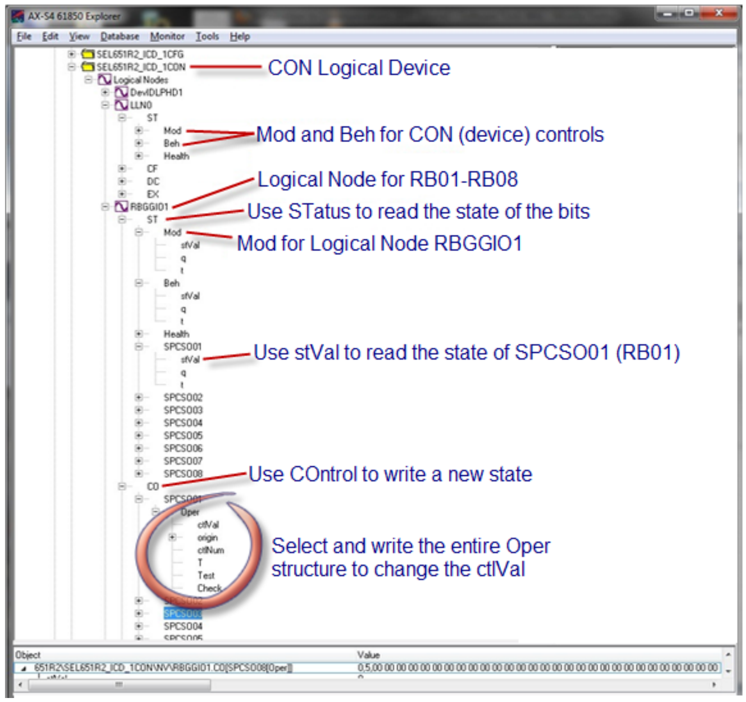

Figure G.7 MMS Client View of the CON Logical Device

Control Error Messages

If a control request results in an error condition, the relay will respond with an AddCause value in an MMS information report. See Clause 20.5.2.9 of IEC 61850-7-2 for additional information on the AddCause values. The SEL-787 Relay supports the AddCause values in *Table G.8* as part of the LastApplError information report.

Table G.8 AddCause Descriptions (Sheet 1 of 2)

AddCause Enumeration	AddCause Description	Error Condition
0	Unknown	No other AddCause value defined within this section applies
2	Blocked-by-switching-hierarchy	Logical node is set to local mode, i.e. Loc.stVal = true
3	Select-failed	Originator category not allowed to issue control commands or SelectWithValue operation fails

Table G.8 AddCause Descriptions (Sheet 2 of 2)

AddCause Enumeration	AddCause Description	Error Condition
4	Invalid-position	For controls with enhanced security, an AddCause of “Invalid-position” (4) will be sent if the control status changes to an unexpected value. If no control status change is detected after the operate time-out period, an AddCause of “Time-limit-over” (16) will be sent.
5	Position-reached	Control status is already at the desired state
6	Parameter-change-in-execution	Control object is already selected by the client, and 1. Logical node is set to local mode i.e., Loc.stVal = true, or 2. Originator category not allowed to issue control commands
8	Blocked-by-mode	Mode of logical device or node is not ON
10	Blocked-by-interlocking	Control operation of switch device failed due to interlock check
12	Command-already-in-execution	Execution of a previous control is not completed
13	Blocked-by-health	Health of logical device or node is not OK
16	Time-limit-over	CommandTermination gives a negative response. (The control failed to reach its intended state prior to time-out.)
18	Object-not-selected	Cancel operation fails

Any AddCause value not specified above is not supported. Control CDC data attributes which are associated with unsupported AddCause values and are not part of a control structure will be accepted but ignored. For example, the attribute CmdBlk.stVal which is associated with the AddCause value “blocked-by-command” and is not part of a SBOw, Oper, or Cancel structure will be ignored.

Group Switch Via MMS

The Group Switch feature in IEC 61850 is primarily a convenience feature for users so that they can institute a settings group switch from an IEC 61850 client without having to revert to the command line or some other tool. However, this has great potential for integration with IEC 61850 SCADA systems which would be able to control setting groups through IEC 61850 MMS.

The IEC 61850 specification outlines a method for switching the current settings group to another preconfigured settings group. The setting group control block, or SGCB, contains the SettingControl element which enables settings group control. An SEL-787 CID file that supports group switch functionality will only contain one SGCB. The SGCB contains the number of settings groups in the relay and may also contain the current active setting group, ActSG. Note that if the CID file contains a value for ActSG, it will be ignored and the relay will use the actual active setting group value for ActSG at the time of CID file download.

When the IEC 61850 functions of the relay are enabled, the selectActiveSG service allows an MMS client to request that the relay change the active setting group. The MMS client can request a group switch by writing a valid setting group number to ActSG. The relay updates the ActSG value under the following conditions:

- The value written to ActSG is valid and not the current active group
- There is no group switch in progress
- The setting of the active group was successful

Note that if the value written to ActSG is the same as the current group, the relay will not attempt to switch settings groups. Please refer to *Multiple Settings Groups on page 4.119* for more information on setting group selection.

Service Tracking

The IEC 61850 standard defines many services to be provided by an IED (server). These services include control services, reporting services, logging services, and group switch control services. IEC 61850 Edition 2 defines the service tracking feature to allow these services to be reported or logged, whether they succeed or fail.

The SEL-787 supports the service tracking feature for control commands, report control block edits, and group switch selection. You can report these services.

Tracking of these services is enabled by data objects in the service tracking logical node LTRK. *Table G.9* lists the service tracking data objects. Their data attributes mirror those in the service request or in the control block that was the target of the service request.

Table G.9 Service Tracking Data Objects

Data Object	CDC	Description
SpcTrk	CTS	Tracks control service requests targeted at a controllable single-point object
DpcTrk	CTS	Tracks control service requests targeted at a controllable double-point object
EncTrk	CTS	Tracks control service requests targeted at a controllable enumerated status object
UrcbTrk	UTS	Tracks unbuffered report control block edits
BrcbTrk	BTS	Tracks buffered report control block edits
SgcbTrk	STS	Tracks active settings group selection

Refer to *Table G.40* for information regarding the available attributes in each tracking data object.

Each tracking data object includes the data attributes objRef, serviceType, and errorCode. The attribute objRef provides the reference to the control object or control block instance that was the target of the service request. The attribute serviceType provides an enumerated value for the specific service requested or executed. *Table G.10* defines the service type enumerations.

Table G.10 IEC 61850 Service Type Enumeration

Service Type	Service Name	Description
16	SelectActiveSG	Active settings group switch request
24	SetBRCBValues	Write request on one or more of the following buffered report control block attributes: RptID, RptEna, OptFlds, BufTm, TrgOps, IntgPd, PurgeBuf, EntryID, or GI
26	SetURCBValues	Write request on one or more of the following unbuffered report control block attributes: RptID, RptEna, OptFlds, BufTm, TrgOps, IntgPd, Resv, or GI
44	SelectWithValue	Select control request
45	Cancel	Cancel control request
46	Operate	Operate control request
47	CommandTermination	Control processing completed on a control object configured with enhanced security control model
54	InternalChange	Report control block has been automatically disabled, i.e., RptEna is set to False after a loss of association with the client

The attribute errorCode provides the error code that indicates whether the service was successful or unsuccessful. *Table G.11* lists the codes and the corresponding ACSI errors.

Table G.11 IEC 61850 ACSI Service Error

Error Code	ACSI Error
0	no-error
1	instance-not-available
3	access-violation
5	parameter-value-inappropriate
6	parameter-value-inconsistent
7	class-not-supported
8	instance-locked-by-other-client
10	type-conflict
11	failed-due-to-communications-constraint
12	failed-due-to-server-constraint

When creating datasets to track the services through information reporting, it is important to include the tracking data objects as a whole object (FCD—functionally constrained data), and not as individual data attributes (FCDA—functional constrained data attribute). Only the objRef attribute has a trigger option (dupd—data update) and can trigger a report. The dupd trigger option must also be enabled in the report control block that is reporting changes in the tracking data objects.

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 messages several times, increasing the likelihood that other devices receive the messages.

IEC 61850 GOOSE objects can quickly and conveniently transfer status, controls, and measured values between peers on an IEC 61850 network. Configure SEL devices to respond to GOOSE messages from other network with Architect software. Also, configure outgoing GOOSE messages for SEL devices in Architect. See the Architect online help for more information.

Each IEC 61850 GOOSE sender includes a text identification string (GOOSE Control Block Reference) in each outgoing message and an Ethernet multicast group address. Devices that receive GOOSE messages use the text identification and multicast group to identify and filter incoming GOOSE messages.

NOTE: Virtual bits and remote analogs mapped to GOOSE subscriptions retain their state until they are overwritten, a new CID file is loaded, or the device is restarted. To reset the virtual bits and remote analogs by restarting the device, issue an **STA C** command or remove and then restore power to the device.

Virtual bits (VB001–VB128) are control inputs that you can map to GOOSE receive messages by using the Architect software. See the VB*nnn* bits in *Table G.39* for details on which logical nodes and names are used for these bits. This information can be useful when searching through device data with MMS browsers. If you intend to use any SEL-787 virtual bits for controls, you must create SELOGIC control equations to define these operations. The Virtual Bit Logical Nodes only contain Virtual Bit status, and only those Virtual Bits that are assigned to an SER report are able to track bit transitions (via reporting) between LN data update scans.

The relay is capable of receiving analog values via peer-to-peer GOOSE messages. Remote Analogs (RA001–RA128) are analog inputs that you can map to values from incoming GOOSE messages.

GOOSE Processing

SEL devices support GOOSE processing as defined by IEC 61850-7-1:2011(E), IEC 61850-7-2:2010(E), and IEC 61850-8-1:2011(E) via the Ethernet port.

Outgoing GOOSE messages are processed within the following constraints:

- You can define as many as eight datasets for outgoing GOOSE messages consisting of any data attribute (DA) from any logical node. A single DA can be mapped to one or more outgoing GOOSE datasets, or one or more times within the same outgoing GOOSE dataset. You can also map a single GOOSE dataset to multiple GOOSE control blocks. The number of unique Boolean variables is limited to a combined total of 128 digital bits across all eight outgoing messages.
- The relay transmits all configured GOOSE immediately upon successful initialization. If a GOOSE message is not retriggered; then, following the initial transmission, the relay retransmits that GOOSE based on the minimum time and maximum time configured for that GOOSE message. The first transmission occurs immediately on triggering of an element within the GOOSE dataset. The second transmission occurs Min. Time later. The third transmission occurs Min. Time after the second transmission. The fourth transmission occurs twice Min. Time after the third transmission. All subsequent transmissions occur at the Max Time interval. For example, a message with a Min. Time of 4 ms and Max. Time of 1000 ms is transmitted upon triggering, then retransmitted at intervals of 4 ms, 4 ms, 8 ms, and then at 1000 ms indefinitely or until

another change triggers a new GOOSE message (See IEC 61850-8-1, Sec. 18.1). The default Min. Time value is 8 ms. This is also the suggested Min. Time value to use.

- GOOSE transmission is squelched (silenced) after a permanent (latching) self-test failure.
- Each outgoing GOOSE includes communications parameters (VLAN, Priority, and Multicast Address) and is transmitted entirely in a single network frame.
- The SEL-787 maintains the configuration of outgoing GOOSE through a power cycle and device reset.

Incoming GOOSE messages are processed within the following constraints:

- You can configure the SEL-787 to subscribe to as many as 64 incoming GOOSE messages.
- Control bits in the relay get data from incoming GOOSE messages which are mapped to virtual bits (VB*nnn*). Virtual bits are volatile and are reset to zero when a new CID file is loaded, the device is restarted, or they are overwritten by data from a subscribed GOOSE message.
- The SEL-787 recognizes incoming GOOSE messages as valid based on the following content. Any GOOSE message that fails these checks is rejected.
  - Source broadcast MAC address
  - Dataset Reference
  - Application ID
  - GOOSE Control Reference
- Rejection of all DA contained in an incoming GOOSE, based on the accumulation of the following error indications created by inspection of the received GOOSE:
  - **Configuration Mismatch**: the configuration number of the incoming GOOSE changes.
  - **Needs Commissioning**: this Boolean parameter of the incoming GOOSE is true.
  - **Test Mode**: this Boolean parameter of the incoming GOOSE is true.
  - **Decode Error**: the format of the incoming GOOSE is not as configured.
- The SEL-787 discards incoming GOOSE under the following conditions:
  - after a permanent (latching) self-test failure
  - when the relay is disabled
  - when EGSE is set to No

Link-layered priority tagging and virtual LAN is supported as described in Annex C of IEC 61850-8-1:2011.

Simulation Mode

The SEL-787 relay can be configured to operate in simulation mode. In this mode, the SEL-787 relay continues to process normal GOOSE messages until a simulated GOOSE message is received for a subscription. Once a simulated GOOSE message is received, only simulated GOOSE messages are processed for that subscription. The simulated mode only terminates when LPHDSIM is returned to FALSE. When the relay is not in the simulation mode, only normal GOOSE messages are processed for all subscriptions. You can place the SEL-787 in simulation mode by setting LPHDSIM (CFG.DevIDLPHD1.Sim.stVal) to true via MMS messaging.

Alternatively, you can use SELOGIC variable SC850SM to set LPHDSIM. The rising edge of SC850SM sets LPHDSIM, and the falling edge of SC850SM clears LPHDSIM. When you use SC850SM to enter simulation mode, the relay rejects MMS attempts to enter or exit simulation mode until SC850SM deasserts.

IEC 61850 Mode/Behavior

The IEC 61850-7-4:2010 standard defines the behavior of the different modes to facilitate testing. The different modes are only available in IEDs with IEC 61850 Edition 2 support.

SEL-787 relays support the following modes:

- On
- Blocked
- Test
- Test/Blocked
- Off

IEC 61850 Behavior is determined by the logical device mode and its logical node mode according to the IEC 61850 standard. For SEL-787 relays, the selected IEC 61850 Mode/Behavior applies to the entire IED, including all the logical devices and all the logical nodes. The behavior of the IED is always the same as the selected mode. *Table G.12* describes the available services based on the mode/behavior of the IED.

Table G.12 IEC 61850 Services Based on Mode/Behavior

Mode	MMS	GOOSE Publication and Subscription
On	Available	Available
Blocked	Available	Available
Test	Available	Available
Test/Blocked	Available	Available
Off	No services[a]	Publication[b]

[a] All MMS control requests to change the mode with Test = false will be processed.
[b] GOOSE publication in Off mode is disabled if EOFFMTX = N.

The analog quantity I850MOD is an enumerated number that corresponds to mode and behavior as shown in *Table G.13*. You can view the value of this analog quantity by assigning it to a math variable.

Table G.13 Analog Quantity I850MOD Status Based on the Selected IEC 61850 Mode/Behavior

I850MOD	IEC 61850 Mode/Behavior
1	On
2	Blocked
3	Test
4	Test/Blocked
5	Off
0	Not Supported

Mode/Behavior Control

Enable Mode/Behavior Control

IEC 61850 Mode/Behavior, by default, is disabled in SEL-787 relays. To enable IEC 61850 Mode/Behavior, you must set the Port 1 setting E61850 equal to Y. To enable IEC 61850 Mode/Behavior Control, you must set Port setting E850MBC equal to Y and the CID file setting controllableModeSupported to True. You can set the controllableModeSupported setting by selecting **Enable control of IEC 61850 Mode/Behavior** when adding an IED to an ACSELERATOR Architect SEL-5032 Software project, as shown in *Figure G.8*.

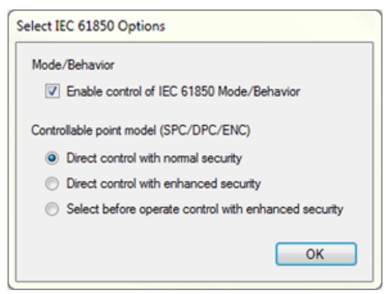

Figure G.8 Set controllableModeSupported = True

Enhances Secure Mode Control

Relay setting E850MBC and CID file setting controllableModeSupported provide security to prevent accidental switching into an unplanned IEC 61850 Mode/Behavior during normal operations. For example, following IED testing, a technician can disable unplanned switching of IEC 61850 Mode/Behavior by setting E850MBC to N after switching the relay back to On mode.

Change Mode Via MMS or SELOGIC

If IEC 61850 Mode/Behavior is set as controllable, you can control the IEC 61850 Mode/Behavior via MMS writes to the LLN0 logical node mode data object (Mod.ctlVal) in logical device CFG. Note that Mod.ctVal in other logical devices does not accept MMS writes. See *Table G.14* for the list of writable values.

Table G.14 IEC 61850 Mode/Behavior List of Writable Values

Write Values to Mod.ctVal in Logical Device CFG	Selected IEC 61850 Mode/Behavior
1	On
2	Blocked
3	Test
4	Test/Blocked
5	Off

You can also control IEC 61850 Mode/Behavior through use of the **SET G** command with protection SELOGIC variables SC850TM and SC850BM on the left side of the SELOGIC control equations. These variables are the SELOGIC controls for the Test and Blocked modes, respectively.

Table G.15 IEC 61850 Mode/Behavior Evaluated States of SC850TM and SC850BM

SC850TM	SC850BM	Selected IEC 61850 Mode/Behavior
0	0	See note[a]
1	0	Test
0	1	Blocked
1	1	Test/Blocked
See note[b]	See note[b]	Off

[a] The SELOGIC controls have higher priority than MMS clients in controlling the Test and Blocked modes. When SC850TM and SC850BM both evaluate to 0 (false), IEC 61850 Mode/Behavior control is available to MMS clients. If either SC850TM or SC850BM evaluates to 1 (true), SELOGIC determines the IEC 61850 Mode/Behavior of the IED regardless of MMS control values.

[b] You cannot control Off mode by using SC850TM and SC850BM. When an MMS client causes the IED to be in Off mode, the SELOGIC controls are disabled and SC850TM and SC850BM are not evaluated.

EXAMPLE G.1 Change Mode Via SELOGIC

In this example, Pushbuttons PB01 and PB02 control SC850TM. Pushbuttons PB03 and PB04 control SC850BM. If you press PB01, the relay enters Test mode. If you press PB03, the relay transitions from Test mode into Test/Blocked mode. Press PB02 and PB04 to reset Test and Blocked modes, respectively.

```
=>>SHO L <Enter>

Latch Bits Eqns
SET01    := PB01
RST01    := PB02
SET02    := PB03
RST02    := PB04
```

```
=>>SHO G <Enter>

IEC 61850 Mode/Behavior Configuration
SC850BM    := LT02
SC850TM    := LT01
```

Mode and Behavior Control

Regardless of mode (On, Blocked, Test, Test/Blocked, Off) the Mod, Beh, and Health quality bitstring will always be quality.validity = Good, quality.failure = False, and quality.test = False. This behavior is not the same when using the **TEST DB** command. The **TEST DB** command behavior is independent of this.

Incoming Messages Processing

IEC 61850 incoming data processing is jointly determined by quality validity, test, and operatorBlocked. SEL-787 relays, by default, check if the quality operatorBlocked equals False; if not, the relays treat the messages as invalid. You can disable the default check by changing the quality mask of GOOSE subscriptions. *Figure G.9* illustrates the default quality check for GOOSE subscription in SEL-787 relays.

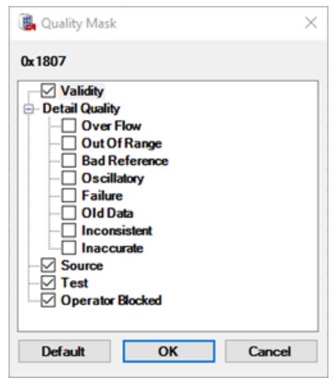

Figure G.9 Default Quality Check on GOOSE Subscription if Quality is Present

Relay Operation for Different IEC 61850 Modes/Behaviors

Mode: On

In On mode, the relay operates normally; it reports IEC 61850 Mode/Behavior status as On and processes all inputs and outputs normally. If the quality of the subscribed GOOSE messages satisfies the GOOSE processing (see *GOOSE Processing on page G.18*), the relay processes the received GOOSE messages as valid. *Table G.16* and *Table G.17* illustrate how the relay handles incoming and outgoing messages while in On mode.

Table G.16 IEC 61850 Incoming Message Handling in On Mode

IEC 61850 Messages	Incoming Message With Quality Test Bit Set to False (0)	Incoming Message With Quality Test Bit Set to True (1)
MMS	Processed	Processed as invalid
GOOSE	Processed	Processed as invalid

Table G.17 IEC 61850 Outgoing Message Handling in On Mode

IEC 61850 Messages	Outgoing Message Quality Test Bit Status
MMS	False
GOOSE	False

Figure G.10 illustrates the On Mode/Behavior.

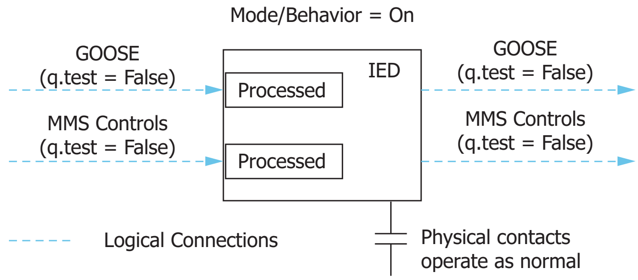

Figure G.10 Relay Operations in On Mode

Mode: Blocked

Blocked mode is similar to On mode, but in Blocked mode, none of the physical contact outputs are operated. However, it does continue to operate control bits, such as remote bits and output contact bits. *Figure G.11* illustrates the Blocked Mode/Behavior.

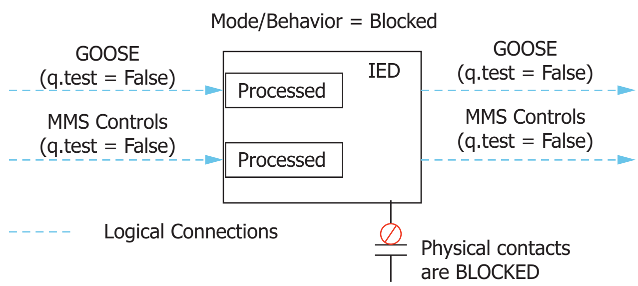

Figure G.11 Relay Operations in Blocked Mode

Mode: Test

In Test mode, the relay processes valid incoming test signals or normal messages and operates physical contact outputs, if triggered. In this Mode/Behavior, outgoing MMS and GOOSE messages have the quality test bit set to True if the quality test bit is present. If the quality of the subscribed GOOSE messages satisfies the user-defined quality type definition (regardless of whether the quality test bit is set to True or False—see *GOOSE Processing on page G.18*), the relay processes the received GOOSE messages as valid. *Table G.18* and *Table G.19* illustrate how the relay handles incoming and outgoing messages while in Test mode.

Table G.18 IEC 61850 Incoming Message Handling in Test Mode

IEC 61850 Messages	Incoming Message With Quality Test Bit Set to False (0)	Incoming Message With Quality Test Bit Set to True (1)
MMS	Not Processed	Processed
GOOSE	Processed	Processed

Table G.19 IEC 61850 Outgoing Message Handling in Test Mode

IEC 61850 Messages	Outgoing Message Quality Test Bit Status
MMS	True
GOOSE	True

Figure G.12 illustrates the Test Mode/Behavior.

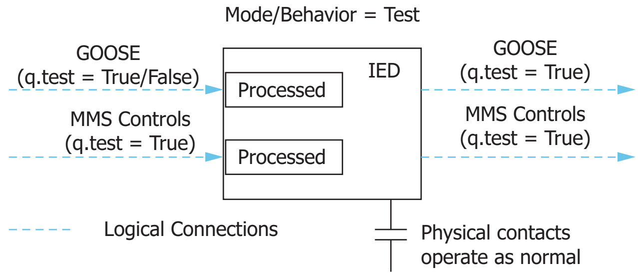

Figure G.12 Relay Operations in Test Mode

Mode: Test/Blocked

In Test/Blocked mode, the relay processes valid incoming test signals or normal messages but blocks any physical contact outputs from operating. In this Mode/Behavior, outgoing MMS and GOOSE messages have the quality test bit set to True if the quality test bit is present. If the quality of the subscribed GOOSE messages satisfies the user-defined quality type definition (regardless of whether the quality test bit is set to True or False— see *GOOSE Processing on page G.18*), the relay processes the received GOOSE messages as valid.

Figure G.13 illustrates the Test/Blocked Mode/Behavior.

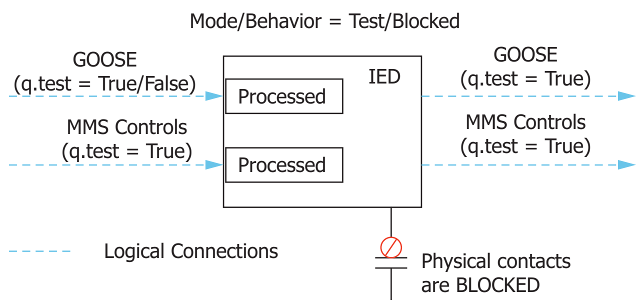

Figure G.13 Relay Operations in Test/Blocked Mode

Mode: Off

In Off mode, the relay no longer processes incoming GOOSE messages. The relay processes MMS control requests to change the IEC 61850 Mode/ Behavior if the quality Test bit is set to False. In this mode, the relay is in a disabled state and it no longer trips any physical contact outputs. The Relay Word bit ENABLED is set to False. The device processes MMS control requests to change the active mode of IEC 61850 Mode/Behavior if the quality test bit of the control is set to False. If EOFFMTX is set to Y, the relay continues to transmit GOOSE messages with the quality test bit set to False (0) and the validity set to Invalid (01) if the quality bit is present in the messages. If EOFFMTX is set to N, the relay does not transmit GOOSE messages in this mode. *Table G.20* and *Table G.21* describe how the relay handles incoming and outgoing messages while in Off mode.

Table G.20 IEC 61850 Incoming Message Handling in Off Mode

IEC 61850 Messages	Incoming Message With Quality Test Bit Set to False (0)	Incoming Messages With Quality Test Bit Set to True (1)
MMS	Relay Only Processes Messages to Control the Mode	Not Processed
GOOSE	Not Processed	Not Processed

Table G.21 IEC 61850 Outgoing Message Handling in Off Mode

IEC 61850 Messages	Outgoing Message Quality Validity Bit
MMS	Invalid
GOOSE	Invalid

Figure G.14 illustrates the Off Mode/Behavior.

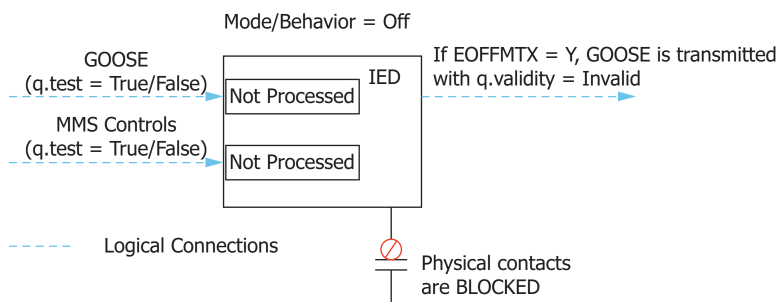

Figure G.14 Relay Operations in Off Mode

IEC 61850 Configuration

Settings

Table G.22 lists IEC 61850 settings. IEC 61850 settings are only available if your device includes the optional IEC 61850 protocol. Configure all other IEC 61850 settings, including subscriptions to incoming GOOSE messages, with Architect.

Table G.22 IEC 61850 Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLES IEC 61850 PROTOCOL	Y, N	E61850 := N
ENABLES IEC 61850 GSE[a]	Y[b], N	EGSE := N
ENABLES MMS FILE SERVICES[a]	Y[b], N	EMMSFS := N
ENABLES IEC 61850 MODE/BEHAVIOR CONTROL	Y, N	E850MBC := N
ENABLES GOOSE TX IN OFF MODE	Y, N	EOFFMTX := N

[a] These settings are hidden when E61850 is set to N.
[b] Requires that E61850 be set to Y.

Architect Software

The Architect Software enables users to design and commission IEC 61850 substations containing SEL IEDs. Users can use Architect to do the following:

- Organize and configure all SEL IEDs in a substation project.
- Configure incoming and outgoing GOOSE messages.
- Edit and create GOOSE datasets.
- Read non-SEL IED Capability Description (ICD) and Configured IED Description (CID) files and determine the available IEC 61850 messaging options.
- Use or edit preconfigured datasets for reports.
- Load IEC 61850 CID files into SEL IEDs.
- Generate ICD and CID files that provide SEL IED descriptions to other manufacturers' tools so they can use SEL GOOSE messages and reporting features.
- Edit deadband settings for measured values.

NOTE: Other manufacturers' ICD and CID files must have IEC 61850 outgoing GOOSE messages with Application IDs (APPIDs) of exactly four characters and VLAN IDs of exactly three characters so that the relay can successfully subscribe to them. If you attempt to configure a relay to subscribe to a GOOSE message that does not meet this criteria, the relay will reject the CID file upon download. Edit other manufacturers' ICD and CID files prior to importing them into Architect by adding leading zeros to the APPID and VLAN ID of outgoing GOOSE messages, as necessary.

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

acSELerator 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 acSELerator 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 acSELerator 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-787 ICD files can be found in *Table A.9*.

The Logical Nodes description detailed in this manual revision corresponds to the SEL-787 006 ICD file. Information about the previous SEL-787 004 ICD files can be found in the previous manual revisions. Please refer to *Table A.9* to find the manual revision corresponding to the ICD file you are using.

Logical Nodes

Each logical device (LD) has a set of common data objects at the top level LN0. These represent the current state of the device, as well as some informational data. These data objects are: Mod (Mode), Beh (Behavior), Health, and NamPlt. See the following sections for a brief description of each object.

Mode

The SEL-700 series relays include at the top-level LN0 within each LD the following enumerations for **Mod.stVal**:

Mod.stVal Enumeration	Description
1	On
2	Blocked
3	Test
4	Test/Blocked
5	Off
0	IEC 61850 Mode/Behavior disabled

The top-level logical node of each LD also includes the following Mod attributes:

Mod.q represents quality.

Mod.t represents time stamps.

Mod.stVal represents the current Mode/Behavior.

You can control IEC 61850 Mode/Behavior via LLN0COMod$Oper in your CFG logical device.

Behavior

SEL-700 series relays LNs include the following enumerations for Beh stVal:

Beh stVal Enumeration	Description
1	On
2	Blocked
3	Test
4	Test/Blocked
5	Off
0	IEC 61850 Mode/Behavior disabled

Logical nodes also include the following Beh attributes:

Beh q and **Beh t** according to the *Time Stamps and Quality* section.

Health

The SEL-700 series relays include at the top-level LN0 within each LD the following enumerations for Health stVal:

Health stVal Enumeration	Health stVal Value	Description
1	OK	RELAY_EN Relay Word bit = 1
3	Alarm	RELAY_EN Relay Word bit = 0

The top-level logical node of each LD also includes the following Health attributes:

Health q and **Health t** according to the *Time Stamps and Quality* section.

NamPlt

The top-level LN0 of each LD includes the following NamPlt attributes:

- NamPlt vendor which is set to "SEL".
- NamPlt swRev which contains the relay FID string value.
- NamPlt d, which is the LD description.

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 G.23 New Logical Node Extensions

Logical Nodes	IEC 61850	Description or Comments
Thermal Measurements (for equipment or ambient temperature readings)	MTHR	This LN shall be used to represent values from RTDs and to calculate thermal capacity and usage mainly used for Thermal Monitoring.
Demand Metering Statistics	MDST	This LN shall be used for calculation of demand currents in a three-phase system. This shall not be used for billing purposes.
Metering Statistics	MSTA	This LN shall be used for power system metering statistics.
Physical Communication Channel Supervision	LCCH	This LN is used for supervision of physical communication channels
GOOSE Subscription	LGOS	This LN is used for GOOSE subscription statistics
Time Master Supervision	LTMS	This LN is used for time synchronization master supervision

Table G.24 defines the data class Thermal Metering Data. This class is a collection of simultaneous measurements (or evaluations) that represent the RTD thermal metering values. Valid data depend on the presence and configuration of the RTD module(s).

Table G.24 Thermal Metering Data Logical Node Class Definition (Sheet 1 of 2)

MTHR Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2.		
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class.		M
EEHealth	INS	External equipment health (RTD Communications Status)		E

Table G.24 Thermal Metering Data Logical Node Class Definition (Sheet 2 of 2)

MTHR Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
Data Objects				
Measured Values				
MaxAmbTmp	MV	Maximum Ambient Temperature		E
MaxOthTmp	MV	Maximum Other Temperature		E
Tmp	MV	Temperature		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 G.25 defines the data class Demand Metering Statistics. This class is a collection of demand currents and energy.

Table G.25 Demand Metering Statistics Logical Node Class Definitions

MDST Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2.		
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class.		M
Data Objects				
Measured values				
DmdA	WYE	Demand Currents		E
DmdAnseq	MV	Negative Sequence Demand Current		E
PkDmdA	WYE	Peak Demand Currents		E
PkDmdAnseq	MV	Negative Sequence Peak Demand Current		E
SupWh	BCR[c]	Real energy supply (default supply direction: energy flow towards busbar)		E
SupVArh	BCR[c]	Reactive energy supply (default supply direction: energy flow towards busbar)		E
DmdWh	BCR[c]	Real energy demand (default demand direction: energy flow from busbar away)		E
DmdVArh	BCR[c]	Reactive energy demand (default demand direction: energy flow from busbar away)		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.
[c] For IEC 61850 Edition 1 relays, this data object is defined as MV common data class.

Table G.26 Metering Statistics Logical Node Class Definition

MSTA Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2.		
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class.		M
Data Objects				
Measured and Metered values				
AvAmps	MV	Average current		E
MaxAmps	MV	Maximum current		E
MinAmps	MV	Minimum current		E
AvVolts	MV	Average voltage		E
MaxVA	MV	Maximum apparent power		E
MinVA	MV	Minimum apparent power		E
MaxW	MV	Maximum real power		E
MinW	MV	Minimum real power		E
MaxVAr	MV	Maximum reactive power		E
MinVAr	MV	Minimum reactive power		E
MaxA	WYE	Maximum phase currents		E
MinA	WYE	Minimum phase currents		E
MaxPhV	WYE	Maximum phase-to-ground voltages		E
MinPhV	WYE	Minimum phase-to-ground voltages		E
MaxP2PV	DEL	Maximum phase-to-phase voltages		E
MinP2PV	DEL	Minimum phase-to-phase voltages		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 G.27 LCCH Physical Communication Channel Supervision (Sheet 1 of 2)

LCCH Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix, and LN-Instance-ID according to IEC 61850-7-2, Clause 22.		
Data Objects				
Common Logical Node Information				
Beh	ENS	Behavior		M
NamPlt	LPL	Name plate		O

Table G.27 LCCH Physical Communication Channel Supervision (Sheet 2 of 2)

LCCH Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
Status Information				
ChLiv	SPS	Physical channel status		M
RedChLiv	SPS	Physical channel status of redundant channel		C
FerCh	INS	Frame error rate on this channel		O
RedFerCh	INS	Frame error rate on redundant channel		O
Measured and Metered Values				
RxCnt	BCR	Number of received messages		O
RedRxCnt	BCR	Number of received messages on redundant channel		O
TxCnt	BCR	Number of sent messages		O
Controls				
RsStat	SPC	Reset device statistics		E
Settings				
NetMod	ENG	Network mode		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 G.28 LGOS GOOSE Subscription (Sheet 1 of 2)

LGOS Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix, and LN-Instance-ID according to IEC 61850-7-2, Clause 22		
Data Objects				
Common Logical Node Information				
Beh	ENS	Behavior		M
NamPlt	LPL	Name plate		O
Status Information				
NdsCom	SPS	Subscription needs commissioning		O
St	SPS	Status of the subscription		M
SimSt	SPS	Status showing that Sim messages are received and accepted		O
LastStNum	INS	Last state number received		O
LastSqNum	INS	Last sequence number received		E
LastTal	INS	Last time-allowed-to-live received		E
ConfRevNum	INS	Expected configuration revision number		O

Table G.28 LGOS GOOSE Subscription (Sheet 2 of 2)

LGOS Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
RxConfRev Num	INS	Configuration revision number of the received messages		O
ErrSt	ENS	Current error status of the subscription		E
OosCnt	INS	Number of out-of-sequence (OOS) errors		E
TalCnt	INS	Number of time-allowed-to-live violations		E
DecErrCnt	INS	Number of messages that failed decoding		E
BufOvflCnt	INS	Number of messages lost due to buffer overflow		E
MsgLosCnt	INS	Number of messages lost due to OOS errors (estimated)		E
MaxMsgLos	INS	Max. number of sequential messages lost due to OOS error (estimated)		E
InvQualCnt	INS	Number of mapped incoming GOOSE data with invalid quantity		E
Measured and Metered Values				
TotDwnTm	MV	Total downtime in seconds		E
MaxDwnTm	MV	Maximum continuous downtime in seconds		E
Controls				
RsStat	SPC	Reset/clear statistics		E
Settings				
GoCBRef	ORG	Reference to the subscribed GOOSE control block		O
DatSet	ORG	Configured dataset reference		E
GoID	VSG	Configured GOOSE ID		E
Addr	VSG	Configured multicast MAC address		E
VlanID	ING	Configured VLAN ID		E
VlanPri	ING	Configured VLAD priority		E
AppID	ING	Configured APPID		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 G.29 LTMS Time Master Supervision (Sheet 1 of 2)

LTMS Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix, and LN-Instance-ID according to IEC 61850-7-2, Clause 22		

Table G.29 LTMS Time Master Supervision (Sheet 2 of 2)

LTMS Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
Data Objects				
Common Logical Node Information				
Beh	ENS	Behavior		M
NamPlt	LPL	Name plate		O
Status Information				
TmAcc	INS	Number of significant bits in fraction of second in the time accuracy part of the time stamp		O
TmSrc	VSS	Current time source identity		M
SelTmSrcTyp	ENS	Type of the clock source		E
SelTmSyn	ENS	Actual time synchronization applied		E
SelTmSynLkd	ENS	Locked status of clock synchronization		E
Measured and Metered Values				
SelTmTosPer	MV	Duration, in milliseconds, between two consecutive top-of-second points on the synchronized time		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 G.30 Compatible Logical Nodes With Extensions

Logical Node	IEC 61850	Description or comments
Measurement	MMXU	This LN is used for power system measurement data.
Metering Statistics	MSTA	This LN is used for power system metering statistics.
Circuit Breaker	XCBR	This LN is used for circuit breaker status and measurement data.
Generic Process I/O	GGIO	This LN is used for remote analog data.
Circuit Breaker Wear Supervision	SCBR	This LN is used for supervision of circuit breakers.

Table G.31 Measurement Logical Node Class Definition (Sheet 1 of 2)

MMXU Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2.		
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class.		M

Table G.31 Measurement Logical Node Class Definition (Sheet 2 of 2)

MMXU Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
Data Objects				
Measured and Metered values				
TotW	MV	Total active power		O
TotVAr	MV	Total reactive power		O
TotVA	MV	Total apparent 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
Vhz	MV	Volts per Hz		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 G.32 Measurement Logical Node Class Definition

MMXU Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2.		
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class.		M
Data Objects				
Measured and Metered values				
TotW	MV	Total active power		O
TotVAr	MV	Total reactive power		O
TotVA	MV	Total apparent 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
VSyn	MV	Synchronizing 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 G.33 Circuit Breaker Logical Node Class Definition

XCBR Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2.		
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class.		M
Data Objects				
Status Information				
Loc	SPS	Local control behavior		M
OpCnt	INS	Operation counter		M
OpCntEx	INS	Operation counter–external		E
Measured and Metered values				
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.

Table G.34 Generic Process I/O Logical Node Class Definition

GGIO Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2.		
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class.		M
Data Objects				
Measured values				
AnIn	MV	Analog input		O
Ra	MV	Remote analog		E
Controls				
SPCSO	SPC	Single point controllable status output		O
Status Information				
Ind	SPS	General indication (binary input)		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 G.35 Circuit Breaker Supervision (Per-Phase) Logical Node Class Definition

SCBR Class				
Data Object Name	**Common Data Class**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2.		
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class.		M
Data Objects				
Status Information				
ColOpn	SPS	Open command of trip coil		M
Measured Values				
AbrPrt	MV	Calculated or measured wear (e.g. of main contact), expressed in % where 0% corresponds to new condition		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.

Device Logical Nodes

The following tables, *Table G.36* through *Table G.40*, show the Logical Nodes (LN) supported in the SEL-787 and the associated Relay Word bits or analog quantities.

Table G.36 shows the LN associated with protection elements defined as Logical Device PRO.

Table G.36 Logical Device: PRO (Protection) (Sheet 1 of 22)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = CO			
W1CSWI1	Pos.Oper.ctlVal	CC1:OC1[a]	Breaker 1 close/open command
W2CSWI2	Pos.Oper.ctlVal	CC2:OC2[a]	Breaker 2 close/open command
W3CSWI3	Pos.Oper.ctlVal	CC3:OC3[a]	Breaker 3 close/open command
W4CSWI4	Pos.Oper.ctlVal	CC4:OC4[a]	Breaker 4 close/open command
DC1CSWI1	Pos.Oper.ctlVal	89CC2P1: 89OC2P1[a]	Two-Position Disconnect 1 close/open command
DC2CSWI2	Pos.Oper.ctlVal	89CC2P2: 89OC2P2[a]	Two-Position Disconnect 2 close/open command
DC3CSWI3	Pos.Oper.ctlVal	89CC2P3: 89OC2P3[a]	Two-Position Disconnect 3 close/open command
DC4CSWI4	Pos.Oper.ctlVal	89CC2P4: 89OC2P4[a]	Two-Position Disconnect 4 close/open command
DC5CSWI5	Pos.Oper.ctlVal	89CC2P5: 89OC2P5[a]	Two-Position Disconnect 5 close/open command
DC6CSWI6	Pos.Oper.ctlVal	89CC2P6: 89OC2P6[a]	Two-Position Disconnect 6 close/open command

Table G.36 Logical Device: PRO (Protection) (Sheet 2 of 22)

Logical Node	Attribute	Data Source	Comment
DC7CSWI7	Pos.Oper.ctlVal	89CC2P7: 89OC2P7[a]	Two-Position Disconnect 7 close/open command
DC8CSWI8	Pos.Oper.ctlVal	89CC2P8: 89OC2P8[a]	Two-Position Disconnect 8 close/open command
DC9CSWI9	Pos.Oper.ctlVal	89CC2P9: 89OC2P9[a]	Two-Position Disconnect 9 close/open command
DC10CSWI10	Pos.Oper.ctlVal	89CC2P10: 89OC2P10[a]	Two-Position Disconnect 10 close/open command
DC11CSWI11	Pos.Oper.ctlVal	89CC2P11: 89OC2P11[a]	Two-Position Disconnect 11 close/open command
DC12CSWI12	Pos.Oper.ctlVal	89CC2P12: 89OC2P12[a]	Two-Position Disconnect 12 close/open command
DC13CSWI13	Pos.Oper.ctlVal	89CC2P13: 89OC2P13[a]	Two-Position Disconnect 13 close/open command
DC14CSWI14	Pos.Oper.ctlVal	89CC2P14: 89OC2P14[a]	Two-Position Disconnect 14 close/open command
DC15CSWI15	Pos.Oper.ctlVal	89CC2P15: 89OC2P15[a]	Two-Position Disconnect 15 close/open command
DC16CSWI16	Pos.Oper.ctlVal	89CC2P16: 89OC2P16[a]	Two-Position Disconnect 16 close/open command
DC17CSWI17	Pos.Oper.ctlVal	89CC3PL1: 89OC3PL1[a]	Three-Position In-Line Disconnect 1 close/open command
DC18CSWI18	Pos.Oper.ctlVal	89CC3PL2: 89OC3PL2[a]	Three-Position In-Line Disconnect 2 close/open command
DC19CSWI19	Pos.Oper.ctlVal	89CC3PE1: 89OC3PE1[a]	Three-Position Earthing Disconnect 1 close/open command
DC20CSWI20	Pos.Oper.ctlVal	89CC3PE2: 89OC3PE2[a]	Three-Position Earthing Disconnect 2 close/open command
Functional Constraint = DC			
DevIDLPHD1	PhyNam.model	PARTNO	Part number
Functional Constraint = ST			
BFR1RBRF1	OpEx.general	BFT1	Breaker 1 failure trip
BFR1RBRF1	Str.general	BFI1	Breaker 1 failure initiation
BFR2RBRF2	OpEx.general	BFT2	Breaker 2 failure trip
BFR2RBRF2	Str.general	BFI2	Breaker 2 failure initiation
BFR3RBRF3	OpEx.general	BFT3	Breaker 3 failure trip
BFR3RBRF3	Str.general	BFI3	Breaker 3 failure initiation
BFR4RBRF4	OpEx.general	BFT4	Breaker 4 failure trip
BFR4RBRF4	Str.general	BFI4	Breaker 4 failure initiation
C2PVPH2	Op.general	24C2T	Level 2 Volts/Hertz composite element timed out
C2PVPH2	Str.general	24C2	Level 2 Volts/Hertz composite element pickup
C2PVPH2	Str.dirGeneral	unknown	Direction undefined
D1PTOF1	Op.general	81D1T	Level 1 definite-time over-/underfrequency trip
D1PTOF1	Str.general	81D1T	Level 1 definite-time over-/underfrequency trip

Table G.36 Logical Device: PRO (Protection) (Sheet 3 of 22)

Logical Node	Attribute	Data Source	Comment
D1PTOF1	Str.dirGeneral	unknown	Direction undefined
D1PVPH1	Op.general	24D1T	Level 1 Volts/Hertz definite-time element timed out
D1PVPH1	Str.general	24D1	Level 1 Volts/Hertz instantaneous pickup
D1PVPH1	Str.dirGeneral	unknown	Direction undefined
D2PTOF2	Op.general	81D2T	Level 2 definite-time over-/underfrequency trip
D2PTOF2	Str.general	81D2T	Level 2 definite-time over-/underfrequency trip
D2PTOF2	Str.dirGeneral	unknown	Direction undefined
D3PTOF3	Op.general	81D3T	Level 3 definite-time over-/underfrequency trip
D3PTOF3	Str.general	81D3T	Level 3 definite-time over-/underfrequency trip
D3PTOF3	Str.dirGeneral	unknown	Direction undefined
D4PTOF4	Op.general	81D4T	Level 4 definite-time over-/underfrequency trip
D4PTOF4	Str.general	81D4T	Level 4 definite-time over-/underfrequency trip
D4PTOF4	Str.dirGeneral	unknown	Direction undefined
D87APDIF3	Op.general	87AT	Differential current alarm element trip
D87APDIF3	Str.general	87AP	Differential current alarm element pickup
D87APDIF3	Str.dirGeneral	unknown	Direction undefined
D87QPDIF13	Op.general	87Q	Negative-sequence differential element operated
D87QPDIF13	Str.general	87QP	Minimum pickup and slope conditions satisfied for negative-sequence different element
D87RPDIF2	Op.general	87R	Restrained Differential Element trip
D87RPDIF2	Op.phsA	87R1	Restrained Differential Element 1
D87RPDIF2	Op.phsB	87R2	Restrained Differential Element 2
D87RPDIF2	Op.phsC	87R3	Restrained Differential Element 3
D87UPDIF1	Op.general	87U	Unrestrained differential element trip
D87UPDIF1	Op.phsA	87U1	Unrestrained Differential Element 1 trip
D87UPDIF1	Op.phsB	87U2	Unrestrained Differential Element 2 trip
D87UPDIF1	Op.phsC	87U3	Unrestrained Differential Element 3 trip
DC1CILO1	EnaCls.stVal	89CE2P1	Two-Position Disconnect 1 close enabled
DC1CILO1	EnaOpn.stVal	89OE2P1	Two-Position Disconnect 1 open enabled
DC2CILO2	EnaCls.stVal	89CE2P2	Two-Position Disconnect 2 close enabled
DC2CILO2	EnaOpn.stVal	89OE2P2	Two-Position Disconnect 2 open enabled
DC3CILO3	EnaCls.stVal	89CE2P3	Two-Position Disconnect 3 close enabled
DC3CILO3	EnaOpn.stVal	89OE2P3	Two-Position Disconnect 3 open enabled
DC4CILO4	EnaCls.stVal	89CE2P4	Two-Position Disconnect 4 close enabled
DC4CILO4	EnaOpn.stVal	89OE2P4	Two-Position Disconnect 4 open enabled
DC5CILO5	EnaCls.stVal	89CE2P5	Two-Position Disconnect 5 close enabled
DC5CILO5	EnaOpn.stVal	89OE2P5	Two-Position Disconnect 5 open enabled
DC6CILO6	EnaCls.stVal	89CE2P6	Two-Position Disconnect 6 close enabled
DC6CILO6	EnaOpn.stVal	89OE2P6	Two-Position Disconnect 6 open enabled

Table G.36 Logical Device: PRO (Protection) (Sheet 4 of 22)

Logical Node	Attribute	Data Source	Comment
DC7CILO7	EnaCls.stVal	89CE2P7	Two-Position Disconnect 7 close enabled
DC7CILO7	EnaOpn.stVal	89OE2P7	Two-Position Disconnect 7 open enabled
DC8CILO8	EnaCls.stVal	89CE2P8	Two-Position Disconnect 8 close enabled
DC8CILO8	EnaOpn.stVal	89OE2P8	Two-Position Disconnect 8 open enabled
DC9CILO9	EnaCls.stVal	89CE2P9	Two-Position Disconnect 9 close enabled
DC9CILO9	EnaOpn.stVal	89OE2P9	Two-Position Disconnect 9 open enabled
DC10CILO10	EnaCls.stVal	89CE2P10	Two-Position Disconnect 10 close enabled
DC101CILO10	EnaOpn.stVal	89OE2P10	Two-Position Disconnect 10 open enabled
DC111CILO11	EnaCls.stVal	89CE2P11	Two-Position Disconnect 11 close enabled
DC11CILO11	EnaOpn.stVal	89OE2P11	Two-Position Disconnect 11 open enabled
DC12CILO12	EnaCls.stVal	89CE2P12	Two-Position Disconnect 12 close enabled
DC12CILO12	EnaOpn.stVal	89OE2P12	Two-Position Disconnect 12 open enabled
DC13CILO13	EnaCls.stVal	89CE2P13	Two-Position Disconnect 13 close enabled
DC13CILO13	EnaOpn.stVal	89OE2P13	Two-Position Disconnect 13 open enabled
DC14CILO14	EnaCls.stVal	89CE2P14	Two-Position Disconnect 14 close enabled
DC14CILO14	EnaOpn.stVal	89OE2P14	Two-Position Disconnect 14 open enabled
DC15CILO15	EnaCls.stVal	89CE2P15	Two-Position Disconnect 15 close enabled
DC15CILO15	EnaOpn.stVal	89OE2P15	Two-Position Disconnect 15 open enabled
DC16CILO16	EnaCls.stVal	89CE2P16	Two-Position Disconnect 16 close enabled
DC16CILO16	EnaOpn.stVal	89OE2P16	Two-Position Disconnect 16 open enabled
DC17CILO17	EnaCls.stVal	89CE3PL1	Three-Position In-Line Disconnect 1 close enabled
DC17CILO17	EnaOpn.stVal	89OE3PL1	Three-Position In-Line Disconnect 1 open enabled
DC18CILO18	EnaCls.stVal	89CE3PL2	Three-Position In-Line Disconnect 2 close enabled
DC18CILO18	EnaOpn.stVal	89OE3PL2	Three-Position In-Line Disconnect 2 open enabled
DC19CILO19	EnaCls.stVal	89CE3PE1	Three-Position Earthing Disconnect 1 close enabled
DC19CILO19	EnaOpn.stVal	89OE3PE1	Three-Position Earthing Disconnect 1 open enabled
DC20CILO20	EnaCls.stVal	89CE3PE2	Three-Position Earthing Disconnect 2 close enabled
DC20CILO20	EnaOpn.stVal	89OE3PE2	Three-Position Earthing Disconnect 2 open enabled
DC1CSWI1	OpCls.general	89C2P1	Two-Position Disconnect 1 closed
DC1CSWI1	OpOpn.general	89O2P1	Two-Position Disconnect 1 open
DC1CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
DC1CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
DC1CSWI1	Pos.stVal	89CL2P1| 89OP2P1?0:1:2:3[b]	Two-Position Disconnect 1 close/open status
DC2CSWI2	OpCls.general	89C2P2	Two-Position Disconnect 2 closed
DC2CSWI2	OpOpn.general	89O2P2	Two-Position Disconnect 2 open
DC2CSWI2	Loc.stVal	LOC	Control authority at local (bay) level
DC2CSWI2	LocSta.stVal	LOCSTA	Control authority at station level

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Logical Node	Attribute	Data Source	Comment
DC2CSWI2	Pos.stVal	89CL2P2| 89OP2P2?0:1:2:3[b]	Two-Position Disconnect 2 close/open status
DC3CSWI3	OpCls.general	89C2P3	Two-Position Disconnect 3 closed
DC3CSWI3	OpOpn.general	89O2P3	Two-Position Disconnect 3 open
DC3CSWI3	Loc.stVal	LOC	Control authority at local (bay) level
DC3CSWI3	LocSta.stVal	LOCSTA	Control authority at station level
DC3CSWI3	Pos.stVal	89CL2P3| 89OP2P3?0:1:2:3[b]	Two-Position Disconnect 3 close/open status
DC4CSWI4	OpCls.general	89C2P4	Two-Position Disconnect 4 closed
DC4CSWI4	OpOpn.general	89O2P4	Two-Position Disconnect 4 open
DC4CSWI4	Loc.stVal	LOC	Control authority at local (bay) level
DC4CSWI4	LocSta.stVal	LOCSTA	Control authority at station level
DC4CSWI4	Pos.stVal	89CL2P4| 89OP2P4?0:1:2:3[b]	Two-Position Disconnect 4 close/open status
DC5CSWI5	OpCls.general	89C2P5	Two-Position Disconnect 5 closed
DC5CSWI5	OpOpn.general	89O2P5	Two-Position Disconnect 5 open
DC5CSWI5	Loc.stVal	LOC	Control authority at local (bay) level
DC5CSWI5	LocSta.stVal	LOCSTA	Control authority at station level
DC5CSWI5	Pos.stVal	89CL2P5| 89OP2P5?0:1:2:3[b]	Two-Position Disconnect 5 close/open status
DC6CSWI6	OpCls.general	89C2P6	Two-Position Disconnect 6 closed
DC6CSWI6	OpOpn.general	89O2P6	Two-Position Disconnect 6 open
DC6CSWI6	Loc.stVal	LOC	Control authority at local (bay) level
DC6CSWI6	LocSta.stVal	LOCSTA	Control authority at station level
DC6CSWI6	Pos.stVal	89CL2P6| 89OP2P6?0:1:2:3[b]	Two-Position Disconnect 6 close/open status
DC7CSWI7	OpCls.general	89C2P7	Two-Position Disconnect 7 closed
DC7CSWI7	OpOpn.general	89O2P7	Two-Position Disconnect 7 open
DC7CSWI7	Loc.stVal	LOC	Control authority at local (bay) level
DC7CSWI7	LocSta.stVal	LOCSTA	Control authority at station level
DC7CSWI7	Pos.stVal	89CL2P7| 89OP2P7?0:1:2:3[b]	Two-Position Disconnect 7 close/open status
DC8CSWI8	OpCls.general	89C2P8	Two-Position Disconnect 8 closed
DC8CSWI8	OpOpn.general	89O2P8	Two-Position Disconnect 8 open
DC8CSWI8	Loc.stVal	LOC	Control authority at local (bay) level
DC8CSWI8	LocSta.stVal	LOCSTA	Control authority at station level
DC8CSWI8	Pos.stVal	89CL2P8| 89OP2P8?0:1:2:3[b]	Two-Position Disconnect 8 close/open status
DC9CSWI9	OpCls.general	89C2P9	Two-Position Disconnect 9 closed
DC9CSWI9	OpOpn.general	89O2P9	Two-Position Disconnect 9 open
DC9CSWI9	Loc.stVal	LOC	Control authority at local (bay) level

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Logical Node	Attribute	Data Source	Comment
DC9CSWI9	LocSta.stVal	LOCSTA	Control authority at station level
DC9CSWI9	Pos.stVal	89CL2P9|89OP2P9?0:1:2:3[b]	Two-Position Disconnect 9 close/open status
DC10CSWI10	OpCls.general	89C2P10	Two-Position Disconnect 10 closed
DC10CSWI10	OpOpn.general	89O2P10	Two-Position Disconnect 10 open
DC10CSWI10	Loc.stVal	LOC	Control authority at local (bay) level
DC10CSWI10	LocSta.stVal	LOCSTA	Control authority at station level
DC10CSWI10	Pos.stVal	89CL2P10|89OP2P10?0:1:2:3[b]	Two-Position Disconnect 10 close/open status
DC11CSWI11	OpCls.general	89C2P11	Two-Position Disconnect 11 closed
DC11CSWI11	OpOpn.general	89O2P11	Two-Position Disconnect 11 open
DC11CSWI11	Loc.stVal	LOC	Control authority at local (bay) level
DC11CSWI11	LocSta.stVal	LOCSTA	Control authority at station level
DC11CSWI11	Pos.stVal	89CL2P11|89OP2P11?0:1:2:3[b]	Two-Position Disconnect 11 close/open status
DC12CSWI12	OpCls.general	89C2P12	Two-Position Disconnect 12 closed
DC12CSWI12	OpOpn.general	89O2P12	Two-Position Disconnect 12 open
DC12CSWI12	Loc.stVal	LOC	Control authority at local (bay) level
DC12CSWI12	LocSta.stVal	LOCSTA	Control authority at station level
DC12CSWI12	Pos.stVal	89CL2P12|89OP2P12?0:1:2:3[b]	Two-Position Disconnect 12 close/open status
DC13CSWI13	OpCls.general	89C2P13	Two-Position Disconnect 13 closed
DC13CSWI13	OpOpn.general	89O2P13	Two-Position Disconnect 13 open
DC13CSWI13	Loc.stVal	LOC	Control authority at local (bay) level
DC13CSWI13	LocSta.stVal	LOCSTA	Control authority at station level
DC13CSWI13	Pos.stVal	89CL2P13|89OP2P13?0:1:2:3[b]	Two-Position Disconnect 13 close/open status
DC14CSWI14	OpCls.general	89C2P14	Two-Position Disconnect 14 closed
DC14CSWI14	OpOpn.general	89O2P14	Two-Position Disconnect 14 open
DC14CSWI14	Loc.stVal	LOC	Control authority at local (bay) level
DC14CSWI14	LocSta.stVal	LOCSTA	Control authority at station level
DC14CSWI14	Pos.stVal	89CL2P14|89OP2P14?0:1:2:3[b]	Two-Position Disconnect 14 close/open status
DC15CSWI15	OpCls.general	89C2P15	Two-Position Disconnect 15 closed
DC15CSWI15	OpOpn.general	89O2P15	Two-Position Disconnect 15 open
DC15CSWI15	Loc.stVal	LOC	Control authority at local (bay) level
DC15CSWI15	LocSta.stVal	LOCSTA	Control authority at station level
DC15CSWI15	Pos.stVal	89CL2P15|89OP2P15?0:1:2:3[b]	Two-Position Disconnect 15 close/open status
DC16CSWI16	OpCls.general	89C2P16	Two-Position Disconnect 16 closed
DC16CSWI16	OpOpn.general	89O2P16	Two-Position Disconnect 16 open

Table G.36 Logical Device: PRO (Protection) (Sheet 7 of 22)

Logical Node	Attribute	Data Source	Comment
DC16CSWI16	Loc.stVal	LOC	Control authority at local (bay) level
DC16CSWI16	LocSta.stVal	LOCSTA	Control authority at station level
DC16CSWI16	Pos.stVal	89CL2P16| 89OP2P16?0:1:2:3[b]	Two-Position Disconnect 16 close/open status
DC17CSWI17	OpCls.general	89C3PL1	Three-Position In-Line Disconnect 1 closed
DC17CSWI17	OpOpn.general	89O3PL1	Three-Position In-Line Disconnect 1 open
DC17CSWI17	Loc.stVal	LOC	Control authority at local (bay) level
DC17CSWI17	LocSta.stVal	LOCSTA	Control authority at station level
DC17CSWI17	Pos.stVal	89CL3PL1| 89OP3PL1?0:1:2:3[b]	Three-Position In-Line Disconnect 1 close/open status
DC18CSWI18	OpCls.general	89C3PL2	Three-Position In-Line Disconnect 2 closed
DC18CSWI18	OpOpn.general	89O3PL2	Three-Position In-Line Disconnect 2 open
DC18CSWI18	Loc.stVal	LOC	Control authority at local (bay) level
DC18CSWI18	LocSta.stVal	LOCSTA	Control authority at station level
DC18CSWI18	Pos.stVal	89CL3PL2| 89OP3PL2?0:1:2:3[b]	Three-Position In-Line Disconnect 2 close/open status
DC19CSWI19	OpCls.general	89C3PE1	Three-Position Earthing Disconnect 1 closed
DC19CSWI19	OpOpn.general	89O3PE1	Three-Position Earthing Disconnect 1 open
DC19CSWI19	Loc.stVal	LOC	Control authority at local (bay) level
DC19CSWI19	LocSta.stVal	LOCSTA	Control authority at station level
DC19CSWI19	Pos.stVal	89CL3PE1| 89OP3PE1?0:1:2:3[b]	Three-Position Earthing Disconnect 1 close/open status
DC20CSWI20	OpCls.general	89C3PE2	Three-Position Earthing Disconnect 2 closed
DC20CSWI20	OpOpn.general	89O3PE2	Three-Position Earthing Disconnect 2 open
DC20CSWI20	Loc.stVal	LOC	Control authority at local (bay) level
DC20CSWI20	LocSta.stVal	LOCSTA	Control authority at station level
DC20CSWI20	Pos.stVal	89CL3PE2| 89OP3PE2?0:1:2:3[b]	Three-Position Earthing Disconnect 2 close/open status
DC1XSWI1	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC1XSWI1	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC1XSWI1	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC1XSWI1	OpCnt.stVal	0	
DC1XSWI1	Pos.stVal	89CL2P1?1:2[c]	Disconnect 1 position
DC1XSWI1	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC1XSWI1	SwTyp.stVal	Disconnector	Disconnect type
DC2XSWI2	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC2XSWI2	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC2XSWI2	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC2XSWI2	OpCnt.stVal	0	
DC2XSWI2	Pos.stVal	89CL2P2?1:2[c]	Disconnect 2 position

Table G.36 Logical Device: PRO (Protection) (Sheet 8 of 22)

Logical Node	Attribute	Data Source	Comment
DC2XSWI2	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC2XSWI2	SwTyp.stVal	Disconnector	Disconnect type
DC3XSWI3	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC3XSWI3	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC3XSWI3	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC3XSWI3	OpCnt.stVal	0	
DC3XSWI3	Pos.stVal	89CL2P3?1:2[c]	Disconnect 3 position
DC3XSWI3	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC3XSWI3	SwTyp.stVal	Disconnector	Disconnect type
DC4XSWI4	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC4XSWI4	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC4XSWI4	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC4XSWI4	OpCnt.stVal	0	
DC4XSWI4	Pos.stVal	89CL2P4?1:2[c]	Disconnect 4 position
DC4XSWI4	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC4XSWI4	SwTyp.stVal	Disconnector	Disconnect type
DC5XSWI5	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC5XSWI5	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC5XSWI5	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC5XSWI5	OpCnt.stVal	0	
DC5XSWI5	Pos.stVal	89CL2P5?1:2[c]	Disconnect 5 position
DC5XSWI5	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC5XSWI5	SwTyp.stVal	Disconnector	Disconnect type
DC6XSWI6	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC6XSWI6	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC6XSWI6	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC6XSWI6	OpCnt.stVal	0	
DC6XSWI6	Pos.stVal	89CL2P6?1:2[c]	Disconnect 6 position
DC6XSWI6	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC6XSWI6	SwTyp.stVal	Disconnector	Disconnect type
DC7XSWI7	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC7XSWI7	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC7XSWI7	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC7XSWI7	OpCnt.stVal	0	
DC7XSWI7	Pos.stVal	89CL2P7?1:2[c]	Disconnect 7 position
DC7XSWI7	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC7XSWI7	SwTyp.stVal	Disconnector	Disconnect type
DC8XSWI8	BlkCls.stVal	false	Disconnect close blocking not configured by default

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Logical Node	Attribute	Data Source	Comment
DC8XSWI8	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC8XSWI8	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC8XSWI8	OpCnt.stVal	0	
DC8XSWI8	Pos.stVal	89CL2P8?1:2[c]	Disconnect 8 position
DC8XSWI8	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC8XSWI8	SwTyp.stVal	Disconnector	Disconnect Type
DC19XSWI9	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC9XSWI9	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC9XSWI9	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC9XSWI9	OpCnt.stVal	0	
DC9XSWI9	Pos.stVal	89CL2P9?1:2[c]	Disconnect 9 position
DC9XSWI9	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC9XSWI9	SwTyp.stVal	Disconnector	Disconnect Type
DC10XSWI10	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC10XSWI10	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC10XSWI10	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC10XSWI10	OpCnt.stVal	0	
DC10XSWI10	Pos.stVal	89CL2P10?1:2[c]	Disconnect 10 position
DC10XSWI10	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC10XSWI10	SwTyp.stVal	Disconnector	Disconnect type
DC11XSWI11	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC11XSWI11	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC11XSWI11	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC11XSWI11	OpCnt.stVal	0	
DC11XSWI11	Pos.stVal	89CL2P11?1:2[c]	Disconnect 11 position
DC11XSWI11	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC11XSWI11	SwTyp.stVal	Disconnector	Disconnect type
DC12XSWI12	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC12XSWI12	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC12XSWI12	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC12XSWI12	OpCnt.stVal	0	
DC12XSWI12	Pos.stVal	89CL2P12?1:2[c]	Disconnect 12 position
DC12XSWI12	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC12XSWI12	SwTyp.stVal	Disconnector	Disconnect type
DC13XSWI13	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC13XSWI13	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC13XSWI13	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC13XSWI13	OpCnt.stVal	0	

Table G.36 Logical Device: PRO (Protection) (Sheet 10 of 22)

Logical Node	Attribute	Data Source	Comment
DC13XSWI13	Pos.stVal	89CL2P13?1:2[c]	Disconnect 13 position
DC13XSWI13	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC13XSWI13	SwTyp.stVal	Disconnector	Disconnect type
DC14XSWI14	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC14XSWI14	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC14XSWI14	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC14XSWI14	OpCnt.stVal	0	
DC14XSWI14	Pos.stVal	89CL2P14?1:2[c]	Disconnect 14 position
DC14XSWI14	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC14XSWI14	SwTyp.stVal	Disconnector	Disconnect type
DC15XSWI15	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC15XSWI15	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC15XSWI15	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC15XSWI15	OpCnt.stVal	0	
DC15XSWI15	Pos.stVal	89CL2P15?1:2[c]	Disconnect 15 position
DC15XSWI15	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC15XSWI15	SwTyp.stVal	Disconnector	Disconnect type
DC16XSWI16	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC16XSWI16	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC16XSWI16	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC16XSWI16	OpCnt.stVal	0	
DC16XSWI16	Pos.stVal	89CL2P16?1:2[c]	Disconnect 16 position
DC16XSWI16	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC16XSWI16	SwTyp.stVal	Disconnector	Disconnect type
DC17XSWI17	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC17XSWI17	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC17XSWI17	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC17XSWI17	OpCnt.stVal	0	
DC17XSWI17	Pos.stVal	89CL3PL1?1:2[c]	In-Line Disconnect 1 position
DC17XSWI17	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC17XSWI17	SwTyp.stVal	Disconnector	Disconnect type
DC18XSWI18	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC18XSWI18	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC18XSWI18	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC18XSWI18	OpCnt.stVal	0	
DC18XSWI18	Pos.stVal	89CL3PL2?1:2[c]	In-Line Disconnect 2 position
DC18XSWI18	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC18XSWI18	SwTyp.stVal	Disconnector	Disconnect type

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Logical Node	Attribute	Data Source	Comment
DC19XSWI19	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC19XSWI19	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC19XSWI19	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC19XSWI19	OpCnt.stVal	0	
DC19XSWI19	Pos.stVal	89CL3PE1?1:2[c]	Earthing Disconnect 1 position
DC19XSWI19	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC19XSWI19	SwTyp.stVal	Disconnector	Disconnect type
DC20XSWI20	BlkCls.stVal	false	Disconnect close blocking not configured by default
DC20XSWI20	BlkOpn.stVal	false	Disconnect open blocking not configured by default
DC20XSWI20	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
DC20XSWI20	OpCnt.stVal	0	
DC20XSWI20	Pos.stVal	89CL3PE2?1:2[c]	Earthing Disconnect 2 position
DC20XSWI20	SwOpCap.stVal	None	Disconnect operation capabilities not known to relay
DC20XSWI20	SwTyp.stVal	Disconnector	Disconnect type
FLTRDRE1	RcdMade.stVal	FLREP	Event report present
FLTRDRE1	FltNum.stVal	FLRNUM	Unique event ID number
G11PIOC19	Op.general	50G11T	Level 1 residual ground instantaneous overcurrent element trip—Winding 1
G11PIOC19	Str.general	50G11P	Level 1 residual ground instantaneous overcurrent element pickup—Winding 1
G11PIOC19	Str.dirGeneral	unknown	Direction undefined
G12PIOC20	Op.general	50G12T	Level 2 residual ground instantaneous overcurrent element trip—Winding 1
G12PIOC20	Str.general	50G12P	Level 2 residual ground instantaneous overcurrent element pickup—Winding 1
G12PIOC20	Str.dirGeneral	unknown	Direction undefined
G1PTOC6	Op.general	51G1T	Residual ground time-overcurrent element trip—Winding 1
G1PTOC6	Str.general	51G1P	Residual ground time-overcurrent element pickup—Winding 1
G1PTOC6	Str.dirGeneral	unknown	Direction undefined
G1TPTOV5	Op.general	59G1T	Level 1 zero-sequence over voltage element trip
G1TPTOV5	Str.general	59G1	Level 1 zero-sequence over voltage element pickup
G1TPTOV5	Str.dirGeneral	unknown	Direction undefined
G21PIOC21	Op.general	50G21T	Level 1 residual ground instantaneous overcurrent element trip—Winding 2
G21PIOC21	Str.general	50G21P	Level 1 residual ground instantaneous overcurrent element pickup—Winding 2
G21PIOC21	Str.dirGeneral	unknown	Direction undefined
G22PIOC22	Op.general	50G22T	Level 2 residual ground instantaneous overcurrent element trip—Winding 2
G22PIOC22	Str.general	50G22P	Level 2 residual ground instantaneous overcurrent element pickup—Winding 2

Table G.36 Logical Device: PRO (Protection) (Sheet 12 of 22)

Logical Node	Attribute	Data Source	Comment
G22PIOC22	Str.dirGeneral	unknown	Direction undefined
G2PTOC7	Op.general	51G2T	Residual ground time-overcurrent element trip—Winding 2
G2PTOC7	Str.general	51G2P	Residual ground time-overcurrent element pickup—Winding 2
G2PTOC7	Str.dirGeneral	unknown	Direction undefined
G2TPTOV6	Op.general	59G2T	Level 2 zero-sequence overvoltage element trip
G2TPTOV6	Str.general	59G2	Level 2 zero-sequence overvoltage element pickup
G2TPTOV6	Str.dirGeneral	unknown	Direction undefined
G31PIOC23	Op.general	50G31T	Level 1 residual ground instantaneous overcurrent element trip—Winding 3
G31PIOC23	Str.general	50G31P	Level 1 residual ground instantaneous overcurrent element pickup—Winding 3
G31PIOC23	Str.dirGeneral	unknown	Direction undefined
G32PIOC24	Op.general	50G32T	Level 2 residual ground instantaneous overcurrent element trip—Winding 3
G32PIOC24	Str.general	50G32P	Level 2 residual ground instantaneous overcurrent element pickup—Winding 3
G32PIOC24	Str.dirGeneral	unknown	Direction undefined
G3PTOC8	Op.general	51G3T	Residual ground time-overcurrent element trip—Winding 3
G3PTOC8	Str.general	51G3P	Residual ground time-overcurrent element pickup—Winding 3
G3PTOC8	Str.dirGeneral	unknown	Direction undefined
G41PIOC25	Op.general	50G41T	Level 1 residual ground instantaneous overcurrent element trip—Winding 4
G41PIOC25	Str.general	50G41P	Level 1 residual ground instantaneous overcurrent element pickup—Winding 4
G41PIOC25	Str.dirGeneral	unknown	Direction undefined
G42PIOC26	Op.general	50G42T	Level 2 residual ground instantaneous overcurrent element trip—Winding 4
G42PIOC26	Str.general	50G42P	Level 2 residual ground instantaneous overcurrent element pickup—Winding 4
G42PIOC26	Str.dirGeneral	unknown	Direction undefined
G4PTOC9	Op.general	51G4T	Residual ground time-overcurrent element trip—Winding 4
G4PTOC9	Str.general	51G4P	Residual ground time-overcurrent element pickup—Winding 4
G4PTOC9	Str.dirGeneral	unknown	Direction undefined
GC12PTOC19	Op.general	51GC12T	Residual ground time-overcurrent element trip—Combined Winding 1 and Winding 2
GC12PTOC19	Str.general	51GC12P	Residual ground time-overcurrent element pickup—Combined Winding 1 and Winding 2
GC12PTOC19	Str.dirGeneral	unknown	Direction undefined
GC34PTOC20	Op.general	51GC34T	Residual ground time-overcurrent element trip—Combined Winding 3 and Winding 4
GC34PTOC20	Str.general	51GC34P	Residual ground time-overcurrent element pickup—Combined Winding 3 and Winding 4
GC34PTOC20	Str.dirGeneral	unknown	Direction undefined

Table G.36 Logical Device: PRO (Protection) (Sheet 13 of 22)

Logical Node	Attribute	Data Source	Comment
HB24PHAR1	Str.phsA	2_4HB1	Second- or fourth-harmonic block asserted for Differential Element 1
HB24PHAR1	Str.phsB	2_4HB2	Second- or fourth-harmonic block asserted for Differential Element 2
HB24PHAR1	Str.phsC	2_4HB3	Second- or fourth-harmonic block asserted for Differential Element 3
HB24PHAR1	Str.general	2_4HBL	Second- or fourth-harmonic block asserted (2_4HB1 OR 2_4HB2 OR 2_4HB3)
HB24PHAR1	Str.dirGeneral	unknown	Direction undefined
HB24PHAR1	Str.dirPhsA	unknown	Direction undefined
HB24PHAR1	Str.dirPhsB	unknown	Direction undefined
HB24PHAR1	Str.dirPhsC	unknown	Direction undefined
HB5PHAR2	Str.phsA	5HB1	Fifth-harmonic block asserted for Differential Element 1
HB5PHAR2	Str.phsB	5HB2	Fifth-harmonic block asserted for Differential Element 2
HB5PHAR2	Str.phsC	5HB3	Fifth-harmonic block asserted for Differential Element 3
HB5PHAR2	Str.general	5HBL	Fifth-harmonic block asserted (5HB1 OR 5HB2 OR 5HB3)
HB5PHAR2	Str.dirGeneral	unknown	Direction undefined
HB5PHAR2	Str.dirPhsA	unknown	Direction undefined
HB5PHAR2	Str.dirPhsB	unknown	Direction undefined
HB5PHAR2	Str.dirPhsC	unknown	Direction undefined
HB87PHAR3	Str.phsA	87BL1	Harmonic block asserted for Differential Element 1
HB87PHAR3	Str.phsB	87BL2	Harmonic block asserted for Differential Element 2
HB87PHAR3	Str.phsC	87BL3	Harmonic block asserted for Differential Element 3
HB87PHAR3	Str.general	87HB	Harmonic block differential element asserted
HB87PHAR3	Str.dirGeneral	unknown	Direction undefined
HB87PHAR3	Str.dirPhsA	unknown	Direction undefined
HB87PHAR3	Str.dirPhsB	unknown	Direction undefined
HB87PHAR3	Str.dirPhsC	unknown	Direction undefined
HR87PHAR4	Str.general	87HR	Harmonic restrained element (HR1 OR HR2 OR HR3) * harmonic restrained enable
HR87PHAR4	Str.phsA	87HR1	Harmonic Restrained Element 1
HR87PHAR4	Str.phsB	87HR2	Harmonic Restrained Element 2
HR87PHAR4	Str.phsC	87HR3	Harmonic Restrained Element 3
HR87PHAR4	Str.dirGeneral	unknown	Direction undefined
HR87PHAR4	Str.dirPhsA	unknown	Direction undefined
HR87PHAR4	Str.dirPhsB	unknown	Direction undefined
HR87PHAR4	Str.dirPhsC	unknown	Direction undefined
I1TPTOV12	Op.general	59I1T	Level 1 inverse overvoltage element trip
I1TPTOV12	Str.general	59I1	Level 1 inverse overvoltage element pickup
I1TPTOV12	Str.dirGeneral	unknown	Direction undefined
I1TPTOV13	Op.general	59I2T	Level 2 inverse overvoltage element trip
I1TPTOV13	Str.general	59I2	Level 2 inverse overvoltage element pickup

Table G.36 Logical Device: PRO (Protection) (Sheet 14 of 22)

Logical Node	Attribute	Data Source	Comment
I1TPTOV13	Str.dirGeneral	unknown	Direction undefined
I1TPTOV14	Op.general	59I3T	Level 3 inverse overvoltage element trip
I1TPTOV14	Str.general	59I3	Level 3 inverse overvoltage element pickup
I1TPTOV14	Str.dirGeneral	unknown	Direction undefined
I1TPTOV15	Op.general	59I4T	Level 4 inverse overvoltage element trip
I1TPTOV15	Str.general	59I4	Level 4 inverse overvoltage element pickup
I1TPTOV15	Str.dirGeneral	unknown	Direction undefined
I1TPTUV9	Op.general	27I1T	Level 1 inverse undervoltage element trip
I1TPTUV9	Str.general	27I1	Level 1 inverse undervoltage element pickup
I1TPTUV9	Str.dirGeneral	unknown	Direction undefined
I1TPTUV10	Op.general	27I2T	Level 2 inverse undervoltage element trip
I1TPTUV10	Str.general	27I2	Level 2 inverse undervoltage element pickup
I1TPTUV10	Str.dirGeneral	unknown	Direction undefined
LLN0	Loc.stVal	LOC	Control authority at local (bay) level
LLN0	LocSta.stVal	LOCSTA	Control authority at station level
LOPPTUV8	Op.general	LOP	Loss of potential
LOPPTUV8	Str.general	LOP	Loss of potential
LOPPTUV8	Str.dirGeneral	unknown	Direction undefined
N11PIOC17	Op.general	50N11T	Level 1 neutral ground instantaneous overcurrent element trip—Input 1
N11PIOC17	Str.general	50N11P	Level 1 neutral ground instantaneous overcurrent element pickup—Input 1
N11PIOC17	Str.dirGeneral	unknown	Direction undefined
N12PIOC18	Op.general	50N12T	Level 2 neutral ground instantaneous overcurrent element trip—Input 1
N12PIOC18	Str.general	50N12P	Level 2 neutral ground instantaneous overcurrent element pickup—Input 1
N12PIOC18	Str.dirGeneral	unknown	Direction undefined
N1PTOC5	Op.general	51N1T	Neutral ground time-overcurrent element trip—Input 1
N1PTOC5	Str.general	51N1P	Neutral ground time-overcurrent element pickup—Input 1
N1PTOC5	Str.dirGeneral	unknown	Direction undefined
P11PIOC1	Op.general	50P11T	Level 1 phase instantaneous overcurrent element trip—Winding 1
P11PIOC1	Str.general	50P11P	Level 1 phase instantaneous overcurrent element pickup—Winding 1
P11PIOC1	Str.dirGeneral	unknown	Direction undefined
P12PIOC2	Op.general	50P12T	Level 2 phase instantaneous overcurrent element trip—Winding 1
P12PIOC2	Str.general	50P12P	Level 2 phase instantaneous overcurrent element pickup—Winding 1
P12PIOC2	Str.dirGeneral	unknown	Direction undefined
P13PIOC3	Op.general	50P13T	Level 3 phase instantaneous overcurrent element trip—Winding 1
P13PIOC3	Str.general	50P13P	Level 3 phase instantaneous overcurrent element pickup—Winding 1
P13PIOC3	Str.dirGeneral	unknown	Direction undefined

Table G.36 Logical Device: PRO (Protection) (Sheet 15 of 22)

Logical Node	Attribute	Data Source	Comment
P14PIOC4	Op.general	50P14T	Level 4 phase instantaneous overcurrent element trip—Winding 1
P14PIOC4	Str.general	50P14P	Level 4 phase instantaneous overcurrent element pickup—Winding 1
P14PIOC4	Str.dirGeneral	unknown	Direction undefined
P1PTOC1	Op.general	51P1T	Maximum phase time-overcurrent element trip—Winding 1
P1PTOC1	Str.general	51P1P	Maximum phase time-overcurrent element pickup—Winding 1
P1PTOC1	Str.dirGeneral	unknown	Direction undefined
P1PTOV1	Op.general	59P1T	Level 1 phase overvoltage element trip
P1PTOV1	Str.general	59P1	Level 1 phase overvoltage element pickup
P1PTOV1	Str.dirGeneral	unknown	Direction undefined
P1PTUV1	Op.general	27P1T	Level 1 phase undervoltage element trip
P1PTUV1	Str.general	27P1	Level 1 phase undervoltage element pickup
P1PTUV1	Str.dirGeneral	unknown	Direction undefined
P21PIOC5	Op.general	50P21T	Level 1 phase instantaneous overcurrent element trip—Winding 2
P21PIOC5	Str.general	50P21P	Level 1 phase instantaneous overcurrent element pickup—Winding 2
P21PIOC5	Str.dirGeneral	unknown	Direction undefined
P22PIOC6	Op.general	50P22T	Level 2 phase instantaneous overcurrent element trip—Winding 2
P22PIOC6	Str.general	50P22P	Level 2 phase instantaneous overcurrent element pickup—Winding 2
P22PIOC6	Str.dirGeneral	unknown	Direction undefined
P23PIOC7	Op.general	50P23T	Level 3 phase instantaneous overcurrent element trip—Winding 2
P23PIOC7	Str.general	50P23P	Level 3 phase instantaneous overcurrent element pickup—Winding 2
P23PIOC7	Str.dirGeneral	unknown	Direction undefined
P24PIOC8	Op.general	50P24T	Level 3 phase instantaneous overcurrent element trip—Winding 2
P24PIOC8	Str.general	50P24P	Level 3 phase instantaneous overcurrent element pickup—Winding 2
P24PIOC8	Str.dirGeneral	unknown	Direction undefined
P2PTOC2	Op.general	51P2T	Maximum phase time-overcurrent element trip—Winding 2
P2PTOC2	Str.general	51P2P	Maximum phase time-overcurrent element pickup—Winding 2
P2PTOC2	Str.dirGeneral	unknown	Direction undefined
P2PTOV2	Op.general	59P2T	Level 2 phase overvoltage element trip
P2PTOV2	Str.general	59P2	Level 2 phase overvoltage element pickup
P2PTOV2	Str.dirGeneral	unknown	Direction undefined
P2PTUV2	Op.general	27P2T	Level 2 phase undervoltage element trip
P2PTUV2	Str.general	27P2	Level 2 phase undervoltage element pickup
P2PTUV2	Str.dirGeneral	unknown	Direction undefined
P31APIOC35	Op.general	50P31AT	Level 1 phase instantaneous overcurrent element trip—Phase A of Winding 3
P31APIOC35	Str.general	50P31AP	Level 1 phase instantaneous overcurrent element pickup—Phase A of Winding 3
P31APIOC35	Str.dirGeneral	unknown	Direction undefined
P31BPIOC36	Op.general	50P31BT	Level 1 phase instantaneous overcurrent element trip—Phase B of Winding 3

Table G.36 Logical Device: PRO (Protection) (Sheet 16 of 22)

Logical Node	Attribute	Data Source	Comment
P31BPIOC36	Str.general	50P31BP	Level 1 phase instantaneous overcurrent element pickup—Phase B of Winding 3
P31BPIOC36	Str.dirGeneral	unknown	Direction undefined
P31CPIOC37	Op.general	50P31CT	Level 1 phase instantaneous overcurrent element trip—Phase C of Winding 3
P31CPIOC37	Str.general	50P31CP	Level 1 phase instantaneous overcurrent element pickup—Phase C of Winding 3
P31CPIOC37	Str.dirGeneral	unknown	Direction undefined
P31PIOC9	Op.general	50P31T	Level 1 phase instantaneous overcurrent element trip—Winding 3
P31PIOC9	Str.general	50P31P	Level 1 phase instantaneous overcurrent element pickup—Winding 3
P31PIOC9	Str.dirGeneral	unknown	Direction undefined
P32APIOC38	Op.general	50P32AT	Level 2 phase instantaneous overcurrent element trip—Phase A of Winding 3
P32APIOC38	Str.general	50P32AP	Level 2 phase instantaneous overcurrent element pickup—Phase A of Winding 3
P32APIOC38	Str.dirGeneral	unknown	Direction undefined
P32BPIOC39	Op.general	50P32BT	Level 2 phase instantaneous overcurrent element trip—Phase B of Winding 3
P32BPIOC39	Str.general	50P32BP	Level 2 phase instantaneous overcurrent element pickup—Phase B of Winding 3
P32BPIOC39	Str.dirGeneral	unknown	Direction undefined
P32CPIOC40	Op.general	50P32CT	Level 2 phase instantaneous overcurrent element trip—Phase C of Winding 3
P32CPIOC40	Str.general	50P32CP	Level 2 phase instantaneous overcurrent element pickup—Phase C of Winding 3
P32CPIOC40	Str.dirGeneral	unknown	Direction undefined
P32PIOC10	Op.general	50P32T	Level 2 phase instantaneous overcurrent element trip—Winding 3
P32PIOC10	Str.general	50P32P	Level 2 phase instantaneous overcurrent element pickup—Winding 3
P32PIOC10	Str.dirGeneral	unknown	Direction undefined
P33PIOC11	Op.general	50P33T	Level 3 phase instantaneous overcurrent element trip—Winding 3
P33PIOC11	Str.general	50P33P	Level 3 phase instantaneous overcurrent element pickup—Winding 3
P33PIOC11	Str.dirGeneral	unknown	Direction undefined
P34PIOC12	Op.general	50P34T	Level 4 phase instantaneous overcurrent element trip—Winding 3
P34PIOC12	Str.general	50P34P	Level 4 phase instantaneous overcurrent element pickup—Winding 3
P34PIOC12	Str.dirGeneral	unknown	Direction undefined
P3APTOC14	Op.general	51P3AT	Phase time-overcurrent element trip—Phase A of Winding 3
P3APTOC14	Str.general	51P3AP	Phase time-overcurrent element pickup—Phase A of Winding 3
P3APTOC14	Str.dirGeneral	unknown	Direction undefined
P3BPTOC15	Op.general	51P3BT	Phase time-overcurrent element trip—Phase B of Winding 3
P3BPTOC15	Str.general	51P3BP	Phase time-overcurrent element pickup—Phase B of Winding 3
P3BPTOC15	Str.dirGeneral	unknown	Direction undefined
P3CPTOC16	Op.general	51P3CT	Phase time-overcurrent element trip—Phase C of Winding 3

Table G.36 Logical Device: PRO (Protection) (Sheet 17 of 22)

Logical Node	Attribute	Data Source	Comment
P3CPTOC16	Str.general	51P3CP	Phase time-overcurrent element pickup—Phase C of Winding 3
P3CPTOC16	Str.dirGeneral	unknown	Direction undefined
P3PTOC3	Op.general	51P3T	Maximum phase time-overcurrent element trip—Winding 3
P3PTOC3	Str.general	51P3P	Maximum phase time-overcurrent element pickup—Winding 3
P3PTOC3	Str.dirGeneral	unknown	Direction undefined
P3PTOV11	Op.general	3P59	Three-phase overvoltage pickup when all three phases are above 59P1P
P3PTOV11	Str.general	3P59	Three-phase overvoltage pickup when all three phases are above 59P1P
P3PTOV11	Str.dirGeneral	unknown	Direction undefined
P3PTUV7	Op.general	3P27	Three-phase undervoltage pickup when all three phases are below 27P1P
P3PTUV7	Str.general	3P27	Three-phase undervoltage pickup when all three phases are below 27P1P
P3PTUV7	Str.dirGeneral	unknown	Direction undefined
P41PIOC13	Op.general	50P41T	Level 1 phase instantaneous overcurrent element trip—Winding 4
P41PIOC13	Str.general	50P41P	Level 1 phase instantaneous overcurrent element pickup—Winding 4
P41PIOC13	Str.dirGeneral	unknown	Direction undefined
P42PIOC14	Op.general	50P42T	Level 2 phase instantaneous overcurrent element trip—Winding 4
P42PIOC14	Str.general	50P42P	Level 2 phase instantaneous overcurrent element pickup—Winding 4
P42PIOC14	Str.dirGeneral	unknown	Direction undefined
P43PIOC15	Op.general	50P43T	Level 3 phase instantaneous overcurrent element trip—Winding 4
P43PIOC15	Str.general	50P43P	Level 3 phase instantaneous overcurrent element pickup—Winding 4
P43PIOC15	Str.dirGeneral	unknown	Direction undefined
P44PIOC16	Op.general	50P44T	Level 4 phase instantaneous overcurrent element trip—Winding 4
P44PIOC16	Str.general	50P44P	Level 4 phase instantaneous overcurrent element pickup—Winding 4
P44PIOC16	Str.dirGeneral	unknown	Direction undefined
P4PTOC4	Op.general	51P4T	Maximum phase time-overcurrent element trip—Winding 4
P4PTOC4	Str.general	51P4P	Maximum phase time-overcurrent element pickup—Winding 4
P4PTOC4	Str.dirGeneral	unknown	Direction undefined
PC12PTOC17	Op.general	51PC12T	Maximum phase time-overcurrent element trip—Combined Winding 1 and Winding 2
PC12PTOC17	Str.general	51PC12P	Maximum phase time-overcurrent element pickup—Combined Winding 1 and Winding 2
PC12PTOC17	Str.dirGeneral	unknown	Direction undefined
PC34PTOC18	Op.general	51PC34T	Residual ground time-overcurrent element trip—Combined Winding 3 and Winding 4
PC34PTOC18	Str.general	51PC34P	Residual ground time-overcurrent element pickup—Combined Winding 3 and Winding 4
PC34PTOC18	Str.dirGeneral	unknown	Direction undefined
PP1TPTOV3	Op.general	59PP1T	Level 1 phase-to-phase overvoltage element trip

Table G.36 Logical Device: PRO (Protection) (Sheet 18 of 22)

Logical Node	Attribute	Data Source	Comment
PP1TPTOV3	Str.general	59PP1	Level 1 phase-to-phase overvoltage element pickup
PP1TPTOV3	Str.dirGeneral	unknown	Direction undefined
PP1TPTUV3	Op.general	27PP1T	Level 1 phase-to-phase undervoltage element trip
PP1TPTUV3	Str.general	27PP1	Level 1 phase-to-phase undervoltage element pickup
PP1TPTUV3	Str.dirGeneral	unknown	Direction undefined
PP2TPTOV4	Op.general	59PP2T	Level 2 phase-to-phase overvoltage element trip
PP2TPTOV4	Str.general	59PP2	Level 2 phase-to-phase overvoltage element pickup
PP2TPTOV4	Str.dirGeneral	unknown	Direction undefined
PP2TPTUV4	Op.general	27PP2T	Level 2 phase-to-phase undervoltage element trip
PP2TPTUV4	Str.general	27PP2	Level 2 phase-to-phase undervoltage element pickup
PP2TPTUV4	Str.dirGeneral	unknown	Direction undefined
PWR1PDOP1	Op.general	3PWR1T	Three-phase Power Element 1 trip
PWR1PDOP1	Str.general	3PWR1P	Three-phase Power Element 1 pickup
PWR1PDOP1	Str.dirGeneral	unknown	Direction undefined
PWR1PDUP1	Op.general	3PWR1T	Three-phase Power Element 1 trip
PWR1PDUP1	Str.general	3PWR1P	Three-phase Power Element 1 pickup
PWR1PDUP1	Str.dirGeneral	unknown	Direction undefined
PWR2PDOP2	Op.general	3PWR2T	Three-phase Power Element 2 trip
PWR2PDOP2	Str.general	3PWR2P	Three-phase Power Element 2 pickup
PWR2PDOP2	Str.dirGeneral	unknown	Direction undefined
PWR2PDUP2	Op.general	3PWR2T	Three-phase Power Element 2 trip
PWR2PDUP2	Str.general	3PWR2P	Three-phase Power Element 2 pickup
PWR2PDUP2	Str.dirGeneral	unknown	Direction undefined
Q11PIOC27	Op.general	50Q11T	Level 1 negative-sequence instantaneous overcurrent element trip—Winding 1
Q11PIOC27	Str.general	50Q11P	Level 1 negative-sequence instantaneous overcurrent element pickup—Winding 1
Q11PIOC27	Str.dirGeneral	unknown	Direction undefined
Q12PIOC28	Op.general	50Q12T	Level 2 negative-sequence instantaneous overcurrent element trip—Winding 1
Q12PIOC28	Str.general	50Q12P	Level 2 negative-sequence instantaneous overcurrent element pickup—Winding 1
Q12PIOC28	Str.dirGeneral	unknown	Direction undefined
Q1PTOC10	Op.general	51Q1T	Negative-sequence time-overcurrent element trip—Winding 1
Q1PTOC10	Str.general	51Q1P	Negative-sequence time-overcurrent element pickup—Winding 1
Q1PTOC10	Str.dirGeneral	unknown	Direction undefined
Q1TPTOV7	Op.general	59Q1T	Level 1 negative-sequence overvoltage element trip
Q1TPTOV7	Str.general	59Q1	Level 1 negative-sequence overvoltage element pickup
Q1TPTOV7	Str.dirGeneral	unknown	Direction undefined

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Logical Node	Attribute	Data Source	Comment
Q21PIOC29	Op.general	50Q21T	Level 1 negative-sequence instantaneous overcurrent element trip—Winding 2
Q21PIOC29	Str.general	50Q21P	Level 1 negative-sequence instantaneous overcurrent element pickup—Winding 2
Q21PIOC29	Str.dirGeneral	unknown	Direction undefined
Q22PIOC30	Op.general	50Q22T	Level 2 negative-sequence instantaneous overcurrent element trip—Winding 2
Q22PIOC30	Str.general	50Q22P	Level 2 negative-sequence instantaneous overcurrent element pickup—Winding 2
Q22PIOC30	Str.dirGeneral	unknown	Direction undefined
Q2PTOC11	Op.general	51Q2T	Negative-sequence time-overcurrent element trip—Winding 2
Q2PTOC11	Str.general	51Q2P	Negative-sequence time-overcurrent element pickup—Winding 2
Q2PTOC11	Str.dirGeneral	unknown	Direction undefined
Q2TPTOV8	Op.general	59Q2T	Level 2 negative-sequence overvoltage element trip
Q2TPTOV8	Str.general	59Q2	Level 2 negative-sequence overvoltage element pickup
Q2TPTOV8	Str.dirGeneral	unknown	Direction undefined
Q31PIOC31	Op.general	50Q31T	Level 1 negative-sequence instantaneous overcurrent element trip—Winding 3
Q31PIOC31	Str.general	50Q31P	Level 1 negative-sequence instantaneous overcurrent element pickup—Winding 3
Q31PIOC31	Str.dirGeneral	unknown	Direction undefined
Q32PIOC32	Op.general	50Q32T	Level 2 negative-sequence instantaneous overcurrent element trip—Winding 3
Q32PIOC32	Str.general	50Q32P	Level 2 negative-sequence instantaneous overcurrent element pickup—Winding 3
Q32PIOC32	Str.dirGeneral	unknown	Direction undefined
Q3PTOC12	Op.general	51Q3T	Negative-sequence time-overcurrent element trip—Winding 3
Q3PTOC12	Str.general	51Q3P	Negative-sequence time-overcurrent element pickup—Winding 3
Q3PTOC12	Str.dirGeneral	unknown	Direction undefined
Q41PIOC33	Op.general	50Q41T	Level 1 negative-sequence instantaneous overcurrent element trip—Winding 4
Q41PIOC33	Str.general	50Q41P	Level 1 negative-sequence instantaneous overcurrent element pickup—Winding 4
Q41PIOC33	Str.dirGeneral	unknown	Direction undefined
Q42PIOC34	Op.general	50Q42T	Level 2 negative-sequence instantaneous overcurrent element trip—Winding 4
Q42PIOC34	Str.general	50Q42P	Level 2 negative-sequence instantaneous overcurrent element pickup—Winding 4
Q42PIOC34	Str.dirGeneral	unknown	Direction undefined
Q4PTOC13	Op.general	51Q4T	Negative-sequence time-overcurrent element trip—Winding 4
Q4PTOC13	Str.general	51Q4P	Negative-sequence time-overcurrent element pickup—Winding 4
Q4PTOC13	Str.dirGeneral	unknown	Direction undefined
REF1FPDIF4	Op.general	REF1F	REF element forward (internal) fault declaration

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Logical Node	Attribute	Data Source	Comment
REF1PPDIF6	Op.general	REF1P	Restricted earth fault inverse-time O/C element timed out
REF1RPDIF5	Op.general	REF1R	REF element reverse (external) fault declaration
REF3AFPDIF7	Op.general	REF3AF	REF3A element forward (internal) fault declaration
REF3APPDIF9	Op.general	REF3AP	REF3A inverse-time O/C element timed-out
REF3ARPDIF8	Op.general	REF3AR	REF3A element reverse (external) fault declaration
REF3BFPDIF10	Op.general	REF3BF	REF3B element forward (internal) fault declaration
REF3BPPDIF12	Op.general	REF3BP	REF3B inverse-time O/C element timed-out
REF3BRPDIF11	Op.general	REF3BR	REF3B element reverse (external) fault declaration
S1PTOV9	Op.general	59S1T	Level 1 VS channel overvoltage element trip
S1PTOV9	Str.general	59S1	Level 1 VS channel overvoltage element pickup
S1PTOV9	Str.dirGeneral	unknown	Direction undefined
S1TPTUV5	Op.general	27S1T	Level 1 VS channel undervoltage element trip
S1TPTUV5	Str.general	27S1	Level 1 VS channel undervoltage element pickup
S1TPTUV5	Str.dirGeneral	unknown	Direction undefined
S2PTOV10	Op.general	59S2T	Level 2 VS channel overvoltage element trip
S2PTOV10	Str.general	59S2	Level 2 VS channel overvoltage element pickup
S2PTOV10	Str.dirGeneral	unknown	Direction undefined
S2TPTUV6	Op.general	27S2T	Level 2 VS channel undervoltage element trip
S2TPTUV6	Str.general	27S2	Level 2 VS channel undervoltage element pickup
S2TPTUV6	Str.dirGeneral	unknown	Direction undefined
SYN1RSYN1	Rel.stVal	25A1	Intertie slip/breaker-time compensated phase angle less than 25ANG1 setting
SYN1RSYN1	HzInd.stVal	SF	Slip frequency is within acceptable bounds (between 25SLO and 25SHI settings)
SYN2RSYN2	Rel.stVal	25A2	Intertie slip/breaker-time compensated phase angle less than 25ANG2 setting
SYN2RSYN2	HzInd.stVal	SF	Slip frequency is within acceptable bounds (between 25SLO and 25SHI settings)
TRIP1PTRC1	Tr.general	TRIP1	Trip 1 logic output
TRIP2PTRC2	Tr.general	TRIP2	Trip 2 logic output
TRIP3PTRC3	Tr.general	TRIP3	Trip 3 logic output
TRIP4PTRC4	Tr.general	TRIP4	Trip 4 logic output
TRIPXPTRC5	Tr.general	TRIPXFMR	TripXFMR logic output
W1CILO1	EnaCls.stVal	BKENC1	BKENC1 supervises the close operation of Breaker 1
W1CILO1	EnaOpn.stVal	BKENO1	BKENO1 supervises the open operation of Breaker 1
W1CSWI1	OpCls.general	CC1	Breaker1 close control
W1CSWI1	OpOpn.general	OC1	Breaker1 open control
W1CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
W1CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
W1CSWI1	Pos.stVal	52A1|52B1?0:1:2:3[b]	Breaker 1 close/open status

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Logical Node	Attribute	Data Source	Comment
W1XCBR1	BlkCls.stVal	0	Breaker close blocking not configured by default
W1XCBR1	BlkOpn.stVal	0	Breaker open blocking not configured by default
W1XCBR1	CBOpCap.stVal	None	Breaker physical operation capabilities not known to relay
W1XCBR1	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
W1XCBR1	OpCnt.stVal	INTTW1	Winding 1 internal trips counter
W1XCBR1	OpCntEx.stVal	EXTTW1	Winding 1 external trips counter
W1XCBR1	Pos.stVal	52A1|52B1?0:1:2:3[b]	Breaker 1 close/open status
W2CILO2	EnaCls.stVal	BKENC2	BKENC2 supervises the close operation of Breaker 2
W2CILO2	EnaOpn.stVal	BKENO2	BKENO2 supervises the open operation of Breaker 2
W2CSWI2	OpCls.general	CC2	Breaker 2 close control
W2CSWI2	OpOpn.general	OC2	Breaker 2 open control
W2CSWI2	Loc.stVal	LOC	Control authority at local (bay) level
W2CSWI2	LocSta.stVal	LOCSTA	Control authority at station level
W2CSWI2	Pos.stVal	52A2|52B2?0:1:2:3[b]	Breaker 2 close/open status
W2XCBR2	BlkCls.stVal	0	Breaker close blocking not configured by default
W2XCBR2	BlkOpn.stVal	0	Breaker open blocking not configured by default
W2XCBR2	CBOpCap.stVal	None	Breaker physical operation capabilities not known to relay
W2XCBR2	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
W2XCBR2	OpCnt.stVal	INTTW2	Winding 2 Internal trips counter
W2XCBR2	OpCntEx.stVal	EXTTW2	Winding 2 external trips counter
W2XCBR2	Pos.stVal	52A2|52B2?0:1:2:3[b]	Breaker 2 close/open status
W3CILO3	EnaCls.stVal	BKENC3	BKENC3 supervises the close operation of Breaker 3
W3CILO3	EnaOpn.stVal	BKENO3	BKENO3 supervises the open operation of Breaker 3
W3CSWI3	OpCls.general	CC3	Breaker 3 close control
W3CSWI3	OpOpn.general	OC3	Breaker 3 open control
W3CSWI3	Loc.stVal	LOC	Control authority at local (bay) level
W3CSWI3	LocSta.stVal	LOCSTA	Control authority at station level
W3CSWI3	Pos.stVal	52A3|52B3?0:1:2:3[b]	Breaker 3 close/open status
W3XCBR3	BlkCls.stVal	0	Breaker close blocking not configured by default
W3XCBR3	BlkOpn.stVal	0	Breaker open blocking not configured by default
W3XCBR3	CBOpCap.stVal	None	Breaker physical operation capabilities not known to relay
W3XCBR3	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
W3XCBR3	OpCnt.stVal	INTTW3	Winding 3 internal trips counter
W3XCBR3	OpCntEx.stVal	EXTTW3	Winding 3 external trips counter
W3XCBR3	Pos.stVal	52A3|52B3?0:1:2:3[b]	Breaker 3 close/open status
W4CILO4	EnaCls.stVal	BKENC4	BKENC4 supervises the close operation of Breaker 4
W4CILO4	EnaOpn.stVal	BKENO4	BKENO4 supervises the open operation of Breaker 4
W4CSWI4	OpCls.general	CC4	Breaker 4 close control

Table G.36 Logical Device: PRO (Protection) (Sheet 22 of 22)

Logical Node	Attribute	Data Source	Comment
W4CSWI4	OpOpn.general	OC4	Breaker 4 open control
W4CSWI4	Loc.stVal	LOC	Control authority at local (bay) level
W4CSWI4	LocSta.stVal	LOCSTA	Control authority at station level
W4CSWI4	Pos.stVal	52A4|52B4?0:1:2:3[b]	Breaker 4 close/open status
W4XCBR4	BlkCls.stVal	0	Breaker close blocking not configured by default
W4XCBR4	BlkOpn.stVal	0	Breaker open blocking not configured by default
W4XCBR4	CBOpCap.stVal	None	Breaker physical operation capabilities not known to relay
W4XCBR4	Loc.stVal	OREDLOC	Logical OR of LOC and LOCAL Relay Word bits
W4XCBR4	OpCnt.stVal	INTTW4	Winding 4 internal trips counter
W4XCBR4	OpCntEx.stVal	EXTTW4	Winding 4 external trips counter
W4XCBR4	Pos.stVal	52A4|52B4?0:1:2:3[b]	Breaker 4 close/open status
Functional Constraint = SP			
LLN0	GrRef.setSrcRef	IdName	Functional name
LLN0	MltLev.setVal	MLTLEV	Multilevel mode of control authority

[a] Writing a 0 to Pos.Oper.ctlVal will cause the Open control bit to assert and writing any other value will cause the Close control bit to assert.
[b] If the breaker/disconnect is closed, value = 10(2). If the breaker/disconnect is open, value = 01(1). Value 00(0) indicates an in progress or intermediate state and value = 11(3) indicates an alarm or bad state.
[c] If the disconnect is closed, value = 10(2). If the disconnect is open, value = 01(1).

Table G.37 shows the LN associated with measuring elements defined as Logical Device MET.

Table G.37 Logical Device: MET (Metering) (Sheet 1 of 9)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = DC			
DevIDLPHD1	PhyNam.model	PARTNO	Part number
Functional Constraint = MX[a b]			
DCZBAT1	Vol.instMag.f	VDC	Station dc battery voltage
METMDST1	DmdAnseq.instCVal.mag.f	3I2D	Negative-sequence current demand
METMDST1	DmdA.phsA.instCVal.mag.f	IAD	Phase A current demand
METMDST1	DmdA.phsB.instCVal.mag.f	IBD	Phase B current demand
METMDST1	DmdA.phsC.instCVal.mag.f	ICD	Phase C current demand
METMDST1	DmdA.res.instCVal.mag.f	IGD	Residual current demand
METMDST1	PkDmdAnseq.instCVal.mag.f	3I2PD	Negative-sequence current peak demand
METMDST1	PkDmdA.phsA.instCVal.mag.f	IAPD	Phase A current peak demand
METMDST1	PkDmdA.phsB.instCVal.mag.f	IBPD	Phase B current peak demand
METMDST1	PkDmdA.phsC.instCVal.mag.f	ICPD	Phase C current peak demand
METMDST1	PkDmdA.res.instCVal.mag.f	IGPD	Residual current peak demand
METMHAI1	ThdA1.phsA.instCVal.mag.f	IAW1_THD	Winding 1 A-phase current THD
METMHAI1	ThdA1.phsB.instCVal.mag.f	IBW1_THD	Winding 1 B-phase current THD
METMHAI1	ThdA1.phsC.instCVal.mag.f	ICW1_THD	Winding 1 C-phase current THD

Table G.37 Logical Device: MET (Metering) (Sheet 2 of 9)

Logical Node	Attribute	Data Source	Comment
METMHAI1	ThdA1.neut.instCVal.mag.f	IN_THD	Neutral current THD
METMHAI1	ThdA2.phsA.instCVal.mag.f	IAW2_THD	Winding 2 A-phase current THD
METMHAI1	ThdA2.phsB.instCVal.mag.f	IBW2_THD	Winding 2 B-phase current THD
METMHAI1	ThdA2.phsC.instCVal.mag.f	ICW2_THD	Winding 2 C-phase current THD
METMHAI1	ThdA3.phsA.instCVal.mag.f	IAW3_THD	Winding 3 A-phase current THD
METMHAI1	ThdA3.phsB.instCVal.mag.f	IBW3_THD	Winding 3 B-phase current THD
METMHAI1	ThdA3.phsC.instCVal.mag.f	ICW3_THD	Winding 3 C-phase current THD
METMHAI1	ThdA4.phsA.instCVal.mag.f	IAW4_THD	Winding 4 A-phase current THD
METMHAI1	ThdA4.phsB.instCVal.mag.f	IBW4_THD	Winding 4 B-phase current THD
METMHAI1	ThdA4.phsC.instCVal.mag.f	ICW4_THD	Winding 4 C-phase current THD
METMHAI1	ThdPhV.phsA.instCVal.mag.f	VA_THD	A-phase-to-neutral voltage THD
METMHAI1	ThdPhV.phsB.instCVal.mag.f	VB_THD	B-phase-to-neutral voltage THD
METMHAI1	ThdPhV.phsC.instCVal.mag.f	VC_THD	C-phase-to-neutral voltage THD
METMHAI1	ThdPPV.phsAB.instCVal.mag.f	VAB_THD	A-to-B-phase voltage THD
METMHAI1	ThdPPV.phsBC.instCVal.mag.f	VBC_THD	B-to-C-phase voltage THD
METMHAI1	ThdPPV.phsCA.instCVal.mag.f	VCA_THD	C-to-A-phase voltage THD
METMSTA1	MaxAmps.instMag.f	INMX	Current, neutral, maximum magnitude
METMSTA1	MaxA1.phsA.instCVal.mag.f	IAW1MX	Winding 1 current, A-phase, maximum magnitude
METMSTA1	MaxA1.phsB.instCVal.mag.f	IBW1MX	Winding 1 current, B-phase, maximum magnitude
METMSTA1	MaxA1.phsC.instCVal.mag.f	ICW1MX	Winding 1 current, C-phase, maximum magnitude
METMSTA1	MaxA1.res.instCVal.mag.f	IGW1MX	Winding 1 current, residual, maximum magnitude
METMSTA1	MaxA2.phsA.instCVal.mag.f	IAW2MX	Winding 2 current, A-phase, maximum magnitude
METMSTA1	MaxA2.phsB.instCVal.mag.f	IBW2MX	Winding 2 current, B-phase, maximum magnitude
METMSTA1	MaxA2.phsC.instCVal.mag.f	ICW2MX	Winding 2 current, C-phase, maximum magnitude
METMSTA1	MaxA2.res.instCVal.mag.f	IGW2MX	Winding 2 current, residual, maximum magnitude
METMSTA1	MaxA3.phsA.instCVal.mag.f	IAW3MX	Winding 3 current, A-phase, maximum magnitude
METMSTA1	MaxA3.phsB.instCVal.mag.f	IBW3MX	Winding 3 current, B-phase, maximum magnitude
METMSTA1	MaxA3.phsC.instCVal.mag.f	ICW3MX	Winding 3 current, C-phase, maximum magnitude
METMSTA1	MaxA3.res.instCVal.mag.f	IGW3MX	Winding 3 current, residual, maximum magnitude
METMSTA1	MaxA4.phsA.instCVal.mag.f	IAW4MX	Winding 4 current, A-phase, maximum magnitude
METMSTA1	MaxA4.phsB.instCVal.mag.f	IBW4MX	Winding 4 current, B-phase, maximum magnitude
METMSTA1	MaxA4.phsC.instCVal.mag.f	ICW4MX	Winding 4 current, C-phase, maximum magnitude
METMSTA1	MaxA4.res.instCVal.mag.f	IGW4MX	Winding 4 current, residual, maximum magnitude
METMSTA1	MaxP2PV.phsAB.instCVal.mag.f	VABMX	Voltage, A-to-B-phase, maximum magnitude
METMSTA1	MaxP2PV.phsBC.instCVal.mag.f	VBCMX	Voltage, B-to-C-phase, maximum magnitude
METMSTA1	MaxP2PV.phsCA.instCVal.mag.f	VCAMX	Voltage, C-to-A-phase, maximum magnitude
METMSTA1	MaxPhV.phsA.instCVal.mag.f	VAMX	Voltage, A-phase-to-neutral, maximum magnitude
METMSTA1	MaxPhV.phsB.instCVal.mag.f	VBMX	Voltage, B-phase-to-neutral, maximum magnitude

Table G.37 Logical Device: MET (Metering) (Sheet 3 of 9)

Logical Node	Attribute	Data Source	Comment
METMSTA1	MaxPhV.phsC.instCVal.mag.f	VCMX	Voltage, C-phase-to-neutral, maximum magnitude
METMSTA1	MaxVA.instMag.f	KVA3PMX	Apparent power magnitude, three-phase, maximum
METMSTA1	MaxVAr.instMag.f	KVAR3PMX	Reactive power magnitude, three-phase, maximum
METMSTA1	MaxW.instMag.f	KW3PMX	Real power magnitude, three-phase, maximum
METMSTA1	MinAmps.instMag.f	INMN	Current, neutral, minimum magnitude
METMSTA1	MinA1.phsA.instCVal.mag.f	IAW1MN	Winding 1 current, A-phase, minimum magnitude
METMSTA1	MinA1.phsB.instCVal.mag.f	IBW1MN	Winding 1 current, B-phase, minimum magnitude
METMSTA1	MinA1.phsC.instCVal.mag.f	ICW1MN	Winding 1 current, C-phase, minimum magnitude
METMSTA1	MinA1.res.instCVal.mag.f	IGW1MN	Winding 1 current, residual, minimum magnitude
METMSTA1	MinA2.phsA.instCVal.mag.f	IAW2MN	Winding 2 current, A-phase, minimum magnitude
METMSTA1	MinA2.phsB.instCVal.mag.f	IBW2MN	Winding 2 current, B-phase, minimum magnitude
METMSTA1	MinA2.phsC.instCVal.mag.f	ICW2MN	Winding 2 current, C-phase, minimum magnitude
METMSTA1	MinA2.res.instCVal.mag.f	IGW2MN	Winding 2 current, residual, minimum magnitude
METMSTA1	MinA3.phsA.instCVal.mag.f	IAW3MN	Winding 3 current, A-phase, minimum magnitude
METMSTA1	MinA3.phsB.instCVal.mag.f	IBW3MN	Winding 3 current, B-phase, minimum magnitude
METMSTA1	MinA3.phsC.instCVal.mag.f	ICW3MN	Winding 3 current, C-phase, minimum magnitude
METMSTA1	MinA3.res.instCVal.mag.f	IGW3MN	Winding 3 current, residual, minimum magnitude
METMSTA1	MinA4.phsA.instCVal.mag.f	IAW4MN	Winding 4 current, A-phase, minimum magnitude
METMSTA1	MinA4.phsB.instCVal.mag.f	IBW4MN	Winding 4 current, B-phase, minimum magnitude
METMSTA1	MinA4.phsC.instCVal.mag.f	ICW4MN	Winding 4 current, C-phase, minimum magnitude
METMSTA1	MinA4.res.instCVal.mag.f	IGW4MN	Winding 4 current, residual, minimum magnitude
METMSTA1	MinP2PV.phsAB.instCVal.mag.f	VABMN	Voltage, A-to-B-phase, minimum magnitude
METMSTA1	MinP2PV.phsBC.instCVal.mag.f	VBCMN	Voltage, B-to-C-phase, minimum magnitude
METMSTA1	MinP2PV.phsCA.instCVal.mag.f	VCAMN	Voltage, C-to-A-phase, minimum magnitude
METMSTA1	MinPhV.phsA.instCVal.mag.f	VAMN	Voltage, A-phase-to-neutral, minimum magnitude
METMSTA1	MinPhV.phsB.instCVal.mag.f	VBMN	Voltage, B-phase-to-neutral, minimum magnitude
METMSTA1	MinPhV.phsC.instCVal.mag.f	VCMN	Voltage, C-phase-to-neutral, minimum magnitude
METMSTA1	MinVA.instMag.f	KVA3PMN	Apparent power magnitude, three-phase, minimum
METMSTA1	MinVAr.instMag.f	KVAR3PMN	Reactive power magnitude, three-phase, minimum
METMSTA1	MinW.instMag.f	KW3PMN	Real power magnitude, three-phase, minimum
METSMMXU8	A.neut.instCVal.ang.f	IN_ANG	Current, neutral, angle
METSMMXU8	A.neut.instCVal.mag.f	IN_MAG	Current, neutral, magnitude
METSMMXU8	Hz.instMag.f	FREQS	Sync frequency
METSMMXU8	VSyn.instCVal.ang.f	VS_ANG	Sync voltage, angle
METSMMXU8	VSyn.instCVal.mag.f	VS_MAG	Sync voltage, magnitude
METVMMXU7	TotW.instMag.f	P	Real power magnitude, three-phase
METVMMXU7	TotVAr.instMag.f	Q	Reactive power magnitude, three-phase
METVMMXU7	TotVA.instMag.f	S	Apparent power magnitude, three-phase

Table G.37 Logical Device: MET (Metering) (Sheet 4 of 9)

Logical Node	Attribute	Data Source	Comment
METVMMXU7	TotPF.instMag.f	PF	Power factor, magnitude three-phase
METVMMXU7	W.phsA.instCVal.mag.f	PA	Real power, A-phase, magnitude
METVMMXU7	W.phsB.instCVal.mag.f	PB	Real power, B-phase, magnitude
METVMMXU7	W.phsC.instCVal.mag.f	PC	Real power, C-phase, magnitude
METVMMXU7	VAr.phsA.instCVal.mag.f	QA	Reactive power, A-phase, magnitude
METVMMXU7	VAr.phsB.instCVal.mag.f	QB	Reactive power, B-phase, magnitude
METVMMXU7	VAr.phsC.instCVal.mag.f	QC	Reactive power, C-phase, magnitude
METVMMXU7	VA.phsA.instCVal.mag.f	SA	Apparent power, A-phase, magnitude
METVMMXU7	VA.phsB.instCVal.mag.f	SB	Apparent power, B-phase, magnitude
METVMMXU7	VA.phsC.instCVal.mag.f	SC	Apparent power, C-phase, magnitude
METVMMXU7	PF.phsA.instCVal.mag.f	PFA	Power factor, A-phase, magnitude
METVMMXU7	PF.phsB.instCVal.mag.f	PFB	Power factor, B-phase, magnitude
METVMMXU7	PF.phsC.instCVal.mag.f	PFC	Power factor, C-phase, magnitude
METVMMXU7	Hz.instMag.f	FREQ	Frequency
METVMMXU7	PhV.phsA.instCVal.ang.f	VA_ANG	Voltage, A-phase-to-neutral, angle
METVMMXU7	PhV.phsA.instCVal.mag.f	VA_MAG	Voltage, A-phase-to-neutral, magnitude
METVMMXU7	PhV.phsB.instCVal.ang.f	VB_ANG	Voltage, B-phase-to-neutral, angle
METVMMXU7	PhV.phsB.instCVal.mag.f	VB_MAG	Voltage, B-phase-to-neutral, magnitude
METVMMXU7	PhV.phsC.instCVal.ang.f	VC_ANG	Voltage, C-phase-to-neutral, angle
METVMMXU7	PhV.phsC.instCVal.mag.f	VC_MAG	Voltage, C-phase-to-neutral, magnitude
METVMMXU7	PhV.res.instCVal.ang.f	VG_ANG	Zero-sequence voltage, angle
METVMMXU7	PhV.res.instCVal.mag.f	VG_MAG	Zero-sequence voltage, magnitude
METVMMXU7	PPV.phsAB.instCVal.ang.f	VAB_ANG	Voltage, A-to-B-phase, angle
METVMMXU7	PPV.phsAB.instCVal.mag.f	VAB_MAG	Voltage, A-to-B-phase, magnitude
METVMMXU7	PPV.phsBC.instCVal.ang.f	VBC_ANG	Voltage, B-to-C-phase, angle
METVMMXU7	PPV.phsBC.instCVal.mag.f	VBC_MAG	Voltage, B-to-C-phase, magnitude
METVMMXU7	PPV.phsCA.instCVal.ang.f	VCA_ANG	Voltage, C-to-A-phase, angle
METVMMXU7	PPV.phsCA.instCVal.mag.f	VCA_MAG	Voltage, C-to-A-phase, magnitude
METVMMXU7	Vhz.instMag.f	VHZ	V/Hz
METVMSQI7	SeqV.c2.instCVal.ang.f	3V2_ANG	Voltage, negative-sequence, angle
METVMSQI7	SeqV.c2.instCVal.mag.f	3V2_MAG	Voltage, negative-sequence, magnitude
METVMSQI7	SeqV.c1.instCVal.ang.f	V1_ANG	Positive-sequence voltage, angle
METVMSQI7	SeqV.c1.instCVal.mag.f	V1_MAG	Positive-sequence voltage, magnitude
METVMSQI7	SeqV.c3.instCVal.ang.f	VG_ANG	Zero-sequence voltage, angle
METVMSQI7	SeqV.c3.instCVal.mag.f	VG_MAG	Zero-sequence voltage, magnitude
METW12MMXU5	A.phsA.instCVal.ang.f	IAW12ANG	Winding 1 and Winding 2 combined current, A-phase, angle
METW12MMXU5	A.phsA.instCVal.mag.f	IAW12MAG	Winding 1 and Winding 2 combined current, A-phase, magnitude

Table G.37 Logical Device: MET (Metering) (Sheet 5 of 9)

Logical Node	Attribute	Data Source	Comment
METW12MMXU5	A.phsB.instCVal.ang.f	IBW12ANG	Winding 1 and Winding 2 combined current, B-phase, angle
METW12MMXU5	A.phsB.instCVal.mag.f	IBW12MAG	Winding 1 and Winding 2 combined current, B-phase, magnitude
METW12MMXU5	A.phsC.instCVal.ang.f	ICW12ANG	Winding 1 and Winding 2 combined current, C-phase, angle
METW12MMXU5	A.phsC.instCVal.mag.f	ICW12MAG	Winding 1 and Winding 2 combined current, C-phase, magnitude
METW12MMXU5	A.res.instCVal.ang.f	IGW12ANG	Winding 1 and Winding 2 combined current, calculated-residual, angle
METW12MMXU5	A.res.instCVal.mag.f	IGW12MAG	Winding 1 and Winding 2 combined current, calculated-residual, magnitude
METW12MSQI5	SeqA.c2.instCVal.ang.f	3I2W12AG	Winding 1 and Winding 2 combined current, negative-sequence, angle
METW12MSQI5	SeqA.c2.instCVal.mag.f	3I2W12MG	Winding 1 and Winding 2 combined current, negative-sequence, magnitude
METW12MSQI5	SeqA.c1.instCVal.ang.f	I1W12ANG	Winding 1 and Winding 2 combined current, positive-sequence, angle
METW12MSQI5	SeqA.c1.instCVal.mag.f	I1W12MAG	Winding 1 and Winding 2 combined current, positive-sequence, magnitude
METW12MSQI5	SeqA.c3.instCVal.ang.f	IGW12ANG	Winding 1 and Winding 2 combined current, calculated-residual, angle
METW12MSQI5	SeqA.c3.instCVal.mag.f	IGW12MAG	Winding 1 and Winding 2 combined current, calculated-residual, magnitude
METW1MMXU1	A.phsA.instCVal.ang.f	IAW1_ANG	Winding 1 current, A-phase, angle
METW1MMXU1	A.phsA.instCVal.mag.f	IAW1_MAG	Winding 1 current, A-phase, magnitude
METW1MMXU1	A.phsB.instCVal.ang.f	IBW1_ANG	Winding 1 current, B-phase, angle
METW1MMXU1	A.phsB.instCVal.mag.f	IBW1_MAG	Winding 1 current, B-phase, magnitude
METW1MMXU1	A.phsC.instCVal.ang.f	ICW1_ANG	Winding 1 current, C-phase, angle
METW1MMXU1	A.phsC.instCVal.mag.f	ICW1_MAG	Winding 1 current, C-phase, magnitude
METW1MMXU1	A.res.instCVal.ang.f	IGW1_ANG	Winding 1 current, calculated-residual, angle
METW1MMXU1	A.res.instCVal.mag.f	IGW1_MAG	Winding 1 current, calculated-residual, magnitude
METW1MSQI1	SeqA.c2.instCVal.ang.f	3I2W1ANG	Winding 1 current, negative-sequence, angle
METW1MSQI1	SeqA.c2.instCVal.mag.f	3I2W1MAG	Winding 1 current, negative-sequence, magnitude
METW1MSQI1	SeqA.c1.instCVal.ang.f	I1W1_ANG	Winding 1 current, positive-sequence, angle
METW1MSQI1	SeqA.c1.instCVal.mag.f	I1W1_MAG	Winding 1 current, positive-sequence, magnitude
METW1MSQI1	SeqA.c3.instCVal.ang.f	IGW1_ANG	Winding 1 current, calculated-residual, angle
METW1MSQI1	SeqA.c3.instCVal.mag.f	IGW1_MAG	Winding 1 current, calculated-residual, magnitude
METW23MMXU8	A.phsA.instCVal.ang.f	IAW23ANG	Winding 2 and Winding 3 combined current, A-phase, angle
METW23MMXU8	A.phsA.instCVal.mag.f	IAW23MAG	Winding 2 and Winding 3 combined current, A-phase, magnitude
METW23MMXU8	A.phsB.instCVal.ang.f	IBW23ANG	Winding 2 and Winding 3 combined current, B-phase, angle

Table G.37 Logical Device: MET (Metering) (Sheet 6 of 9)

Logical Node	Attribute	Data Source	Comment
METW23MMXU8	A.phsB.instCVal.mag.f	IBW23MAG	Winding 2 and Winding 3 combined current, B-phase, magnitude
METW23MMXU8	A.phsC.instCVal.ang.f	ICW23ANG	Winding 2 and Winding 3 combined current, C-phase, angle
METW23MMXU8	A.phsC.instCVal.mag.f	ICW23MAG	Winding 2 and Winding 3 combined current, C-phase, magnitude
METW23MMXU8	A.res.instCVal.ang.f	IGW23ANG	Winding 2 and Winding 3 combined current, calculated residual, angle
METW23MMXU8	A.res.instCVal.mag.f	IGW23MAG	Winding 2 and Winding 3 combined current, calculated residual, magnitude
METW23MSQI8	SeqA.c2.instCVal.ang.f	3I2W23AG	Winding 2 and Winding 3 combined current, negative sequence, angle
METW23MSQI8	SeqA.c2.instCVal.mag.f	3I2W23MG	Winding 2 and Winding 3 combined current, negative sequence, magnitude
METW23MSQI8	SeqA.c1.instCVal.ang.f	I1W23ANG	Winding 2 and Winding 3 combined current, positive sequence, angle
METW23MSQI8	SeqA.c1.instCVal.mag.f	I1W23MAG	Winding 2 and Winding 3 combined current, positive sequence, magnitude
METW23MSQI8	SeqA.c3.instCVal.ang.f	IGW23ANG	Winding 2 and Winding 3 combined current, calculated residual, angle
METW23MSQI8	SeqA.c3.instCVal.mag.f	IGW23MAG	Winding 2 and Winding 3 combined current, calculate residual, magnitude
METW2MMXU2	A.phsA.instCVal.ang.f	IAW2_ANG	Winding 2 current, A-phase, angle
METW2MMXU2	A.phsA.instCVal.mag.f	IAW2_MAG	Winding 2 current, A-phase, magnitude
METW2MMXU2	A.phsB.instCVal.ang.f	IBW2_ANG	Winding 2 current, B-phase, angle
METW2MMXU2	A.phsB.instCVal.mag.f	IBW2_MAG	Winding 2 current, B-phase, magnitude
METW2MMXU2	A.phsC.instCVal.ang.f	ICW2_ANG	Winding 2 current, C-phase, angle
METW2MMXU2	A.phsC.instCVal.mag.f	ICW2_MAG	Winding 2 current, C-phase, magnitude
METW2MMXU2	A.res.instCVal.ang.f	IGW2_ANG	Winding 2 current, calculated-residual, angle
METW2MMXU2	A.res.instCVal.mag.f	IGW2_MAG	Winding 2 current, calculated-residual, magnitude
METW2MSQI2	SeqA.c2.instCVal.ang.f	3I2W2ANG	Winding 2 current, negative-sequence, angle
METW2MSQI2	SeqA.c2.instCVal.mag.f	3I2W2MAG	Winding 2 current, negative-sequence, magnitude
METW2MSQI2	SeqA.c1.instCVal.ang.f	I1W2_ANG	Winding 2 current, positive-sequence, angle
METW2MSQI2	SeqA.c1.instCVal.mag.f	I1W2_MAG	Winding 2 current, positive-sequence, magnitude
METW2MSQI2	SeqA.c3.instCVal.ang.f	IGW2_ANG	Winding 2 current, calculated-residual, angle
METW2MSQI2	SeqA.c3.instCVal.mag.f	IGW2_MAG	Winding 2 current, calculated-residual, magnitude
METW34MMXU6	A.phsA.instCVal.ang.f	IAW34ANG	Winding3 and Winding 4 combined current, A-phase, angle
METW34MMXU6	A.phsA.instCVal.mag.f	IAW34MAG	Winding 3 and Winding 4 combined current, A-phase, magnitude
METW34MMXU6	A.phsB.instCVal.ang.f	IBW34ANG	Winding 3 and Winding 4 combined current, B-phase, angle
METW34MMXU6	A.phsB.instCVal.mag.f	IBW34MAG	Winding 3 and Winding 4 combined current, B-phase, magnitude

Table G.37 Logical Device: MET (Metering) (Sheet 7 of 9)

Logical Node	Attribute	Data Source	Comment
METW34MMXU6	A.phsC.instCVal.ang.f	ICW34ANG	Winding 3 and Winding 4 combined current, C-phase, angle
METW34MMXU6	A.phsC.instCVal.mag.f	ICW34MAG	Winding 3 and Winding 4 combined current, C-phase, magnitude
METW34MMXU6	A.res.instCVal.ang.f	IGW34ANG	Winding 3 and Winding 4 combined current, calculated-residual, angle
METW34MMXU6	A.res.instCVal.mag.f	IGW34MAG	Winding 3 and Winding 4 combined current, calculated-residual, magnitude
METW34MSQI6	SeqA.c2.instCVal.ang.f	3I2W34AG	Winding 3 and Winding 4 combined current, negative-sequence, angle
METW34MSQI6	SeqA.c2.instCVal.mag.f	3I2W34MG	Winding 3 and Winding 4 combined current, negative-sequence, magnitude
METW34MSQI6	SeqA.c1.instCVal.ang.f	I1W34ANG	Winding 3 and Winding 4 combined current, positive-sequence, angle
METW34MSQI6	SeqA.c1.instCVal.mag.f	I1W34MAG	Winding 3 and Winding 4 combined current, positive-sequence, magnitude
METW34MSQI6	SeqA.c3.instCVal.ang.f	IGW34ANG	Winding 3 and Winding 4 combined current, calculated-residual, angle
METW34MSQI6	SeqA.c3.instCVal.mag.f	IGW34MAG	Winding 3 and Winding 4 combined current, calculated-residual, magnitude
METW3MMXU3	A.phsA.instCVal.ang.f	IAW3_ANG	Winding 3 current, A-phase, angle
METW3MMXU3	A.phsA.instCVal.mag.f	IAW3_MAG	Winding 3 current, A-phase, magnitude
METW3MMXU3	A.phsB.instCVal.ang.f	IBW3_ANG	Winding 3 current, B-phase, angle
METW3MMXU3	A.phsB.instCVal.mag.f	IBW3_MAG	Winding 3 current, B-phase, magnitude
METW3MMXU3	A.phsC.instCVal.ang.f	ICW3_ANG	Winding 3 current, C-phase, angle
METW3MMXU3	A.phsC.instCVal.mag.f	ICW3_MAG	Winding 3 current, C-phase, magnitude
METW3MMXU3	A.res.instCVal.ang.f	IGW3_ANG	Winding 3 current, calculated-residual, angle
METW3MMXU3	A.res.instCVal.mag.f	IGW3_MAG	Winding 3 current, calculated-residual, magnitude
METW3MSQI3	SeqA.c2.instCVal.ang.f	3I2W3ANG	Winding 3 current, negative-sequence, angle
METW3MSQI3	SeqA.c2.instCVal.mag.f	3I2W3MAG	Winding 3 current, negative-sequence, magnitude
METW3MSQI3	SeqA.c1.instCVal.ang.f	I1W3_ANG	Winding 3 current, positive-sequence, angle
METW3MSQI3	SeqA.c1.instCVal.mag.f	I1W3_MAG	Winding 3 current, positive-sequence, magnitude
METW3MSQI3	SeqA.c3.instCVal.ang.f	IGW3_ANG	Winding 3 current, calculated-residual, angle
METW3MSQI3	SeqA.c3.instCVal.mag.f	IGW3_MAG	Winding 3 current, calculated-residual, magnitude
METW4MMXU4	A.phsA.instCVal.ang.f	IAW4_ANG	Winding 4 current, A-phase, angle
METW4MMXU4	A.phsA.instCVal.mag.f	IAW4_MAG	Winding 4 current, A-phase, magnitude
METW4MMXU4	A.phsB.instCVal.ang.f	IBW4_ANG	Winding 4 current, B-phase, angle
METW4MMXU4	A.phsB.instCVal.mag.f	IBW4_MAG	Winding 4 current, B-phase, magnitude
METW4MMXU4	A.phsC.instCVal.ang.f	ICW4_ANG	Winding 4 current, C-phase, angle
METW4MMXU4	A.phsC.instCVal.mag.f	ICW4_MAG	Winding 4 current, C-phase, magnitude
METW4MMXU4	A.res.instCVal.ang.f	IGW4_ANG	Winding 4 current, calculated-residual, angle
METW4MMXU4	A.res.instCVal.mag.f	IGW4_MAG	Winding 4 current, calculated-residual, magnitude

Table G.37 Logical Device: MET (Metering) (Sheet 8 of 9)

Logical Node	Attribute	Data Source	Comment
METW4MSQI4	SeqA.c2.instCVal.ang.f	3I2W4ANG	Winding 4 current, negative-sequence, angle
METW4MSQI4	SeqA.c2.instCVal.mag.f	3I2W4MAG	Winding 4 current, negative-sequence, magnitude
METW4MSQI4	SeqA.c1.instCVal.ang.f	I1W4_ANG	Winding 4 current, positive-sequence, angle
METW4MSQI4	SeqA.c1.instCVal.mag.f	I1W4_MAG	Winding 4 current, positive-sequence, magnitude
METW4MSQI4	SeqA.c3.instCVal.ang.f	IGW4_ANG	Winding 4 current, calculated-residual, angle
METW4MSQI4	SeqA.c3.instCVal.mag.f	IGW4_MAG	Winding 4 current, calculated-residual, magnitude
RMSNMMXU14	A.neut.instCVal.mag.f	INRMS	Neutral rms current, magnitude
RMSNMMXU14	VSyn.instCVal.mag.f	VSRMS	RMS sync voltage, magnitude
RMSVMMXU13	PhV.phsA.instCVal.mag.f	VARMS[c]	RMS voltage, A-phase-to-neutral, magnitude
RMSVMMXU13	PhV.phsB.instCVal.mag.f	VBRMS[c]	RMS voltage, B-phase-to-neutral, magnitude
RMSVMMXU13	PhV.phsC.instCVal.mag.f	VCRMS[c]	RMS voltage, C-phase-to-neutral, magnitude
RMSVMMXU13	PPV.phsAB.instCVal.mag.f	VABRMS[c]	RMS voltage, A-to-B-phase, magnitude
RMSVMMXU13	PPV.phsBC.instCVal.mag.f	VBCRMS[c]	RMS voltage, B-to-C-phase, magnitude
RMSVMMXU13	PPV.phsCA.instCVal.mag.f	VCARMS[c]	RMS voltage, C-to-A-phase, magnitude
RMSW1MMXU9	A.phsA.instCVal.mag.f	IAW1RMS	Winding 1 rms current, A-phase, magnitude
RMSW1MMXU9	A.phsB.instCVal.mag.f	IBW1RMS	Winding 1 rms current, B-phase, magnitude
RMSW1MMXU9	A.phsC.instCVal.mag.f	ICW1RMS	Winding 1 rms current, C-phase, magnitude
RMSW2MMXU10	A.phsA.instCVal.mag.f	IAW2RMS	Winding 2 rms current, A-phase, magnitude
RMSW2MMXU10	A.phsB.instCVal.mag.f	IBW2RMS	Winding 2 rms current, B-phase, magnitude
RMSW2MMXU10	A.phsC.instCVal.mag.f	ICW2RMS	Winding 2 rms current, C-phase, magnitude
RMSW3MMXU11	A.phsA.instCVal.mag.f	IAW3RMS	Winding 3 rms current, A-phase, magnitude
RMSW3MMXU11	A.phsB.instCVal.mag.f	IBW3RMS	Winding 3 rms current, B-phase, magnitude
RMSW3MMXU11	A.phsC.instCVal.mag.f	ICW3RMS	Winding 3 rms current, C-phase, magnitude
RMSW4MMXU12	A.phsA.instCVal.mag.f	IAW4RMS	Winding 4 rms current, A-phase, magnitude
RMSW4MMXU12	A.phsB.instCVal.mag.f	IBW4RMS	Winding 4 rms current, B-phase, magnitude
RMSW4MMXU12	A.phsC.instCVal.mag.f	ICW4RMS	Winding 4 rms current, C-phase, magnitude
THERMMTHR1	MaxAmbTmp.instMag.f	RTDAMB[d]	Ambient RTD temperature
THERMMTHR1	MaxOthTmp.instMag.f	RTDOTHMX[d]	Other maximum RTD temperature
THERMMTHR1	Tmp01.instMag.f–Tmp12.instMag.f	RTD1–RTD12[d]	RTD1–RTD12 temperature
Functional Constraint = ST			
DCZBAT1	BatHi.stVal	DCHI	Station dc battery instantaneous overvoltage element
DCZBAT1	BatLo.stVal	DCLO	Station dc battery instantaneous undervoltage element
LLN0	Loc.stVal	LOC	Control authority at local (bay) level
LLN0	LocSta.stVal	LOCSTA	Control authority at station level
METMDST1[e]	DmdVArh.actVal	MVARHP	Reactive energy, three-phase positive
METMDST1[e]	DmdWh.actVal	MWHP	Real energy, three-phase positive
METMDST1[e]	SupVArh.actVal	MVARHN	Reactive energy, three-phase negative
METMDST1[e]	SupWh.actVal	MWHN	Real energy, three-phase negative

Table G.37 Logical Device: MET (Metering) (Sheet 9 of 9)

Logical Node	Attribute	Data Source	Comment
THERMMTHR1	EEHealth.stVal	RTDFLT?1:3[d]	RTD input or communication status
Functional Constraint = SP			
LLN0	GrRef.setSrcRef	IdName	Functional name
LLN0	MltLev.setVal	MltLev.setVal	Multilevel mode of control authority

[a] MX values contain instantaneous attributes (instMag and instCVal), which are updated whenever the source updates, and other attributes that are only updated when the source goes outside the data source's deadband (mag and cVal). Only the instantaneous values are shown in the table.
[b] Data validity depends on the relay model and installed card options. Refer to Section 1: Introduction and Specifications for different relay models and available card options. Refer to Section 5: Metering and Monitoring for the model dependent metering quantities.
[c] If DELTA_Y := Y, only VARMS, VBRMS, and VCRMS are calculated. If DELTA_Y := DELTA, only VABRMS, VBCRMS, and VCARMS are calculated.
[d] Valid data depend on E49RTD and RTD1LOC–RTD12LOC settings.
[e] For IEC 61850 Edition 1 relays, this quantity is located under Functional Constraint MX.

Table G.38 shows the LN associated with control elements defined as Logical Device CON.

Table G.38 Logical Device: CON (Remote Control)

Logical Node	Status	Control	Relay Word Bit	Comment
Functional Constraint = CO				
RBGGIO1	SPCSO01.stVal–SPCSO08.stVal	SPCSO01.Oper.ctlVal–SPCSO08.Oper.ctlVal	RB01–RB08	Remote Bits RB01–RB08
RBGGIO2	SPCSO09.stVal–SPCSO16.stVal	SPCSO09.Oper.ctlVal–SPCSO16.Oper.ctlVal	RB09–RB16	Remote Bits RB09–RB16
RBGGIO3	SPCSO17.stVal–SPCSO24.stVal	SPCSO17.Oper.ctlVal–SPCSO24.Oper.ctlVal	RB17–RB24	Remote Bits RB17–RB24
RBGGIO4	SPCSO25.stVal–SPCSO32.stVal	SPCSO25.Oper.ctlVal–SPCSO32.Oper.ctlVal	RB25–RB32	Remote Bits RB25–RB32
PRBGGIO1	SPCSO01.stVal–SPCSO08.stVal	SPCSO01.Oper.ctlVal–SPCSO08.Oper.ctlVal	RB01–RB08	Pulse Remote Bits RB01–RB08
PRBGGIO2	SPCSO09.stVal–SPCSO16.stVal	SPCSO09.Oper.ctlVal–SPCSO16.Oper.ctlVal	RB09–RB16	Pulse Remote Bits RB09–RB16
PRBGGIO3	SPCSO17.stVal–SPCSO24.stVal	SPCSO17.Oper.ctlVal–SPCSO24.Oper.ctlVal	RB17–RB24	Pulse Remote Bits RB17–RB24
PRBGGIO4	SPCSO25.stVal–SPCSO32.stVal	SPCSO25.Oper.ctlVal–SPCSO32.Oper.ctlVal	RB25–RB32	Pulse Remote Bits RB25–RB32
Functional Constraint = ST				
LLN0	Loc.stVal	—	LOC	Control authority at local (bay) level
LLN0	LocSta.stVal	LocSta.Oper.ctlVal	LOCSTA	Control authority at station level
Functional Constraint = SP				
LLN0	GrRef.setSrcRef	—	IdName	Functional name
LLN0	MltLev.stVal	—	MLTLEV	Multilevel mode of control authority

Table G.39 shows the LN associated with annunciation elements defined as Logical Device ANN.

Table G.39 Logical Device: ANN (Annunciation) (Sheet 1 of 7)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = DC			
DevIDLPHD1	PhyNam.model	PARTNO	Part number
Functional Constraint = MX[a]			
AINCGGIO21	AnIn01.instMag.f–AnIn04.instMag.f	AI301–AI304[b]	Analog Inputs (AI301 to AI304)—Slot C
AINDGGIO22	AnIn01.instMag.f–AnIn04.instMag.f	AI401–AI404[b]	Analog Inputs (AI401 to AI404)—Slot D
AINEGGIO23	AnIn01.instMag.f–AnIn04.instMag.f	AI501–AI504[b]	Analog Inputs (AI501 to AI504)—Slot E
BWA1SCBR1	AccAbr.instMag.f	WEARAW1	W1 breaker—Contact A wear
BWB1SCBR2	AccAbr.instMag.f	WEARBW1	W1 breaker—Contact B wear
BWC1SCBR3	AccAbr.instMag.f	WEARCW1	W1 breaker—Contact C wear
BWA2SCBR4	AccAbr.instMag.f	WEARAW2	W2 breaker—Contact A wear
BWB2SCBR5	AccAbr.instMag.f	WEARBW2	W2 breaker—Contact B wear
BWC2SCBR6	AccAbr.instMag.f	WEARCW2	W2 breaker—Contact C wear
BWA3SCBR7	AccAbr.instMag.f	WEARAW3	W3 breaker—Contact A wear
BWB3SCBR8	AccAbr.instMag.f	WEARBW3	W3 breaker—Contact B wear
BWC3SCBR9	AccAbr.instMag.f	WEARCW3	W3 breaker—Contact C wear
BWA4SCBR10	AccAbr.instMag.f	WEARAW4	W4 breaker—Contact A wear
BWB4SCBR11	AccAbr.instMag.f	WEARBW4	W4 breaker—Contact B wear
BWC4SCBR12	AccAbr.instMag.f	WEARCW4	W4 breaker—Contact C wear
FLTGGIO33	AnIn01.instMag.f	FIAW1	Winding 1 A-phase current of the most recent fault event
FLTGGIO33	AnIn02.instMag.f	FIBW1	Winding 1 B-phase current of the most recent fault event
FLTGGIO33	AnIn03.instMag.f	FICW1	Winding 1 C-phase current of the most recent fault event
FLTGGIO33	AnIn04.instMag.f	FIGW1	Winding 1 calculated-residual current of the most recent fault event
FLTGGIO33	AnIn05.instMag.f	FIAW2	Winding 2 A-phase current of the most recent fault event
FLTGGIO33	AnIn06.instMag.f	FIBW2	Winding 2 B-phase current of the most recent fault event
FLTGGIO33	AnIn07.instMag.f	FICW2	Winding 2 C-phase current of the most recent fault event
FLTGGIO33	AnIn08.instMag.f	FIGW2	Winding 2 calculated-residual current of the most recent fault event
FLTGGIO33	AnIn09.instMag.f	FIAW3	Winding 3 A-phase current of the most recent fault event
FLTGGIO33	AnIn10.instMag.f	FIBW3	Winding 3 B-phase current of the most recent fault event
FLTGGIO33	AnIn11.instMag.f	FICW3	Winding 3 C-phase current of the most recent fault event
FLTGGIO33	AnIn12.instMag.f	FIGW3	Winding 3 calculated-residual current of the most recent fault event
FLTGGIO33	AnIn13.instMag.f	FIAW4	Winding 4 A-phase current of the most recent fault event
FLTGGIO33	AnIn14.instMag.f	FIBW4	Winding 4 B-phase current of the most recent fault event
FLTGGIO33	AnIn15.instMag.f	FICW4	Winding 4 C-phase current of the most recent fault event
FLTGGIO33	AnIn16.instMag.f	FIGW4	Winding 4 calculated-residual current of the most recent fault event
FLTGGIO33	AnIn17.instMag.f	FIN	Neutral current of the most recent fault event

Table G.39 Logical Device: ANN (Annunciation) (Sheet 2 of 7)

Logical Node	Attribute	Data Source	Comment
FLTGGIO33	AnIn18.instMag.f	FVAB	A-to-B-phase voltage of the most recent fault event
FLTGGIO33	AnIn19.instMag.f	FVBC	B-to-C-phase voltage of the most recent fault event
FLTGGIO33	AnIn20.instMag.f	FVCA	C-to-A-phase voltage of the most recent fault event
FLTGGIO33	AnIn21.instMag.f	FVAN	A-phase-to-neutral voltage of the most recent fault event
FLTGGIO33	AnIn22.instMag.f	FVBN	B-phase-to-neutral voltage of the most recent fault event
FLTGGIO33	AnIn23.instMag.f	FVCN	C-phase-to-neutral voltage of the most recent fault event
FLTGGIO33	AnIn24.instMag.f	FVG	Zero-sequence voltage of the most recent fault event
FLTGGIO33	AnIn25.instMag.f	FFREQ	Frequency of the most recent fault event
PFLLIGGIO37	AnIn01.instMag.f	PFAL	A-phase power factor lead/lag indicator (1: LEAD, 0:LAG)
PFLLIGGIO37	AnIn02.instMag.f	PFBL	B-phase power factor lead/lag indicator (1: LEAD, 0:LAG)
PFLLIGGIO37	AnIn03.instMag.f	PFCL	C-phase power factor lead/lag indicator (1: LEAD, 0:LAG)
PFLLIGGIO37	AnIn04.instMag.f	PFL	Three-phase power factor lead/lag indicator (1: LEAD, 0:LAG)
MVGGIO12	AnIn01.instMag.f–AnIn32.instMag.f	MV01–MV32[c]	Math Variables (MV01 to MV32)
RAGGIO24	Ra001.instMag.f–Ra032.instMag.f	RA001–RA032	Remote Analogs (RA001 to RA032)
RAGGIO25	Ra033.instMag.f–Ra064.instMag.f	RA033–RA064	Remote Analogs (RA033 to RA064)
RAGGIO26	Ra065.instMag.f–Ra096.instMag.f	RA065–RA096	Remote Analogs (RA065 to RA096)
RAGGIO27	Ra097.instMag.f–Ra128.instMag.f	RA097–RA128	Remote Analogs (RA097 to RA128)
SCGGIO20	AnIn01.instMag.f–AnIn32.instMag.f	SC01–SC32[d]	SELOGIC Counters (SC01 to SC32)
Functional Constraint = ST			
B52GGIO35	Ind01.stVal	52B1	Circuit Breaker 1, N/C contact
B52GGIO35	Ind02.stVal	52B2	Circuit Breaker 2, N/C contact
B52GGIO35	Ind03.stVal	52B3	Circuit Breaker 3, N/C contact
B52GGIO35	Ind04.stVal	52B4	Circuit Breaker 4, N/C contact
BWA1SCBR1	ColOpn.stVal	OC1	Open Breaker 1
BWB1SCBR2	ColOpn.stVal	OC1	Open Breaker 1
BWC1SCBR3	ColOpn.stVal	OC1	Open Breaker 1
BWA2SCBR4	ColOpn.stVal	OC2	Open Breaker 2
BWB2SCBR5	ColOpn.stVal	OC2	Open Breaker 2
BWC2SCBR6	ColOpn.stVal	OC2	Open Breaker 2
BWA3SCBR7	ColOpn.stVal	OC3	Open Breaker 3
BWB3SCBR8	ColOpn.stVal	OC3	Open Breaker 3
BWC3SCBR9	ColOpn.stVal	OC3	Open Breaker 3
BWA4SCBR10	ColOpn.stVal	OC4	Open Breaker 4
BWB4SCBR11	ColOpn.stVal	OC4	Open Breaker 4
BWC4SCBR12	ColOpn.stVal	OC4	Open Breaker 4

Table G.39 Logical Device: ANN (Annunciation) (Sheet 3 of 7)

Logical Node	Attribute	Data Source	Comment
DCALMGGIO34	Ind01.stVal	89AL2P1	Two-Position Disconnect 1 alarm
DCALMGGIO34	Ind02.stVal	89AL2P2	Two-Position Disconnect 2 alarm
DCALMGGIO34	Ind03.stVal	89AL2P3	Two-Position Disconnect 3 alarm
DCALMGGIO34	Ind04.stVal	89AL2P4	Two-Position Disconnect 4 alarm
DCALMGGIO34	Ind05.stVal	89AL2P5	Two-Position Disconnect 5 alarm
DCALMGGIO34	Ind06.stVal	89AL2P6	Two-Position Disconnect 6 alarm
DCALMGGIO34	Ind07.stVal	89AL2P7	Two-Position Disconnect 7 alarm
DCALMGGIO34	Ind08.stVal	89AL2P8	Two-Position Disconnect 8 alarm
DCALMGGIO34	Ind09.stVal	89AL2P9	Two-Position Disconnect 9 alarm
DCALMGGIO34	Ind10.stVal	89AL2P10	Two-Position Disconnect 10 alarm
DCALMGGIO34	Ind11.stVal	89AL2P11	Two-Position Disconnect 11 alarm
DCALMGGIO34	Ind12.stVal	89AL2P12	Two-Position Disconnect 12 alarm
DCALMGGIO34	Ind13.stVal	89AL2P13	Two-Position Disconnect 13 alarm
DCALMGGIO34	Ind14.stVal	89AL2P14	Two-Position Disconnect 14 alarm
DCALMGGIO34	Ind15.stVal	89AL2P15	Two-Position Disconnect 15 alarm
DCALMGGIO34	Ind16.stVal	89AL2P16	Two-Position Disconnect 16 alarm
DCST1GGIO32	Ind01.stVal	89A2P1	Two-Position Disconnect 1 N/O contact
DCST1GGIO32	Ind02.stVal	89B2P1	Two-Position Disconnect 1 N/C contact
DCST1GGIO32	Ind03.stVal	89CL2P1	Two-Position Disconnect 1 closed
DCST1GGIO32	Ind04.stVal	89OP2P1	Two-Position Disconnect 1 open
DCST1GGIO32	Ind05.stVal	89A2P2	Two-Position Disconnect 2 N/O contact
DCST1GGIO32	Ind06.stVal	89B2P2	Two-Position Disconnect 2 N/C contact
DCST1GGIO32	Ind07.stVal	89CL2P2	Two-Position Disconnect 2 closed
DCST1GGIO32	Ind08.stVal	89OP2P2	Two-Position Disconnect 2 open
DCST1GGIO32	Ind09.stVal	89A2P3	Two-Position Disconnect 3 N/O contact
DCST1GGIO32	Ind10.stVal	89B2P3	Two-Position Disconnect 3 N/C contact
DCST1GGIO32	Ind11.stVal	89CL2P3	Two-Position Disconnect 3 closed
DCST1GGIO32	Ind12.stVal	89OP2P3	Two-Position Disconnect 3 open
DCST1GGIO32	Ind13.stVal	89A2P4	Two-Position Disconnect 4 N/O contact
DCST1GGIO32	Ind14.stVal	89B2P4	Two-Position Disconnect 4 N/C contact
DCST1GGIO32	Ind15.stVal	89CL2P4	Two-Position Disconnect 4 closed
DCST1GGIO32	Ind16.stVal	89OP2P4	Two-Position Disconnect 4 open
DCST1GGIO32	Ind17.stVal	89A2P5	Two-Position Disconnect 5 N/O contact
DCST1GGIO32	Ind18.stVal	89B2P5	Two-Position Disconnect 5 N/C contact
DCST1GGIO32	Ind19.stVal	89CL2P5	Two-Position Disconnect 5 closed
DCST1GGIO32	Ind20.stVal	89OP2P5	Two-Position Disconnect 5 open
DCST1GGIO32	Ind21.stVal	89A2P6	Two-Position Disconnect 6 N/O contact
DCST1GGIO32	Ind22.stVal	89B2P6	Two-Position Disconnect 6 N/C contact

Table G.39 Logical Device: ANN (Annunciation) (Sheet 4 of 7)

Logical Node	Attribute	Data Source	Comment
DCST1GGIO32	Ind23.stVal	89CL2P6	Two-Position Disconnect 6 closed
DCST1GGIO32	Ind24.stVal	89OP2P6	Two-Position Disconnect 6 open
DCST1GGIO32	Ind25.stVal	89A2P7	Two-Position Disconnect 7 N/O contact
DCST1GGIO32	Ind26.stVal	89B2P7	Two-Position Disconnect 7 N/C contact
DCST1GGIO32	Ind27.stVal	89CL2P7	Two-Position Disconnect 7 closed
DCST1GGIO32	Ind28.stVal	89OP2P7	Two-Position Disconnect 7 open
DCST1GGIO32	Ind29.stVal	89A2P8	Two-Position Disconnect 8 N/O contact
DCST1GGIO32	Ind30.stVal	89B2P8	Two-Position Disconnect 8 N/C contact
DCST1GGIO32	Ind31.stVal	89CL2P8	Two-Position Disconnect 8 closed
DCST1GGIO32	Ind32.stVal	89OP2P8	Two-Position Disconnect 8 open
DCST2GGIO33	Ind01.stVal	89A2P9	Two-Position Disconnect 9 N/O contact
DCST2GGIO33	Ind02.stVal	89B2P9	Two-Position Disconnect 9 N/C contact
DCST2GGIO33	Ind03.stVal	89CL2P9	Two-Position Disconnect 9 closed
DCST2GGIO33	Ind04.stVal	89OP2P9	Two-Position Disconnect 9 open
DCST2GGIO33	Ind05.stVal	89A2P10	Two-Position Disconnect 10 N/O contact
DCST2GGIO33	Ind06.stVal	89B2P10	Two-Position Disconnect 10 N/C contact
DCST2GGIO33	Ind07.stVal	89CL2P10	Two-Position Disconnect 10 closed
DCST2GGIO33	Ind08.stVal	89OP2P10	Two-Position Disconnect 10 open
DCST2GGIO33	Ind09.stVal	89A2P11	Two-Position Disconnect 11 N/O contact
DCST2GGIO33	Ind10.stVal	89B2P11	Two-Position Disconnect 11 N/C contact
DCST2GGIO33	Ind11.stVal	89CL2P11	Two-Position Disconnect 11 closed
DCST2GGIO33	Ind12.stVal	89OP2P11	Two-Position Disconnect 11 open
DCST2GGIO33	Ind13.stVal	89A2P12	Two-Position Disconnect 12 N/O contact
DCST2GGIO33	Ind14.stVal	89B2P12	Two-Position Disconnect 12 N/C contact
DCST2GGIO33	Ind15.stVal	89CL2P12	Two-Position Disconnect 12 closed
DCST2GGIO33	Ind16.stVal	89OP2P12	Two-Position Disconnect 12 open
DCST2GGIO33	Ind17.stVal	89A2P13	Two-Position Disconnect 13 N/O contact
DCST2GGIO33	Ind18.stVal	89B2P13	Two-Position Disconnect 13 N/C contact
DCST2GGIO33	Ind19.stVal	89CL2P13	Two-Position Disconnect 13 closed
DCST2GGIO33	Ind20.stVal	89OP2P13	Two-Position Disconnect 13 open
DCST2GGIO33	Ind21.stVal	89A2P14	Two-Position Disconnect 14 N/O contact
DCST2GGIO33	Ind22.stVal	89B2P14	Two-Position Disconnect 14 N/C contact
DCST2GGIO33	Ind23.stVal	89CL2P14	Two-Position Disconnect 14 closed
DCST2GGIO33	Ind24.stVal	89OP2P14	Two-Position Disconnect 14 open
DCST2GGIO33	Ind25.stVal	89A2P15	Two-Position Disconnect 15 N/O contact
DCST2GGIO33	Ind26.stVal	89B2P15	Two-Position Disconnect 15 N/C contact
DCST2GGIO33	Ind27.stVal	89CL2P15	Two-Position Disconnect 15 closed
DCST2GGIO33	Ind28.stVal	89OP2P15	Two-Position Disconnect 15 open

Table G.39 Logical Device: ANN (Annunciation) (Sheet 5 of 7)

Logical Node	Attribute	Data Source	Comment
DCST2GGIO33	Ind29.stVal	89A2P16	Two-Position Disconnect 16 N/O contact
DCST2GGIO33	Ind30.stVal	89B2P16	Two-Position Disconnect 16 N/C contact
DCST2GGIO33	Ind31.stVal	89CL2P16	Two-Position Disconnect 16 closed
DCST2GGIO33	Ind32.stVal	89OP2P16	Two-Position Disconnect 16 open
INAGGIO1	Ind01.stVal–Ind02.stVal	IN101–IN102	Digital Inputs (IN101 to IN102)—Slot A
INCGGIO13	Ind01.stVal–Ind14.stVal	IN301–IN314[b]	Digital Inputs (IN301 to IN314)—Slot C
INDGGIO15	Ind01.stVal–Ind14.stVal	IN401–IN414[b]	Digital Inputs (IN401 to IN414)—Slot D
INEGGIO17	Ind01.stVal–Ind14.stVal	IN501–IN514[b]	Digital Inputs (IN501 to IN514)—Slot E
LBGGIO29	Ind01.stVal–Ind32.stVal	LB01–LB32[e]	Local Bits (LB01 to LB32)
LLN0	Loc.stVal	LOC	Control authority at local (bay) level
LLN0	LocSta.stVal	LOCSTA	Control authority at station level
LTGGIO5	Ind01.stVal–Ind32.stVal	LT01–LT32[f]	Latch Bits (LT01 to LT32)
MBOKGGIO30	Ind01.stVal	ROKA	Channel A, received data OK
MBOKGGIO30	Ind02.stVal	RBADA	Channel A, outage duration over threshold
MBOKGGIO30	Ind03.stVal	CBADA	Channel A, channel unavailability over threshold
MBOKGGIO30	Ind04.stVal	LBOKA	Channel A, looped back OK
MBOKGGIO30	Ind05.stVal	ROKB	Channel B, received data OK
MBOKGGIO30	Ind06.stVal	RBADB	Channel B, outage duration over threshold
MBOKGGIO30	Ind07.stVal	CBADB	Channel B, channel unavailability over threshold
MBOKGGIO30	Ind08.stVal	LBOKB	Channel B, looped back OK
MISCGGIO31	Ind01.stVal	HALARM	Indication of a diagnostic failure or warning that warrants an ALARM
MISCGGIO31	Ind02.stVal	SALARM	Indication of software or user activity that warrants an ALARM
MISCGGIO31	Ind03.stVal	WARNING	Relay Word bit WARNING
MISCGGIO31	Ind04.stVal	IRIGOK	IRIG-B time sync input data is valid
MISCGGIO31	Ind05.stVal	TSOK	Time synchronization OK
MISCGGIO31	Ind06.stVal	DST	Daylight-Saving Time active
MISCGGIO31	Ind07.stVal	LINKA	Asserted when a valid link is detected on Port 1A
MISCGGIO31	Ind08.stVal	LINKB	Asserted when a valid link is detected on Port 1B
MISCGGIO31	Ind09.stVal	LINKFAIL	Asserted when a valid link is not detected on the active port(s)
MISCGGIO31	Ind10.stVal	PASEL	Asserted when Port 1A is active
MISCGGIO31	Ind11.stVal	PBSEL	Asserted when Port 1B is active
MISCGGIO31	Ind12.stVal	COMMLOSS	DeviceNet communication failure
MISCGGIO31	Ind13.stVal	COMMFLT	DeviceNet internal communication failure
MISCGGIO31	Ind14.stVal	MATHERR	Error in SEL Math computation

Table G.39 Logical Device: ANN (Annunciation) (Sheet 6 of 7)

Logical Node	Attribute	Data Source	Comment
MISCGGIO31	Ind15.stVal	FAULT	Indicates fault condition. Asserts when the SELOGIC control equation FAULT result is a logical 1.
MISCGGIO31	Ind16.stVal	RTDA	Asserts when any RTD alarm is asserted
MISCGGIO31	Ind17.stVal	TESTDB	Asserts when analog and digital values reported via Protocols may be overridden
MISCGGIO31	Ind18.stVal–Ind32.stVal	FALSE	Reserved for future use
OUTAGGIO2	Ind01.stVal–Ind03.stVal	OUT101–OUT103	Digital Outputs (OUT101 to OUT103)—Slot A
OUTCGGIO14	Ind01.stVal–Ind08.stVal	OUT301–OUT308[b]	Digital Outputs (OUT301 to OUT308)—Slot C
OUTDGGIO16	Ind01.stVal–Ind08.stVal	OUT401–OUT408[b]	Digital Outputs (OUT401 to OUT408)—Slot D
OUTEGGIO18	Ind01.stVal–Ind08.stVal	OUT501–OUT508[b]	Digital Outputs (OUT501 to OUT508)—Slot E
PBLEDGGIO7	Ind05.stVal	PB3A_LED	Pushbutton PB3A LED
PBLEDGGIO7	Ind06.stVal	PB3B_LED	Pushbutton PB3B LED
PBLEDGGIO7	Ind07.stVal	PB4A_LED	Pushbutton PB4A LED
PBLEDGGIO7	Ind08.stVal	PB4B_LED	Pushbutton PB4B LED
PBLEDGGIO7	Ind09.stVal	PB5A_LED	Pushbutton PB5A LED
PBLEDGGIO7	Ind10.stVal	PB5B_LED	Pushbutton PB5B LED
PBLEDGGIO7	Ind11.stVal	PB6A_LED	Pushbutton PB6A LED
PBLEDGGIO7	Ind12.stVal	PB6B_LED	Pushbutton PB6B LED
PBLEDGGIO7	Ind13.stVal	PB7A_LED	Pushbutton PB7A LED
PBLEDGGIO7	Ind14.stVal	PB7B_LED	Pushbutton PB7B LED
PBLEDGGIO7	Ind15.stVal	PB8A_LED	Pushbutton PB8A LED
PBLEDGGIO7	Ind16.stVal	PB8B_LED	Pushbutton PB8B LED
PROGGIO28	Ind09.stVal	ULCL3	Unlatch close conditions SELOGIC Control Equation CL3 state
PROGGIO28	Ind10.stVal	ULCL4	Unlatch close conditions SELOGIC Control Equation CL4 state
PROGGIO28	Ind11.stVal	CF1	Breaker 1 close condition failure on
PROGGIO28	Ind12.stVal	CF2	Breaker 2 close condition failure on
PROGGIO28	Ind13.stVal	CF3	Breaker 3 close condition failure on
PROGGIO28	Ind14.stVal	CF4	Breaker 4 close condition failure on
PROGGIO28	Ind15.stVal	RTDT	Asserts when any RTD trip (RTD_T) is asserted
PROGGIO28	Ind16.stVal	AMBTRIP	Ambient temperature trip
PROGGIO28	Ind17.stVal	OTHTRIP	Other temperature trip
PROGGIO28	Ind18.stVal	TH5T	Fifth-harmonic alarm threshold exceeded for longer than TH5D
PROGGIO28	Ind19.stVal	TH5	Fifth-harmonic alarm threshold exceeded
PROGGIO28	Ind20.stVal	RTDFLT	Asserts when an open or short circuit condition is detected on any enabled RTD input, or communication with the external RTD module has been interrupted.
PROGGIO28	Ind21.stVal	PHDEM	Phase current demand pickup

Table G.39 Logical Device: ANN (Annunciation) (Sheet 7 of 7)

Logical Node	Attribute	Data Source	Comment
PROGGIO28	Ind22.stVal	3I2DEM	Negative-sequence current demand pickup
PROGGIO28	Ind23.stVal	GNDEM	Zero-sequence current demand pickup
PROGGIO28	Ind24.stVal	FREQTRK	Frequency tracking enable bit-tracking enabled when bit is asserted
PROGGIO28	Ind25.stVal	50GREF1	REF1 element normalized polarization quantity sensitivity threshold exceeded
PROGGIO28	Ind26.stVal	50NREF1	REF1 element normalized operate quantity sensitivity threshold exceeded
PROGGIO28	Ind27.stVal	50GREF3A	REF3A element normalized polarization quantity sensitivity threshold exceeded
PROGGIO28	Ind28.stVal	50NREF3A	REF3A element normalized operate quantity sensitivity threshold exceeded
PROGGIO28	Ind29.stVal	50GREF3B	REF3B element normalized polarization quantity sensitivity threshold exceeded
PROGGIO28	Ind30.stVal	50NREF3B	REF3B element normalized operate quantity sensitivity threshold exceeded
PROGGIO28	Ind31.stVal	AMBALRM	Ambient temperature alarm
PROGGIO28	Ind32.stVal	OTHALRM	Other temperature alarm
RMBAGGIO8	Ind01.stVal–Ind08.stVal	RMB1A–RMB8A	Receive MIRRORED BITS (RMB1A to RMB8A)
RMBBGGIO10	Ind01.stVal–Ind08.stVal	RMB1B–RMB8B	Receive MIRRORED BITS (RMB1B to RMB8B)
SGGGIO36	Ind01.stVal–Ind04.stVal	SG1–SG4	Setting Group 1 to 4 selection
SVGGIO3	Ind01.stVal–Ind32.stVal	SV01–SV32[g]	SELOGIC Variables (SV01 to SV32)
SVTGGIO4	Ind01.stVal–Ind32.stVal	SV01T–SV32T[g]	SELOGIC Variable Timers (SV01T to SV32T)
TLEDGGIO6	Ind01.stVal	ENABLED	**ENABLED** LED
TLEDGGIO6	Ind02.stVal	TRIP_LED	**TRIP** LED
TLEDGGIO6	Ind03.stVal–Ind08.stVal	TLED_01–TLED_06	Target LEDs TLED_01 to TLED_06
TMBAGGIO9	Ind01.stVal–Ind08.stVal	TMB1A–TMB8A	Transmit MIRRORED BITS (TMB1A to TMB8A)
TMBBGGIO11	Ind01.stVal–Ind08.stVal	TMB1B–TMB8B	Transmit MIRRORED BITS (TMB1B to TMB8B)
VBGGIO19	Ind001.stVal–Ind128.stVal	VB001–VB128	Virtual Bits (VB001 to VB128)
Functional Constraint = SP			
LLN0	GrRef.setSrcRef	IdName	Functional name
LLN0	MltLev.setVal	MLTLEV	Multilevel mode of control authority

[a] MX values contain instantaneous attributes (instMag and instCVal), which are updated whenever the source updates, and other attributes that are only updated when the source goes outside the data source's deadband (mag and CVal). Only the instantaneous values are shown in the table.
[b] Active data only if optional I/O card is installed in the slot.
[c] Active data depends on the EMV setting.
[d] Active data depends on the ESC setting.
[e] Active data depends on the ELAT setting.
[f] Active data depends on the ESV setting.

[g] Active data depends on the ELB setting.

Table G.40 Logical Device: CFG (Configuration) (Sheet 1 of 5)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = CO			
DevIDLPHD1	Sim.Oper.ctlVal	LPHDSIM	IEC 61850 logical node for physical device simulation
GOLCCH2	RsStat.Oper.ctlVal	GORST[a]	Reset statistics for GOOSE traffic
IPLCCH1	RsStat.Oper.ctlVal	IPRST[a]	Reset statistics for general IP traffic (excluding GOOSE traffic)
LLN0	LocSta.Oper.ctlVal	SC850LS	SELOGIC control for control authority at station level
LLN0	Mod.Oper.ctlVal[b]	I60MOD[c]	IEC 61850 mode/behavior control
LGOS*n*[d]	RsStat.Oper.ctlVal	GRST*n*[e]	Reset GOOSE statistics for Message *n*
Functional Constraint = DC			
DevIDLPHD1	PhyNam.model	PARTNO	Part number
DevIDLPHD1	PhyNam.serNum	SER_NUM	Serial number
LLN0	NamPlt.swRev	FID	Firmware revision
Functional Constraint = ST			
DevIDLPHD1	Sim.stVal	LPHDSIM	IEC 61850 logical node for physical device simulation
DevIDLPHD1	PhyHealth.stVal	RELAY_EN	Relay enabled
GOLCCH2	ChLiv.stVal	GOCH[a]	Status of primary GOOSE channel
GOLCCH2	RedChLiv.stVal	GORCH[a]	Status of redundant GOOSE channel. Always reported as false.
GOLCCH2	RxCnt.actVal	GORX[a]	Number of frames received over the primary GOOSE channel
GOLCCH2	RedRxCnt.actVal	GORRX[a]	Number of frames received over the redundant GOOSE channel. Always reported as 0.
GOLCCH2	TxCnt.actVal	GOTX[a]	Number of frames transmitted on both primary and redundant GOOSE channels
GOLCCH2	FerCh.stVal	GOFER[a]	Frame error rate on the primary GOOSE channel
GOLCCH2	RedFerCh.stVal	GORFER[a]	Frame error rate on the redundant GOOSE channel. Always reported as 0.
GOLCCH2	RsStat.stVal	GORST[a]	Status of statistics reset for GOOSE traffic
IPLCCH1	ChLiv.stVal	IPCH[a]	Status of primary IP channel
IPLCCH1	RedChLiv.stVal	IPRCH[a]	Status of redundant IP channel. Always reported as false.
IPLCCH1	RxCnt.actVal	IPRX[a]	Number of frames received over the primary IP channel
IPLCCH1	RedRxCnt.actVal	IPRRX[a]	Number of frames received over the redundant IP channel. Always reported as 0.
IPLCCH1	TxCnt.actVal	IPTX[a]	Number of frames transmitted on both primary and redundant IP channels
IPLCCH1	FerCh.stVal	IPFER[a]	Frame error rate on the primary IP channel
IPLCCH1	RedFerCh.stVal	IPRFER[a]	Frame error rate on the redundant IP channel. Always reported as 0.
IPLCCH1	RsStat.stVal	IPRST[a]	Status of statistics reset for general IP traffic (excludes GOOSE traffic)
LLN0	Mod.stVal	I60MOD[c]	IEC 61850 mode/behavior status
LLN0	Health.stVal	RELAY_EN	Relay enabled
LLN0	Loc.stVal	LOC	Control authority at local (bay) level
LLN0	LocSta.stVal	LOCSTA	Control authority at station level

Table G.40 Logical Device: CFG (Configuration) (Sheet 2 of 5)

Logical Node	Attribute	Data Source	Comment
LGOS*n*[d]	NdsCom.stVal	GNCM*n*[e]	Subscription needs commissioning for GOOSE Message *n*. True if ConfRevNum does not match RxConfRevNum
LGOS*n*[d]	St.stVal	GST*n*[e]	Status of the subscription (True = active, False = not active) for GOOSE Message *n*
LGOS*n*[d]	SimSt.stVal	GSIM*n*[e]	Status showing that simulation messages are received and accepted for GOOSE Message *n*
LGOS*n*[d]	LastStNum.stVal	GLST*n*[e]	Last state number received (StNum) for GOOSE Message *n*
LGOS*n*[d]	LastSqNum.stVal	GLSQ*n*[e]	Last sequence number received (SqNum) for GOOSE Message *n*
LGOS*n*[d]	LastTal.stVal	GTAL*n*[e]	Last time-allowed-to-live received (TTL) for GOOSE Message *n*
LGOS*n*[d]	ConfRevNum.stVal	[f]	Expected configuration revision number for GOOSE Message *n*
LGOS*n*[d]	RxConfRevNum.stVal	GCNF*n*[e]	Received configuration revision number for GOOSE Message *n*
LGOS*n*[d]	ErrSt.stVal[g]	GERR*n*[e]	Error status of the subscription for GOOSE Message *n*
LGOS*n*[d]	OosCnt.stVal	GOOS*n*[e]	Number of out-of-sequence (OOS) errors for GOOSE Message *n*
LGOS*n*[d]	TalCnt.stVal	GTLC*n*[e]	Number of time-allowed-to-live violations for GOOSE Message *n*
LGOS*n*[d]	DecErrCnt.stVal	GDER*n*[e]	Number of messages that failed decoding for GOOSE Message *n*
LGOS*n*[d]	BufOvflCnt.stVal	GBFO*n*[e]	Number of messages lost because of buffer overflow for GOOSE Message *n*
LGOS*n*[d]	MsgLosCnt.stVal	GMSL*n*[e]	Number of messages lost due to OOS errors (estimated) for GOOSE Message *n*
LGOS*n*[d]	MaxMsgLos.stVal	GMXM*n*[e]	Maximum number of sequential messages lost because of OOS error (estimated) for GOOSE Message *n*
LGOS*n*[d]	InvQualCnt.stVal	GIDQ*n*[e]	Number of mapped data with invalid quality for GOOSE Message *n*
LGOS*n*[d]	RsStat.stVal	GRST*n*[e]	Status of statistics reset for GOOSE messages
LTIM	TmDT.stVal	TMDT[a]	Indicates daylight-saving time is currently in effect at the IED location
LTMS	TmAcc.stVal	TSACC[a]	Number of significant bits in the FractionOfSecond (an attribute of TimeStamp) 18: 4 µs accuracy (2^{-18}) 10: 1 ms accuracy (2^{-10}) 7: 10 ms accuracy (2^{-7}) 31: Unknown accuracy
LTMS	TmSrc.stVal	TSSRC[a]	Time-source identity If TmSrcTyp is PTP, TmSrc indicates the grandmaster clock class as defined by IEEE 1588-2008 If TmSrcTyp is SNTP, TmSrc indicates the IP address of the SNTP server For all other values of TmSrcTyp, TmSrc is set to NA
LTMS	SelTmSrcTyp.stVal	TSTYPE[a]	Type of the clock source as defined by Relay Word bits Time.SNTP_PriSrvr, Time.SNTP_BackupSrvr, Time.SyncOk, and Time.IRIG_Ok 1: Unknown 2: SNTP 3: PTP 4: IRIG-B

Table G.40 Logical Device: CFG (Configuration) (Sheet 3 of 5)

Logical Node	Attribute	Data Source	Comment
LTMS	SelTmSyn.stVal	TSSYN[a]	Traceability of the reference time to which the IED is synchronized 3: GlobalAreaClock—TmSrcTyp is PTP with grandmaster clock class of 6, TmSrcTyp is IRIG-B with IRIGC = C37.118, or TmSrcTyp is SNTP 2: LocalAreaClock—TmSrcTyp is PTP with grandmaster clock other than 6 (Future), or TmSrcTyp is IRIG-B with IRIGC ≠ C37.118 1: InternalClock—TmSrcTyp is unknown
LTMS	SelTmSynLkd.stVal	TSSYNLK[a]	Status of clock synchronization: 1: Locked 2: Unlocked for 0–10 seconds 3: Unlocked for 10–100 seconds 4: Unlocked for 100–1000 seconds 5: Unlocked for more than 1000 seconds
Functional Constraint = MX			
LGOS*n*[d]	TotDwnTm.instMag.f	GDWT*n*[e]	Total downtime in seconds for GOOSE Message *n*
LGOS*n*[d]	MaxDwnTm.instMag.f	GMXD*n*[e]	Maximum continuous downtime in seconds for GOOSE Message *n*
LTMS	SelTmTosPer.instMag.f	TSPER[a]	Duration, in milliseconds, between two consecutive top-of-second points on the synchronized time; TmTosPer is set to 0 for time sources other than high-accuracy PTP or IRIG-B
Functional Constraint = SP			
GOLCCH2	NetMod.setVal	NETMODE	Port 1 network operating mode setting 1: Fixed 2: Failover 3: Switched 4: PRP
IPLCCH1	NetMod.setVal	NETMODE	Port 1 network operating mode setting 1: Fixed 2: Failover 3: Switched 4: PRP
LGOS*n*[d]	GoCBRef.setSrcRef	[f]	Configured GOOSE control block reference for GOOSE Message *n*
LGOS*n*[d]	DatSet.setSrcRef	[f]	Configured data set reference for GOOSE Message *n*
LGOS*n*[d]	GoID.setVal	[f]	Configured ID for GOOSE Message *n*
LGOS*n*[d]	Addr.setVal	[f]	Configured multicast MAC address for GOOSE Message *n*
LGOS*n*[d]	VlanID.setVal	[f]	Configured VLAN ID for GOOSE Message *n*
LGOS*n*[d]	VlanPri.setVal	[f]	Configured VLAN priority for GOOSE Message *n*
LGOS*n*[d]	AppID.setVal	[f]	Configured APPID for GOOSE Message *n*
LLN0	MtlLev.setVal	MLTLEV	Multilevel mode of control authority
LTIM	TmOfsTmm.setVal	TMOFFS[a]	Offset of local time from UTC in minutes
LTIM	TmUseDT.setVal	TMUSEDT[a]	Set to True if daylight-saving time is enabled
LTIM	TmChgDT.setTm	TMCHGDT[a]	Local time of next change to daylight-saving time
LTIM	TmChgST.setTm	TMCHGST[a]	Local time of next change to standard time
Functional Constraint = SR			
LTRK1	SpcTrk.objRef	[h]	ACSI reference to the SPC object targeted in the request
LTRK1	SpcTrk.serviceType	[h, i]	Type of service requested or executed
LTRK1	SpcTrk.errorCode	[h, j]	ACSI service error status
LTRK1	SpcTrk.ctlVal	[h]	Control value in the request

Table G.40 Logical Device: CFG (Configuration) (Sheet 4 of 5)

Logical Node	Attribute	Data Source	Comment
LTRK1	SpcTrk.ctlNum	h	Control number in the request
LTRK1	SpcTrk.origin.orCat	h	Originator category value in the request
LTRK1	SpcTrk.origin.orIdent	h	Originator identity value in the request
LTRK1	SpcTrk.T	h	Time-stamp value in the request
LTRK1	SpcTrk.Test	h	Test value in the request
LTRK1	SpcTrk.Check	h	Check condition value in the request
LTRK1	SpcTrk.respAddCause	h	AddCause value returned in the response
LTRK1	DpcTrk.objRef	h	ACSI reference to the DPC object targeted in the request
LTRK1	DpcTrk.serviceType	h, i	Type of service requested or executed
LTRK1	DpcTrk.errorCode	h, j	ACSI service error status
LTRK1	DpcTrk.ctlVal	h	Control value in the request
LTRK1	DpcTrk.ctlNum	h	Control number in the request
LTRK1	DpcTrk.origin.orCat	h	Originator category value in the request
LTRK1	DpcTrk.origin.orIdent	h	Originator identity value in the request
LTRK1	DpcTrk.T	h	Time-stamp value in the request
LTRK1	DpcTrk.Test	h	Test value in the request
LTRK1	DpcTrk.Check	h	Check condition value in the request
LTRK1	DpcTrk.respAddCause	h	AddCause value returned in the response
LTRK1	EncTrk.objRef	h	ACSI reference to the ENC object targeted in the request
LTRK1	EncTrk.serviceType	h, i	Type of service requested or executed
LTRK1	EncTrk.errorCode	h, j	ACSI service error status
LTRK1	EncTrk.ctlVal	h	Control value in the request
LTRK1	EncTrk.ctlNum	h	Control number in the request
LTRK1	EncTrk.origin.orCat	h	Originator category value in the request
LTRK1	EncTrk.origin.orIdent	h	Originator identity value in the request
LTRK1	EncTrk.T	h	Time-stamp value in the request
LTRK1	EncTrk.Test	h	Test value in the request
LTRK1	EncTrk.Check	h	Check condition value in the request
LTRK1	EncTrk.respAddCause	h	AddCause value returned in the response
LTRK1	BrcbTrk.objRef	h	ACSI reference of the BRCB object targeted in the request
LTRK1	BrcbTrk.serviceType	h, i	Type of service requested or executed
LTRK1	BrcbTrk.errorCode	h, j	ACSI service error status
LTRK1	BrcbTrk.rptID	h	RptID attribute value in the request or target BRCB object
LTRK1	BrcbTrk.rptEna	h	RptEna attribute value in the request or target BRCB object
LTRK1	BrcbTrk.datSet	h	DatSet attribute value in the target BRCB object
LTRK1	BrcbTrk.confRev	h	ConfRev attribute value in the target BRCB object
LTRK1	BrcbTrk.optFlds	h	OptFlds attribute value in the request or target BRCB object
LTRK1	BrcbTrk.bufTm	h	BufTm attribute value in the request or target BRCB object
LTRK1	BrcbTrk.sqNum	h	SqNum attribute value in the target BRCB object

Table G.40 Logical Device: CFG (Configuration) (Sheet 5 of 5)

Logical Node	Attribute	Data Source	Comment
LTRK1	BrcbTrk.trgOps	h	TrgOps attribute value in the request or target BRCB object
LTRK1	BrcbTrk.intgPd	h	IntgPd attribute value in the request or target BRCB object
LTRK1	BrcbTrk.gi	h	GI attribute value in the request or target BRCB object
LTRK1	BrcbTrk.purgeBuf	h	PurgeBuf attribute value in the request or target BRCB object
LTRK1	BrcbTrk.entryID	h	EntryID attribute value in the request or target BRCB object
LTRK1	BrcbTrk.timeOfEntry	h	TimeOfEntry attribute value in the request or target BRCB object
LTRK1	UrcbTrk.objRef	h	ACSI reference of the URCB object targeted in the request
LTRK1	UrcbTrk.serviceType	h, i	Type of service requested or executed
LTRK1	UrcbTrk.errorCode	h, j	ACSI service error status
LTRK1	UrcbTrk.rptID	h	RptID attribute value in the request or target URCB object
LTRK1	UrcbTrk.rptEna	h	RptEna attribute value in the request or target URCB object
LTRK1	UrcbTrk.resv	h	Resv attribute value in the request or target URCB object
LTRK1	UrcbTrk.datSet	h	DatSet attribute value in the target URCB object
LTRK1	UrcbTrk.confRev	h	ConfRev attribute value in the target URCB object
LTRK1	UrcbTrk.optFlds	h	OptFlds attrbute value in the request or target URCB object
LTRK1	UrcbTrk.bufTm	h	BufTm attribute value in the request or target URCB object
LTRK1	UrcbTrk.sqNum	h	SqNum attribute value in the target URCB object
LTRK1	UrcbTrk.trgOps	h	TrgOps attribute value in the request or target URCB object
LTRK1	UrcbTrk.intgPd	h	IntgPd attribute value in the request or target URCB object
LTRK1	UrcbTrk.gi	h	GI attribute value in the request or target URCB object
LTRK1	SgcbTrk.objRef	h	ACSI reference of the SGCB object targeted in the request
LTRK1	SgcbTrk.serviceType	h, i	Type of service requested (SelectActiveSG)
LTRK1	SgcbTrk.errorCode	h, j	ACSI service error status
LTRK1	SgcbTrk.numOfSG	h	NumOfSG attribute value in the target SGCB object
LTRK1	SgcbTrk.actSG	h	ActSG attribute value in the request
LTRK1	SgcbTrk.editSG	h	EditSG attribute value in the target SGCB object (0)
LTRK1	SgcbTrk.cnfEdit	h	CnfEdit attribute value in the target SGCB object (FALSE)
LTRK1	SgcbTrk.lActTm	h	LActTm attribute value in the target SGCB object after activation of the settings group

[a] Internal data source and not available to the user.
[b] MMS controls to Mod.Oper are only accepted if IEC 61850 Mode/Behavior is enabled on the relay. Refer to Mode/Behavior Control on page G.21 for more details.
[c] I60MOD is an internal data source derived from the I850MOD analog quantity and is not available to the user.
[d] Where n = 1–16, corresponding to the first 16 GOOSE message subscriptions.
[e] Internal data source not available to the user. See GOOSE on page G.17 for more information.
[f] Data source defined in the IEC 61850 Configured IED Description (CID) file.
[g] Refer to Table 7.27 for a description of each enumeration.
[h] The value depends on the ACSI service type requested, the target object, and the error status.
[i] Refer to Table G.10 for the IEC 61850 service type enumeration.
[j] Refer to Table G.11 for the IEC 61850 ACSI service error.

SEL Nameplate Data

The CID file contains information that describes the physical device attributes according to IEC 61850 standards. The LN0 logical node of each logical device contains the Nameplate DOI (instantiated data object) with the data shown in *Table G.41*.

Table G.41 SEL Nameplate Data

Data Attribute	Value
vendor	"SEL"
swRev	Contents of FID string from **ID** command
configRev	Always 0
1dNs	IEC 61850-7-4:2007A

Protocol Implementation Conformance Statement

The following tables 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 G.42 PICS for A-Profile Support

Profile		Client	Server	Value/Comment
A1	Client/Server	N	Y	
A2	GOOSE/GSE management	Y	Y	Only GOOSE, not GSSE Management
A3	GSSE	N	N	
A4	Time Sync	N	N	

Table G.43 PICS for T-Profile Support

Profile		Client	Server	Value/Comment
T1	TCP/IP	N	Y	
T2	OSI	N	N	
T3	GOOSE/GSE	Y	Y	Only GOOSE, Not GSSE
T4	GSSE	N	N	
T5	Time Sync	Y	N	

Refer to *ACSI Conformance Statements on page G.85* for information on the supported services.

MMS Conformance

The manufacturing message specification (MMS) stack provides the basis for many IEC 61850 protocol services. *Table G.44* defines the service support requirement and restrictions of the MMS services in the SEL-700 Series Relays supporting IEC 61850. Generally, only those services whose implementation is not mandatory are shown. Refer to the IEC 61850 standard Part 8-1 for more information.

Table G.44 MMS Service Supported Conformance (Sheet 1 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
status		Y
getNameList		Y
identify		Y
rename		
read		Y
write		Y
getVariableAccessAttributes		Y
defineNamedVariable		
defineScatteredAccess		
getScatteredAccessAttributes		
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

Table G.44 MMS Service Supported Conformance (Sheet 2 of 3)

MMS Service Supported CBB	Client-CR	Server-CR
	Supported	Supported
createProgramInvocation		
deleteProgramInvocation		
start		
stop		
resume		
reset		
kill		
getProgramInvocationAttributes		
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		
fileDelete		
fileDirectory		Y
unsolicitedStatus		
informationReport		Y

Table G.44 MMS Service Supported Conformance (Sheet 3 of 3)

MMS Service Supported CBB	Client-CR	Server-CR
	Supported	Supported
eventNotification		
attachToEventCondition		
attachToSemaphore		
conclude		Y
cancel		Y
getDataExchangeAttributes		
exchangeData		
defineAccessControlList		
getAccessControlListAttributes		
reportAccessControlledObjects		
deleteAccessControlList		
alterAccessControl		
reconfigureProgramInvocation		

Table G.45 lists specific settings for the MMS parameter Conformance Building Block (CBB).

Table G.45 MMS Parameter CBB

MMS Parameter CBB	Client-CR	Server-CR
	Supported	Supported
STR1		Y
STR2		Y
VNAM		Y
VADR		Y
VALT		Y
TPY		Y
VLIS		Y
CEI		

The following Variable Access conformance statements are listed in the order specified in the IEC 61850 standard, Part 8-1. Generally, only those services whose implementation is not mandatory are shown. Refer to the IEC 61850 standard Part 8-1 for more information.

Table G.46 AlternateAccessSelection Conformance Statement (Sheet 1 of 2)

AlternateAccessSelection	Client-CR Supported	Server-CR Supported
accessSelection		YES
component		YES
index		
indexRange		
allElements		
alternateAccess		YES

Table G.46 AlternateAccessSelection Conformance Statement (Sheet 2 of 2)

AlternateAccessSelection	Client-CR Supported	Server-CR Supported
selectAccess		YES
component		YES
index		
indexRange		
allElements		

Table G.47 VariableAccessSpecification Conformance Statement

VariableAccessSpecification	Client-CR Supported	Server-CR Supported
listOfVariable		YES
variableSpecification		YES
alternateAccess		YES
variableListName		YES

Table G.48 VariableSpecification Conformance Statement

VariableSpecification	Client-CR Supported	Server-CR Supported
name		YES
address		
variableDescription		
scatteredAccessDescription		
invalidated		

Table G.49 Read Conformance Statement

Read	Client-CR Supported	Server-CR Supported
Request		
specificationWithResult		
variableAccessSpecification		
Response		
variableAccessSpecification		YES
listOfAccessResult		YES

Table G.50 GetVariableAccessAttributes Conformance Statement

GetVariableAccessAttributes	Client-CR Supported	Server-CR Supported
Request		
name		
address		
Response		
mmsDeletable		YES
address		
typeSpecification		YES

Table G.51 DefineNamedVariableList Conformance Statement

DefineVariableAccessAttributes	Client-CR Supported	Server-CR Supported
Request		
variableListName		
listOfVariable		
variableSpecification		
alternateAccess		
Response		

Table G.52 GetNamedVariableListAttributes Conformance Statement

GetNamedVariableListAttributes	Client-CR Supported	Server-CR Supported
Request		
ObjectName		
Response		
mmsDeletable		YES
listOfVariable		YES
variableSpecification		YES
alternateAccess		YES

Table G.53 DeleteNamedVariableList

DeleteNamedVariableList	Client-CR Supported	Server-CR Supported
Request		
Scope		
listOfVariableListName		
domainName		
Response		
numberMatched		
numberDeleted		
DeleteNamedVariableList-Error		

GOOSE Services Conformance Statement

Table G.54 GOOSE Conformance

	Subscriber	Publisher	Value/Comment
GOOSE Services	YES	YES	
SendGOOSEMessage		YES	
GetGoReference			
GetGOOSEElementNumber			
GetGoCBValues		YES	
SetGoCBValues			
GSENotSupported			
GOOSE Control Block (GoCB)		YES	

ACSI Conformance Statements

Table G.55 ACSI Basic Conformance Statement

		Client/Subscriber	Server/Publisher	SEL-787 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	Published side	-	O[b]	
B42	Subscriber side	O[b]	-	

[a] c1 shall be mandatory if support for LOGICAL-DEVICE model has been declared.
[b] O = Optional.

Table G.56 ACSI Models Conformance Statement (Sheet 1 of 2)

		Client/Subscriber	Server/Publisher	SEL-787 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	Data set	c5[d]	c5[d]	YES
M5	Substation	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	G1			YES
M8	Unbuffered report control	O[e]	O[e]	YES

Table G.56 ACSI Models Conformance Statement (Sheet 2 of 2)

		Client/Subscriber	Server/Publisher	SEL-787 Support
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				
M9	Log control	O[e]	O[e]	
M9-1	IntgPd	O[e]	O[e]	
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	DataRefInc			YES
M13	GSSE	O[e]	O[e]	
If GSE (B41/42) Is Supported				
M14	Multicast SVC	O[e]	O[e]	
M15	Unicast SVC	O[e]	O[e]	
M16	Time	M[f]	M[f]	
M17	File Transfer	O[e]	O[e]	

[a] c2 shall be "M" if support for LOGICAL-NODE model has been declared.
[b] c3 shall be "M" if support for DATA model has been declared.
[c] c4 shall be "M" if support for DATA-SET, Substitution, Report, Log Control, or Time model has been declared.
[d] c5 shall be "M" if support for Report, GSE, or SV models has been declared.
[e] O = Optional.
[f] M = Mandatory.

Table G.57 ACSI Services Conformance Statement (Sheet 1 of 4)

Services		AA: TP/MC	Client/ Subscriber	Service/ Publisher	SEL-787 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
Logical Node (Clause 9)					
S6	LogicalNodeDirectory	TP	M[a]	M[a]	YES
S7	GetAllDataValues	TP	O[b]	M[a]	YES

Table G.57 ACSI Services Conformance Statement (Sheet 2 of 4)

Services		AA: TP/MC	Client/ Subscriber	Service/ Publisher	SEL-787 Support
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
Data Set (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]	
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
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]	

Table G.57 ACSI Services Conformance Statement (Sheet 3 of 4)

Services		AA: TP/MC	Client/ Subscriber	Service/ Publisher	SEL-787 Support
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	GetGOOSEElement				
Number	TP	O[b]	c9[f]		
S38	GetGoCBValues	TP	O[b]	O[b]	YES
S39	SetGoCBValues	TP	O[b]	O[b]	
ONLY					
GSSE-Control-Block					
S40	SendGSSEMessage	MC	c8[e]	c8[e]	
S41	GetReference	TP	O[b]	c9[f]	
S42	GetGSSEElement				
Number	TP	Ob	c9[f]		
S43	GetGsCBValues	TP	O[b]	O[b]	
S44	GetGsCBValues	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	Ma	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]	
File Transfer (Clause 20)					
S57	GetFile	TP	O[b]	M[a]	
S58	SetFile	TP	O[b]	O[b]	
S59	DeleteFile	TP	O[b]	O[b]	
S60	GetFileAttributeValues	TP	O[b]	M[a]	

Table G.57 ACSI Services Conformance Statement (Sheet 4 of 4)

Services		AA: TP/MC	Client/ Subscriber	Service/ Publisher	SEL-787 Support
Time (Clause 5.5)					
T1	Time resolution of internal clock (nearest negative power of 2 in seconds)				20 (1 µs)
T2	Time accuracy of internal clock				7 (10 ms) for SNTP 18 (4 µs) for IRIG-B
	T1				YES (for IRIG-B)
	T2				YES (for IRIG-B)
	T3				YES (for IRIG-B)
	T4				YES (for IRIG-B)
T3	Supported Time Stamp resolution (nearest negative power of 2 in seconds)				7 (10 ms) for SNTP 18 (4 µs) for IRIG-B

[a] M = Mandatory.
[b] O = Optional.
[c] c6 shall declare support for at least one (BRCB or URCB).
[d] c7 shall declare support for at least one (QueryLogByTime or QueryLogAfter).
[e] c8 shall declare support for at least one (SendGOOSEMessage or SendGSSEMessage).
[f] c9 shall declare support if TP association is available.
[g] c10 shall declare support for at least one (SendMSVMessage or SendUSVMessage).

Potential Client and Automation Application Issues With Edition 2 Upgrades

The following are issues that IEC 61850 Edition 1 (Ed1)-based client or automation applications may experience with IEC 61850 Edition 2 (Ed2) ICD and firmware changes. However, such issues may be resolved by reconfiguring the client or automation application or worked around by restoring the Ed1 (CID) configuration. None of these should prevent a client application from dynamically discovering the data in the IED as long as the application adheres to the specification of the standard. Note that upgrading to Ed2 firmware will not break existing Ed1 configurations (CID files) in the field, nor require loading an Ed2 version of the CID file.

Unexpected Error Messages

Some MMS and control errors have been changed in Ed2. Hence, the firmware now issues only the Ed2-compliant errors. Clients or automation applications that rely on the Ed1-compliant errors will not function correctly. You can resolve this by reconfiguring the client or automation application to accept Ed2-compliant errors.

Missing or Unknown Data Objects and Attributes

Ed2 has changed some data object and attribute names, as well as the data types of some attributes. Ed2 also prohibits the use of proprietary CDCs. See *Logical Nodes on page G.28* and the logical nodes tables in each product-specific manual to determine the Ed2 names. This may cause the failure of clients or automation applications that rely on the Ed1 names. A workaround is to use the Ed1 version of the CID file, if available, to configure the IED. You can also resolve this by reconfiguring the client or automation application to accept the Ed2 names.

Unable to Find Operate Time-Out

A proprietary method was used to specify the operate time-out of control objects in the CID files. A client or automation application that relies on this proprietary method will fail to find the operate time-out in the CID file. A workaround is to use the Ed1 CID file to configure the IED. You can also resolve this by reconfiguring the client or automation application to accept the Ed2 control object operate time-outs.

Unexpected Control Block Data Attribute Type

The string type data attributes in control blocks (RptID, DatSet, etc.) have been changed from a maximum length of 65 to 129 characters, i.e., VisString65 to VisString129. Some clients and automation applications might see this as an error when the type is reported in the MMS GetVariableAccessAttributes response. You can resolve this by reconfiguring the client or automation application.

Unexpected Reports

Ed2 requires report buffering to start when the device is turned on, unlike in the Ed1 implementation where report buffering started after the first report enable. If a client or automation application relies on the Ed1 behavior, it might fail or indicate an error if the IED sends buffered reports immediately after the first enable. You can resolve this by reconfiguring the client or automation application.

Failure to Reselect a Control Object Before the Timeout

In Ed1, if a client reselected a control object before the select-before-operate time-out expired, the reselection would succeed and cause the selected time-out to restart. According to Ed2, this reselection is supposed to fail. Ed1-based clients or automation applications that rely on successful reselection might operate incorrectly. You can resolve this by reconfiguring the client or automation application.

Test Control Commands Fail Immediately

In Ed1, if the test attribute was set in a control command structure, the relay would accept the command but perform no action on the target control object. With enhanced control models, the IED would eventually report an operate timeout error after the operate time-out expired. However, in Ed2, any such test commands will fail immediately with an error indicating that the command is blocked because the IED is not in the appropriate mode. Clients or automation applications that depend on the Ed1 behavior might fail. You can resolve this by reconfiguring the client or automation application.

No Reports

Ed2 specifies that no reports are to be generated for a deadbanded attribute if the deadband is set to 0. Previously in Ed1, a deadband of 0 would cause the relay to generate reports for any change in the instantaneous value. Ed1-based clients or automation applications might not operate correctly because of the lack of reports. You can resolve this by reconfiguring the client or automation application.

Appendix H
IEC 60870-5-103 Communications

Overview

The SEL-787 Transformer Protection Relay provides the IEC 60870-5-103 interface for direct serial connections to the device.

This section covers the following topics:

- *Introduction to IEC 60870-5-103 on page H.1*
- *IEC 60870-5-103 in the SEL-787 on page H.9*
- *IEC 60870-5-103 Documentation on page H.13*

Introduction to IEC 60870-5-103

The International Electrotechnical Commission (IEC) 60870-5 is a protocol standard developed by the IEC Technical Committee of teleprotection, telecontrol, and telecommunications for electrical engineering and power system automation. It defines systems used for supervisory control and data acquisition (SCADA), including details related to communications between devices. IEC 60870-5-103 is a companion standard that allows interoperability between devices in a control system and protection equipment. The IEC 60870-5 standard consists of the documents listed in *Table H.1*.

Table H.1 IEC 60870-5 Standard Documents

Document	Description
IEC 60870-5-1	Transmission Frame Formats
IEC 60870-5-2	Data Link Transmission Services
IEC 60870-5-3	General Structure of Application Data
IEC 60870-5-4	Definition and Coding of Information Elements
IEC 60870-5-5	Basic Application Functions
IEC 60870-5-6	Guidelines for Conformance Testing IEC 60870-5 Companion Standards
IEC 60870-5-7	Security extensions to IEC 60870-5-1010 and IEC 60870-5-104 protocols

The IEC 60870-5-103 document contains the information necessary for successful implementation of this protocol. SEL strongly recommends that anyone involved with the design, installation, configuration, or maintenance of IEC 60870-5-103 systems be familiar with the appropriate sections of this document.

IEC 60870-5 was designed for wide-spread telecontrol networks. It is an international standard based on an international accepted and proven enhanced performance architecture model (see *Table H.2*). The standard provides a balance between efficiency and reliability while using minimal hardware.

Table H.2 IEC 60870-5 Enhanced Performance Architecture Model

Layer	Layer Type
7	Application
•	•
•	•
•	•
2	Datalink
1	Physical

Layer 7 implementation is described in the IEC 60870-5-3 and IEC 60870-5-4 sections of the standard. Layer 2 implementation is described in the IEC 60870-5-2 and IEC 60870-5-1 sections of the standard.

The history of IEC 60870-5 spans from 1990 to 2006. *Table H.3* shows the history during this time period.

Table H.3 History of IEC 60870-5

Section	Description
IEC 60870-5-1	Transmission Frame Formats
IEC 60870-5-2	Data Link Transmission Services
IEC 60870-5-3	General Structure of Application Data
IEC 60870-5-4	Definition and Coding Information Elements
IEC 60870-5-5	Basic Application Functions
IEC 60870-5-101	CS For Basic Telecontrol Tasks
IEC 60870-5-102	CS For Transmission Of Integrated Totals In Electric Power Systems
IEC 60870-5-103	CS for Informative Interface Of Protection Equipment
IEC 60870-5-104	Network Access For TCS101 Using Standard Transport Profiles
IEC 60870-5-101 Ed 2	Addendums Incorporated In Standard
IEC 60870-5-104 Ed 2	Addendums Incorporated In Standard
IEC 60870-5-601	Conformance Test Procedures For TCS 101
IEC 60870-5-604	Conformance Test Procedures For TCS 104

The first five sections are the basic parts of the standard. The next six describe the companion standards, and the last two sections are test procedures of the standard.

Data Handling

Master/Slave Communication

The IEC 60870-5-103 standard is such that the IED only sends a message when the Master asks for it. Communication is set up by the Master and the Master controls the communication between the Master and the IED.

Interoperability

The method of data exchange in the SEL-787 involves Application Service Data Units (ASDUs) along with application procedures for transmission of standardized data messages (see *Table H.4*). The data are recognized by any IEC 60870-5-103 Master because the application data take the form of an IEC 60870-5-103 data type and pairs with an IEC 60870-5-103 address, resulting in device interoperability.

Table H.4 SEL-787 ASDU Types

<table>
<tr><th>ASDU Type</th><th>Description</th></tr>
<tr><td>1</td><td>Time Tagged Message</td></tr>
<tr><td>2</td><td>Time Tagged Message With Relative Time</td></tr>
<tr><td>3</td><td>Measurands I</td></tr>
<tr><td>4</td><td>Time Tagged Measurands With Relative Time</td></tr>
<tr><td>5</td><td>Identification</td></tr>
<tr><td>6</td><td>Time Synchronization</td></tr>
<tr><td>8</td><td>General Interrogation Termination</td></tr>
<tr><td>9</td><td>Measurands II</td></tr>
<tr><td>20</td><td>General Command</td></tr>
<tr><td>205</td><td>Non-Standard
<table>
<tr><td>Type Identification</td><td colspan="8">0xCD (205)</td></tr>
<tr><td>Variable Structure Qualifier</td><td colspan="8">0x81</td></tr>
<tr><td>Cause of Transmission</td><td colspan="8">0x01</td></tr>
<tr><td>Device Address</td><td colspan="8">ADDR</td></tr>
<tr><td>Function Type</td><td colspan="8">FUN</td></tr>
<tr><td>Information Number</td><td colspan="8">INF</td></tr>
<tr><td rowspan="4">Information Element
Meter value: 29-bit signed integer
ER: 0 valid, 1 invalid</td><td>2^{7}</td><td>•</td><td>•</td><td>•</td><td>•</td><td>•</td><td>•</td><td>2^{0}</td></tr>
<tr><td>2^{15}</td><td>•</td><td>•</td><td>•</td><td>•</td><td>•</td><td>•</td><td>2^{8}</td></tr>
<tr><td>2^{23}</td><td>•</td><td>•</td><td>•</td><td>•</td><td>•</td><td>•</td><td>2^{16}</td></tr>
<tr><td>0</td><td>ER</td><td>0</td><td>-2^{28}</td><td>•</td><td>•</td><td>•</td><td>2^{24}</td></tr>
<tr><td>Four Octet Binary Time</td><td colspan="8">Defined in 60870-5-103, 7.2.6.28</td></tr>
</table>
</td></tr>
</table>

Table H.5 lists the available category map settings in the SEL-787. When configuring the settings with the command line, categories can be selected by entering “>” or “<”.

Table H.5 IEC 60870-5-103 Category Map Settings

Setting Prompt	Scaling/Nominal Value Range	Information Number Range	Function Type Range	Setting Name
103 Binary Input Label	NA	0–255	0–255	103BI00
103 Binary Input Label	NA	0–255	0–255	103BI01
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
103 Binary Input Label	NA	0–255	0–255	103BI99
103 Binary Target Label	NA	0–255	0–255	103BT00
103 Binary Target Label	NA	0–255	0–255	103BT01
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
103 Binary Target Label	NA	0–255	0–255	103BT07
103 Binary Control Label	NA	0–255	0–255	103BO00
103 Binary Control Label	NA	0–255	0–255	103BO01
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
103 Binary Control Label	NA	0–255	0–255	103BO31
103 Fault Analog Label	0.000–99999	0–255	0–255	103FA00
103 Fault Analog Label	0.000–99999	0–255	0–255	103FA01
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
103 Fault Analog Label	0.000–99999	0–255	0–255	103FA31
103 Measurand Label	0.001–999999	0–255	0–255	3MLB000
103 Measurand Label	0.001–999999	0–255	0–255	3MLB001
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
103 Measurand Label	0.001–999999	0–255	0–255	3MLB127
103 Meter Quantity Label	0.000–99999	0–255	0–255	103MQ00
103 Meter Quantity Label	0.000–99999	0–255	0–255	103MQ01
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
103 Meter Quantity Label	0.000–99999	0–255	0–255	103MQ31

Cause of Transmission

The Cause of Transmission (COT) represents the reason the SEL-787 sends a message to the Master. See *Table H.6* for the possible COTs.

Table H.6 IEC 60870-5-103 Cause Of Transmission

Cause of Transmission	Description
1	Spontaneous Events
2	Cyclic
3	Reset Frame Count Bit (FCB)
4	Reset Communication Unit (CU)
5	Start/Restart
6	Power On
7	Test Mode
8	Time Synchronization
9	Initiation Of General Interrogation
10	Termination Of General Interrogation
12	Remote Operation
20	General Command (Control Direction), Positive Acknowledgment Of Command (Monitor)
21	Negative Acknowledgment Of Command (Monitor)
31	Disturbance Recorder
40–44	Generic Commands And Data

Information Number

The Information Number (INF) is one of the two octets of the information object identifier. See *Table H.7* for the range and description of Information Numbers in IEC 60870-5-103.

Table H.7 IEC 60870-5-103 Information Numbers (Sheet 1 of 2)

Function Type	Description
Monitor Direction	
0–15	System Functions
16–31	Status
32–47	Supervision
48–63	Earth Fault
64–127	Short Circuit
128–143	Auto Reclose
144–159	Measurands
160–239	Not Used
240–255	Generic Functions
Control Direction	
0–15	System Functions
16–31	General Commands

Table H.7 IEC 60870-5-103 Information Numbers (Sheet 2 of 2)

Function Type	Description
32–239	Not Used
240–255	Generic Functions

Function Type

The Function Type (FUN) is the second of the two octets of the information object identifier.

Together, the pair (INF, FUN) distinctly characterizes each point within each data class. *Table H.8* and *Table H.9* list the Standard Function Types and Data Map for the IEC 60870-5-103 standard.

Table H.8 IEC 60870-5-103 Standard Function Types

Function Type	Description
128	Distance protection
160	Overcurrent protection
176	Transformer Differential Protection
192	Line Differential Protection
254	Generic Function Type
255	Global Function Type

Table H.9 IEC 60870-5-103 Data Map (Sheet 1 of 3)

INF	Description	GI	ASDU Type	COT	FUN
System functions in monitor direction					
0[a]	End of general interrogation	–	8	10	255
0[a]	Time synchronization	–	6	8	255
2[a]	Reset FCB	–	5	3	According to main FUN
3[a]	Reset CU	–	5	4	According to main FUN
4[a]	Start/restart	–	5	5	According to main FUN
5[a]	Power on	–	5	6	According to main FUN
Status indications in monitor direction[b]					
16	Auto-recloser active	Yes	1	1,7,9,11,12,20,21	128, 160, 192
17	Teleprotection active	Yes	1	1,7,9,11,12,20,21	128, 160
18	Protection active	Yes	1	1,7,9,11,12,20,21	128, 160, 176, 192
19	LED Reset	–	1	1,7,11,12,20,21	128, 160, 176, 192
20	Monitor direction blocked	Yes	1	9,11	128, 160, 176, 192
21	Test mode	Yes	1	9,11	128, 160, 176, 192
22	Local parameter setting	Yes	1	9,11	128, 160, 176, 192
23	Characteristic 1[c]	Yes	1	1,7,9,11,12,20,21	128
24	Characteristic 2[c]	Yes	1	1,7,9,11,12,20,21	128
25	Characteristic 3[c]	Yes	1	1,7,9,11,12,20,21	128

Table H.9 IEC 60870-5-103 Data Map (Sheet 2 of 3)

INF	Description	GI	ASDU Type	COT	FUN
26	Characteristic 4[c]	Yes	1	1,7,9,11,12,20,21	128
27	Auxiliary input 1[d]	Yes	1	1,7,9,11	128, 160, 176, 192
28	Auxiliary input 2[d]	Yes	1	1,7,9,11	128, 160, 176, 192
29	Auxiliary input 3[d]	Yes	1	1,7,9,11	128, 160, 176, 192
30	Auxiliary input 4[d]	Yes	1	1,7,9,11	128, 160, 176, 192
Supervision indications in monitor direction[b]					
32	Measurand supervision I	Yes	1	1,7,9	128, 160
33	Measurand supervision V	Yes	1	1,7,9	128, 160
35	Phase sequence supervision	Yes	1	1,7,9	128, 160
36	Trip circuit supervision	Yes	1	1,7,9	128, 160, 176, 192
37	I>> back-up operation	Yes	1	1,7,9	128
38	Voltage transformer fuse failure	Yes	1	1,7,9	128, 160
39	Teleprotection disturbed	Yes	1	1,7,9	128, 160, 192
46	Group warning	Yes	1	1,7,9	128, 160, 176, 192
47	Group alarm	Yes	1	1,7,9	128, 160, 176, 192
Earth fault indications in monitor direction[b]					
48	Earth Fault L_1	Yes	1	1,7,9	128, 160
49	Earth Fault L_2	Yes	1	1,7,9	128, 160
50	Earth Fault L_3	Yes	1	1,7,9	128, 160
51	Earth fault forward, i.e. line	Yes	1	1,7,9	128, 160
52	Earth fault reverse, i.e. busbar	Yes	1	1,7,9	128, 160
Fault indications in monitor direction[e]					
64	Start/pick-up L[b]	Yes	2	1,7,9	128, 160, 192
65	Start/pick-up L[c]	Yes	2	1,7,9	128, 160, 192
66	Start/pick-up L[d]	Yes	2	1,7,9	128, 160, 192
67	Start/pick-up N	Yes	2	1,7,9	128, 160, 192
68	General trip	–	2	1,7	128, 160, 176, 192
69	Trip L_1	–	2	1,7	128, 160, 176, 192
70	Trip L_2	–	2	1,7	128, 160, 176, 192
71	Trip L_3	–	2	1,7	128, 160, 176, 192
72	Trip I>> (back-up operation)	–	2	1,7	128, 160, 176, 192
73	Fault Location X in ohms	–	4	1,7	128
74	Fault forward / line	–	2	1,7	128, 160
75	Fault reverse / busbar	–	2	1,7	128, 160
76	Teleprotection signal transmitted	–	2	1,7	128, 160
77	Teleprotection signal received	–	2	1,7	128, 160
78	Zone 1	–	2	1,7	128
79	Zone 2	–	2	1,7	128
80	Zone 3	–	2	1,7	128
81	Zone 4	–	2	1,7	128

Table H.9 IEC 60870-5-103 Data Map (Sheet 3 of 3)

INF	Description	GI	ASDU Type	COT	FUN
82	Zone 5	–	2	1,7	128
83	Zone 6	–	2	1,7	128
84	General start / pick-up	Yes	2	1,7,9	128, 160, 176, 192
85	Breaker failure	–	2	1,7	128, 160
86	Trip measuring system L_1	–	2	1,7	176
87	Trip measuring system L_2	–	2	1,7	176
88	Trip measuring system L_3	–	2	1,7	176
89	Trip measuring system E	–	2	1,7	176
90	Trip I>	–	2	1,7	160
91	Trip I>>	–	2	1,7	160
92	Trip IN>	–	2	1,7	160
93	Trip IN>>	–	2	1,7	160
Auto-recloser indications in monitor direction[b]					
128	Circuit breaker on by Auto-recloser	–	1	1,7	128, 160, 192
129	Circuit breaker on by long-time Auto-recloser	–	1	1,7	128, 160, 192
130	Auto-recloser blocked	Yes	1	1,7,9	128, 160, 192
Measurands in monitor direction					
144	Measurand I	–	3.1	2,7	128, 160
145	Measurands I, V	–	3.2	2,7	128, 160
146	Measurands I, V, P, Q	–	3.3	2,7	128
147	Measurands I_N, V_{EN}	–	3.4	2,7	128, 160
148	Measurands $I_{L1,2,3}$, $V_{L1,2,3}$, P, Q, f	–	9	2,7	128
System functions in control direction					
0[a]	Initiation of General Interrogation		7	9	255
0[a]	Time synchronization		6	8	255
General commands in control direction[f]					
16	Auto-recloser on/off	ON/OFF	20	20	128, 160, 192
65	Teleprotection on/off	ON/OFF	20	20	128, 160
66	Protection on/off	ON/OFF	20	20	128, 160, 176, 192
67	LED Reset	ON	20	20	128, 160, 176, 192
68	Activate characteristic 1[c]	ON	20	20	128
69	Activate characteristic 2[c]		20	20	128
70	Activate characteristic 3[c]		20	20	128
71	Activate characteristic 4[c]		20	20	128

[a] The SEL-787 supports these points at the specified INF and FUN.
[b] Referred to as Binary Data in the SEL-787.
[c] Mapped to settings group indications and control in the SEL-787.
[d] Mapped to device contact inputs in the SEL-787.
[e] Referred to as Binary Targets and other Fault Information in the SEL-787.
[f] Referred to as Binary Controls in the SEL-787.

IEC 60870-5-103 in the SEL-787

The IEC 60870-5-103 protocol settings in the SEL-787 contain five parameters that must be set properly to get the most out of the protocol. These parameters are called 103ADDR, 103CYC, 103ACYC, 103ATRI, and 103TIME. A description of each of these parameters is provided in *Table H.10*.

Table H.10 SEL-787 IEC 60870-5-103 Port Settings

Parameter	Description	Range/Valid Input
103ADDR	Link layer address of the product	0–254
103CYC	Period at which to report cyclic data	1–3600 seconds
103ACYC	Period at which to report type ASDU 205 data	OFF, 1–3600 seconds
103ATRI	Relay Word bit used to trigger type ASDU 205 report	1 Relay Word bit
103TIME	Time synchronization enable	Y, N

The IEC 60870-5-103 standard in the SEL-787 provides six category types namely, Binary Inputs, Binary Targets, Binary Controls, Measurands, Fault Analogs, and Meter Quantities. Each data point within each class type requires an Information Number and a Function Type. Binary Inputs, Binary Targets, and Binary Controls are defined within the map by a Label Name followed by an Information Number followed by a Function Type. Measurands, Fault Analogs, and Meter Quantities are defined within the map by a Label Name followed by the Scale Factor/Nominal Value followed by the Information Number followed by the Function Type. The Nominal Value pertains only to Measurands and is defined within the following formula.

$$\text{Value seen by Master} = \frac{4096 \bullet \text{Label\_Value}}{2.4 \bullet \text{Nominal\_Value}}$$

Consider for example frequency in the Measurand point (FREQ, 60, 0, 1). Conceptually, when the frequency is 60 Hz, which is 0.4167 of 2.4 • Nominal Value (2.4 • 60 = 144), then the value 0.4167 gets encoded as a 13-bit, fixed-point number that has the same bit-wise representation as the integer that is equal to the Value seen by Master or

$$\frac{4096 \bullet \text{FREQ}}{2.4 \bullet 60\ \text{Hz}}$$

Binary Inputs

In the SEL-787, binary data are reported as ASDU type 1 (Time Tagged Message). Those points, monitored by the SER function of the device, have their changes reported as COT type 1 (Spontaneous Events). The format of a binary input point within the binary input map is (Label, INF, FUN). The Label represents any valid binary input point accepted by the SEL-787. The INF parameter is an integer in the range of 0 to 255. Similarly, the FUN parameter is an integer in the range of 0 to 255. The Label can be entered by itself with the SEL-787 choosing default parameters for INF and FUN. The default parameter for INF is an available, unique value that is selected by the SEL-787. The default parameter for FUN is 250.

The INF, FUN pair needs to either be entered together or not entered at all. The SEL-787 does not accept only one member of the INF, FUN pair. The Label, INF, and FUN can all be manually entered. No other combinations are valid with the SEL-787.

Binary Targets

The binary targets are relay word bits within the SEL-787 under row zero. They also appear as LEDs on the front panel of the SEL-787. There are eight binary targets in the SEL-787 namely, ENABLED, TRIP_LED, TLED_01, TLED_02, TLED_03, TLED_04, TLED_05, and TLED_06. In the SEL-787, binary targets are reported as ASDU type 2 (Time Tagged Message with Relative Time) with COT type 1 (Spontaneous Events). The format of a binary target point within the binary target map is (Label, INF, FUN). The Label represents any valid binary target point accepted by the SEL-787. The INF parameter is an integer in the range of 0 to 255. Similarly, the FUN parameter is an integer in the range of 0 to 255. The Label can be entered by itself with the SEL-787 choosing default parameters for INF and FUN. The default parameter for INF is an available, unique value that is selected by the SEL-787. The default parameter for FUN is 250.

The (INF, FUN) pair needs to either be entered together or not entered at all. The SEL-787 does not accept only one member of the (INF, FUN) pair. And of course, the Label, INF, and FUN can all be manually entered. No other combinations are valid with the SEL-787.

Fault Analogs

The fault analogs are analog quantities in the SEL-787 used to describe faults recognized by the relay, such as fault current or fault location. These quantities are listed in *Table H.11*. In the SEL-787, fault analog quantities are reported as ASDU type 4 (Time Tagged Measurands with Relative Time) with COT type 1 (Spontaneous Events). The format of a fault analog point within the fault analog map is (Label, Scaling, INF, FUN). Label represents any valid fault analog point accepted by the SEL-787. Scaling is the scaling factor applied to the point prior to being sent out of the relay via the protocol. Its range is 0.000 to 99999. The INF parameter is an integer in the range of 0 to 255. Similarly, the FUN parameter is an integer in the range of 0 to 255. Label can be entered by itself with the SEL-787 choosing default parameters for Scaling, INF, and FUN. Label and Scaling values can also be entered together with the SEL-787 choosing default parameters for the INF and FUN. The default parameter for INF is an available, unique value that is selected by the SEL-787. The default parameter for FUN is 250.

In any case, the INF, FUN pair needs to either be entered together or not entered at all. The SEL-787 does not accept only one member of the (INF, FUN) pair. And finally, the Label, Scaling, INF, and FUN values can all be manually entered. No other combinations are valid with the SEL-787.

For a single Master/SEL-787 session, the SEL-787 stores as many as three sets of event data into a buffer. If the buffer is full as a result of multiple events with the poll cycle, any new event data will be discarded. When the buffered data have been reported (using the first-in, first-out (FIFO) principle) to the Master, those data are removed from the buffer to make room for the next event.

Table H.11 SEL-787 Analog Fault Quantities (Sheet 1 of 2)

Analog Fault Quantity	Description
FFREQ	Frequency of the fault event
FIAW1	Winding 1 A-phase of the fault event

Table H.11 SEL-787 Analog Fault Quantities (Sheet 2 of 2)

Analog Fault Quantity	Description
FIBW1	Winding 1 B-phase of the fault event
FICW1	Winding 1 C-phase of the fault event
FIGW1	Winding 1 current, calculated-residual of the fault event
FIAW2	Winding 2 A-phase of the fault event
FIBW2	Winding 2 B-phase of the fault event
FICW2	Winding 2 C-phase of the fault event
FIGW2	Winding 2 current, calculated-residual of the fault event
FIAW3	Winding 3 A-phase of the fault event
FIBW3	Winding 3 B-phase of the fault event
FICW3	Winding 3 C-phase of the fault event
FIGW3	Winding 3 current, calculated-residual of the fault event
FIAW4	Winding 4 A-phase of the fault event
FIBW4	Winding 4 B-phase of the fault event
FICW4	Winding 4 C-phase of the fault event
FIGW4	Winding 4 current, calculated-residual of the fault event
FIN	Neutral current of the fault event
FVAB	A-to-B-phase voltage of the fault event
FVBC	B-to-C-phase voltage of the fault event
FVCA	C-to-A-phase voltage of the fault event
FVAN	A-phase-to-neutral voltage of the fault event
FVBN	B-phase-to-neutral voltage of the fault event
FVCN	C-phase-to-neutral voltage of the fault event
FVG	Zero-sequence voltage of the fault event

Binary Controls

In the SEL-787, two types of controls are permitted under this protocol. They are as follows:

- Latching Single-Point: On/Off operations latch the point to 1 or 0, respectively. The points format is (Label, INF, FUN)
- Pulsing Single-Point: On operation pulses the point or triggers the point. Off has no effect. The point format is (Label, INF, FUN)

When controls are sent to the SEL-787 successfully, the relay responds with ASDU type 1 (Time Tagged Message) and COT type 20 (Positive Acknowledgment on Command) as well as with ASDU type 1 (Time Tagged Message) and COT type 12 (Remote Operation) if the control was sent remotely. The format of a binary control point within the binary control map is (Label, INF, FUN). The Label represents any valid binary control point accepted by the SEL-787. The INF parameter is an integer in the range of 0 to 255. Similarly, the FUN parameter is an integer in the range of 0 to 255. The Label can be entered by itself with the SEL-787 choosing default parameters for INF and FUN. The default parameter for INF is an available, unique value to use that is selected by the SEL-787. The default parameter for FUN is 250.

The (INF, FUN) pair needs to either be entered together or not entered at all. The SEL-787 does not accept only one member of the (INF, FUN) pair. And of course, the Label, INF, and FUN can all be manually entered. No other combinations are valid with the SEL-787.

Measurands

In the SEL-787, a measurand is defined as a group of at most 16 analog quantities with the same (INF, FUN) pair. The SEL-787 allows at most 8 measurands even if the measurand map is not completely filled with analog quantities (total of 128). Measurands are refreshed for the Master at the expiration of the 103CYC parameter and sent to the Master, once polled by the Master.

In the SEL-787, measurands are reported as ASDU type 9 (Measurands II) with COT type 2 (Cyclic). The format of an analog quantity within a measurand in the measurand map is (Label, Nominal, INF, FUN). The Label represents any valid analog quantity accepted by the SEL-787. The Nominal is the nominal value applied to the point prior to being sent out of the relay via the protocol. Its range is 0.001 to 999999. The INF parameter is an integer in the range of 0 to 255. Similarly, the FUN parameter is an integer in the range of 0 to 255. You are required to enter the Nominal value. The Label and Nominal values can be entered by themselves with the SEL-787 choosing default parameters for INF and FUN. The default parameter for INF is an available, unique value to use that is selected by the SEL-787. The default parameter for FUN is 250.

The (INF, FUN) pair needs to either be entered together or not entered at all. The SEL-787 does not accept only one member of the (INF, FUN) pair. And of course, the Label, Nominal, INF, and FUN can all be manually entered. No other combinations are valid with the SEL-787.

Meter Quantities

The meter quantities are analog quantities in the SEL-787. In the SEL-787, meter quantities are reported as ASDU type 205 (Non-Standard) with COT type 1 (Spontaneous Events). The format of a meter quantity point within the meter quantity map is (Label, Scaling, INF, FUN). The Label represents any valid meter quantity point accepted by the SEL-787. The Scaling is the scaling factor applied to the point prior to being sent out of the relay via the protocol. Its range is 0.000 to 99999. The INF parameter is an integer in the range of 0 to 255. Similarly, the FUN parameter is an integer in the range of 0 to 255. The Label can be entered by itself with the SEL-787 choosing default parameters for the Scaling, INF, and FUN. The Label and Scaling can also be entered together with the SEL-787 choosing default parameters for the INF and FUN. The default parameter for INF is an available, unique value to use that is selected by the SEL-787. The default parameter for FUN is 250.

In any case, the (INF, FUN) pair needs to either be entered together or not entered at all. The SEL-787 does not accept only one member of the (INF, FUN) pair. And finally, the Label, Scaling, INF, and FUN can all be manually entered. No other combinations are valid with the SEL-787.

The SEL-787 begins its response within 45 milliseconds of receiving a complete request. The above classes define the IEC 60870-5-103 data map in the SEL-787. The SEL-787 provides for only one IEC 60870-5-103 map. The map consists of 332 definable points. These points include 100 binary input points, 8 binary targets, 32 binary controls, 8 measurands (totaling 128 analog quantities), 32 fault analogs, and 32 meter quantities.

Time Synchronization

The SEL-787 supports time synchronization as indicated with the 103TIME parameter under the device port settings. If the value is set to yes, then the device will use the time provided by the Master when the command is given, as long as the SEL-787 is not connected to an external time source, e.g., IRIG, SNTP, or PTP. The SEL-787 sets the internal time validity bit to indicate proper reception of the time-synchronization command sequence from the Master. The date and time should not be trusted unless the validity bit is set. Time synchronization in the SEL-787 should only be used if IRIG, SNTP, or PTP sources are not available.

IEC 60870-5-103 Documentation

The *IEC 60870-5-103 Configuration/Interoperability Guide for SEL-787-4* is available on the supplied CD or as a download from the SEL website and contains the standard device profile information for the SEL-787. Please refer to this document for complete information on IEC 60870-5-103 configuration and interoperability in the SEL-787.

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Appendix I
DeviceNet Communications

Overview

This appendix describes DeviceNet communications features supported by the SEL-787 Transformer Protection Relay.

DeviceNet is a low-level communications network that provides direct connectivity among industrial devices, resulting in improved communications and device-level diagnostics that are otherwise either unavailable or inaccessible through expensive hardwired I/O interfaces. Industrial devices for which DeviceNet provides this direct connectivity include limit switches, photoelectric sensors, valve manifolds, motor starters, process sensors, bar code readers, variable frequency drives, panel displays, and operator interfaces.

The *SEL DeviceNet Communications Card User's Guide* contains more information on the installation and use of the DeviceNet card.

DeviceNet Card

NOTE: The DeviceNet option has been discontinued and is no longer available as of September 25, 2017.

The DeviceNet Card is an optional accessory that enables connection of the SEL-787 to the DeviceNet automation network. The card (see *Figure I.1*) occupies the communications expansion Slot **C** in the relay.

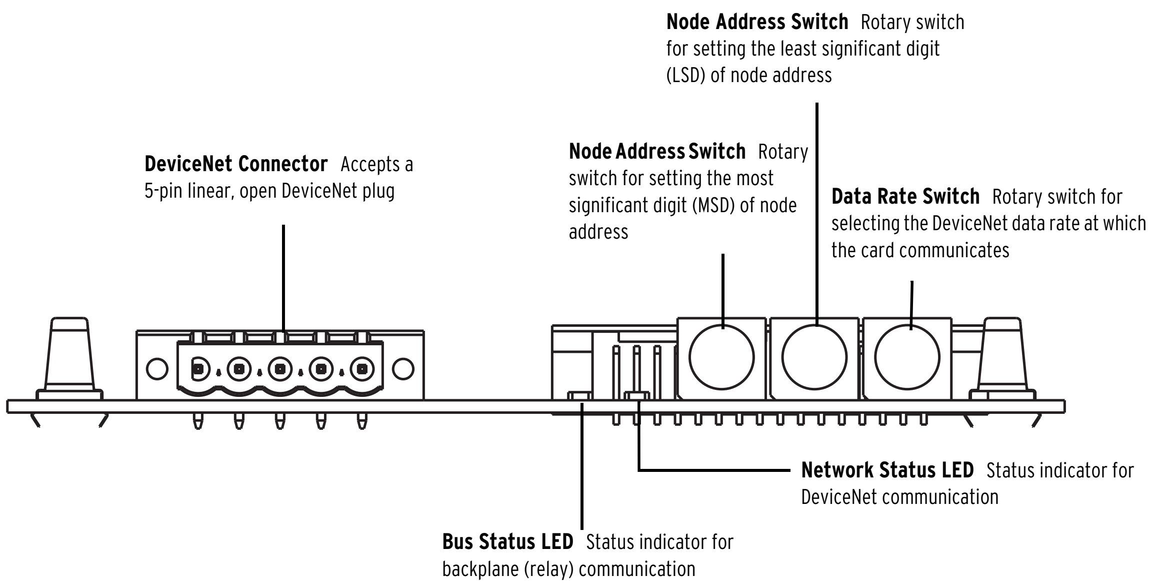

Figure I.1 DeviceNet Card Component Overview

Features

The DeviceNet Card features the following:

- The card receives the required power from the DeviceNet network.
- Rotary switches let you set the node address and network data rate prior to mounting in the SEL-787 and applying power. Alternatively, the switches can be set to positions that allow for configuration of these settings over the DeviceNet network, utilizing a network configuration tool such as RSNetWorx for DeviceNet.
- Status indicators report the status of the device bus and network communications. They are visible from the rear panel of the SEL-787 as installed.

You can do the following with the DeviceNet interface:

- Retrieve metering data such as the following:
  - Currents
  - Voltages
  - Power
  - Energy
  - Max/Min
  - Analog Inputs
  - Counters
- Retrieve transformer statistics data
- Read and set time
- Monitor device status, trip/warning status, and I/O status
- Perform high-speed control
- Reset trip, target, and accumulated data
- Retrieve events history

You can configure the DeviceNet interface through the use of address and data transmission rate switches. Indicators on the card at the back of the relay show network status and network activity.

Electronic Data Sheet

The Electronic Data Sheet (EDS) is a specially formatted file that includes configurable parameters for the device and public interfaces to those parameters. The EDS file contains information such as number of parameters; groupings; parameter name; minimum, maximum, and default values; units; data format; and scaling. This information makes possible user-friendly configuration tools (e.g., RSNetWorx for DeviceNet or DeviceNet Configurator from OMRON) for device parameter monitoring, modification, or both. The interface to the device can also be easily updated without revision of the configuration software tool itself.

All the registers defined in the Modbus Register Map (*Table E.34*) are available as parameters in a DeviceNet configuration. Parameter names, data ranges, and scaling; enumeration values and strings; parameter groups; and product information are the same as specified in the Modbus Register Map defined in *Table E.34*. The parameter numbers are offset by a count of 100 from the register numbers.

The EDS file for the SEL-787, SEL-xxxRxxx.EDS, is located on the SEL-787 Product Literature CD-ROM, or can also be downloaded from the SEL website at selinc.com.

Complete specifications for the DeviceNet protocol are available on the Open DeviceNet Vendor's Association (ODVA) website odva.org. ODVA is an independent supplier organization that manages the DeviceNet specification and supports the worldwide growth of DeviceNet.

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Appendix J
MIRRORED BITS Communications

Overview

IMPORTANT: Be sure to configure the port before connecting to a MIRRORED BITS device. If you connect an unconfigured port to a MIRRORED BITS device, the device appears to be locked up.

NOTE: Complete all of the port settings for a port that you use for MIRRORED BITS communications before you connect an external MIRRORED BITS communications device. If you connect a MIRRORED BITS communications device to a port that is not set for MIRRORED BITS communications operation, the port will be continuously busy.

MIRRORED BITS is a direct relay-to-relay communications protocol that allows IEDs to exchange information quickly, securely, and with minimal expense. Use MIRRORED BITS for functions such as remote control and remote sensing.

The SEL-787 Transformer Protection Relay supports two MIRRORED BITS communications channels, designated A and B. Use the port setting PROTO to assign one of the MIRRORED BITS communications channels to a serial port: PROTO := MBA for MIRRORED BITS communications Channel A or PROTO := MBB for MIRRORED BITS communications Channel B.

MIRRORED BITS are either Transmit MIRRORED BITS (TMB) or Received MIRRORED BITS (RMB). Transmit MIRRORED BITS include TMB1A–TMB8A (Channel A) and TMB1B–TMB8B (Channel B). The last letter (A or B) designates with which channel the bits are associated. Received bits include RMB1A–RMB8A and RMB1B–RMB8B.

Control the transmit MIRRORED BITS with SELOGIC control equations. Use the received MIRRORED BITS as arguments in SELOGIC control equations. The channel status bits are ROKA, RBADA, CBADA, LBOKA, ROKB, RBADB, CBADB, and LBOKB. You can also use these channel status bits as arguments in SELOGIC control equations. Use the **COM** command (see *Section 7: Communications*) for additional channel status information.

Because of different applications, the SEL product range supports several variations of the MIRRORED BITS communications protocol. Through the Port settings, you can set the SEL-787 for compatible operation with SEL-300 series devices, SEL-2505 Remote I/O Modules (ST option only), SEL-700 series devices, and SEL-2100 Logic Processors. When communicating with an SEL-400 series relay, be sure to set the transmission mode setting in the SEL-400 series relay to paced transmission (TXMODE := P).

Operation

Message Transmission

In the SEL-787, the MIRRORED BITS transmission rate is a function of both the data rate and the power system cycle. At data rates below 9600, the SEL-787 transmits MIRRORED BITS as fast as possible for the given rate. At rates at and above 9600 bps the SEL-787 self-paces, using a technique similar to the SEL-400 series pacing mode. There are no settings to enable or disable the self-pacing mode; the SEL-787 automatically enters the self-pacing mode at data rates of 9600, 19200, and 38400. *Table J.1* shows the transmission rates of the MIRRORED BITS messages at different rates.

NOTE: Exercise caution when applying a MIRRORED BITS channel to relays that protect systems which may not be synchronized, because the automatic pacing modes operate under the assumption that both relays are protecting systems of similar frequency. To maintain MIRRORED BITS channel dependability for this application, it is best to use a data rate of either 2400 or 4800.

Table J.1 Number of MIRRORED BITS Messages for Different Data Rates

Data Rate	Transmission Rate of MIRRORED BITS Packets
2400	15 ms
4800	7.5 ms
9600	4 times a power system cycle (automatic pacing mode)
19200	4 times a power system cycle (automatic pacing mode)
38400	4 times a power system cycle (automatic pacing mode)

Transmitting at longer intervals for data rates above 9600 avoids overflowing relays that receive MIRRORED BITS at a slower rate.

Message Reception Overview

During synchronized MIRRORED BITS communications with the communications channel in normal state, the relay decodes and checks each received message. If the message is valid, the relay sends each received logic bit (RMB*n*, where *n* = 1 through 8) to the corresponding pickup and dropout security counters, that in turn set or clear the RMB*n*A and RMB*n*B relay element bits.

Message Decoding and Integrity Checks

Set the RX_ID of the local SEL-787 to match the TX_ID of the remote SEL-787. The SEL-787 provides indication of the status of each MIRRORED BITS communications channel with Relay Word bits ROKA (receive OK) and ROKB. During normal operation, the relay sets the ROK*c* (*c* = A or B). The relay clears the ROK*c* bit when it detects any of the following conditions.

- ➤ The relay is disabled
- ➤ MIRRORED BITS are not enabled
- ➤ Parity, framing, or overrun errors
- ➤ Receive message identification error
- ➤ No message received in the time three messages have been sent when PROTO = MB*c*, or seven messages have been sent when PROTO = MB8*c*
- ➤ Loopback is enabled

The relay asserts ROK*c* only after successful synchronization as described below, and after two consecutive messages pass all of the data checks previously described. After ROK*c* is reasserted, received data can be delayed while passing through the security counters described in the following paragraph.

While ROK*c* is deasserted, the relay does not transfer new RMB data to the pickup-dropout security counters described below. Instead, the relay sends one of the user-definable default values to the security counter inputs. For each RMB*n*, use the RXDFLT setting to determine the default state the MIRRORED BITS should use in place of received data if an error condition is detected. The setting is a mask of 1s, 0s, and/or Xs (for RMB1A–RMB8A), where X represents the most recently received valid value. The positions of the 1s and 0s correspond to the respective positions of the MIRRORED BITS in the Relay Word bits (see *Appendix L: Relay Word Bits*). *Table J.2* is an extract of *Appendix L: Relay Word Bits*, showing the positions of the MIRRORED BITS.

Table J.2 Positions of the MIRRORED BITS

Bit/ Row	7	6	5	4	3	2	1	0
98	RMB8A	RMB7A	RMB6A	RMB5A	RMB4A	RMB3A	RMB2A	RMB1A
100	RMB8B	RMB7B	RMB6B	RMB5B	RMB4B	RMB3B	RMB2B	RMB1B

Table J.3 shows an example of the values of the MIRRORED BITS for a RXDFLT setting of 10100111.

Table J.3 MIRRORED BITS Values for a RXDFLT Setting of 10100111

Bit/ Row	7	6	5	4	3	2	1	0
98	1	0	1	0	0	1	1	1

Individual pickup and dropout security counters supervise the movement of each received data bit into the corresponding RMB*n* element. You can set each pickup/dropout security counter from 1 to 8. A setting of 1 causes a security counter to pass every occurrence, while a setting of 8 causes a counter to wait for eight consecutive occurrences in the received data before updating the data bits. The pickup and dropout security count settings are separate. Control the security count settings with the settings RMB*n*PU and RMB*n*DO.

A pickup/dropout security counter operates identically to a pickup/dropout timer, except that the counter uses units of counted received messages instead of time. Select a setting for the security counter in accordance with the transmission rate (see *Table J.1*). For example, when transmitting at 2400 bps, a security counter set to 2 counts delays a bit by about 30 ms. However, when operating at 9600 bps, a setting of 2 counts delays a bit by about 8.5 ms.

You must consider the impact of the security counter settings in the receiving relay to determine the channel timing performance, particularly when two relays of different processing rates are communicating via MIRRORED BITS, such as an SEL-321 and an SEL-787. The SEL-321 processes power system information each 1/8 power system cycle, but, when transmitting at 19200 bps, the SEL-787 processes MIRRORED BITS messages at 4.15 ms at 60 Hz (4 times per power system cycle at 60 Hz). Although the SEL-321 processes power system information each 1/8 power system cycle, the relay processes the MIRRORED BITS pickup/dropout security counters as MIRRORED BITS messages are received. Because the SEL-787 transmits messages at approximately 1/4-cycle processing interval (9600 bps and above, see *Table J.1*), a counter set to two in the SEL-321 delays a received bit by another approximately 1/2 cycle. However, a security counter in the SEL-787 with a setting of two delays a received bit from the SEL-321 by 1/4 cycle, because the SEL-787 is receiving new MIRRORED BITS messages each 1/8 cycle from the SEL-321.

Channel Synchronization

When an SEL-787 detects a communications error, it deasserts ROKA or ROKB. If an SEL-787 detects two consecutive communications errors, it transmits an attention message, which includes the TXID setting. The relay transmits an attention message until it receives an attention message that includes a match to the TXID setting value. If the attention message is successful, the relay has properly synchronized and data transmission resumes. If the attention message is not successful, the relay repeats the attention message until it is successful.

In summary, when a relay detects an error, it transmits an attention message until it receives an attention message with its own TX_ID included. If three or four relays are connected in a ring topology, the attention message goes all the way around the loop until the originating relay receives it. The message then dies and data transmission resumes. This method of synchronization allows the relays to reliably determine which byte is the first byte of the message. It also forces unsynchronized UARTs to become resynchronized. On the down side, this method takes down the entire loop for a receive error at any relay in the loop. This decreases availability. It also makes one-way communications impossible.

Loopback Testing

Use the **LOOP** command to enable loopback testing. In the loopback mode, you loop the transmit port to the receive port of the same relay to verify transmission messages. While in loopback mode, ROK*c* is deasserted, and another user accessible Relay Word bit, LBOK*c* (Loop Back OK) asserts and deasserts based on the received data checks (see the *Section 7: Communications* for the ACSII commands).

Channel Monitoring

Based on the results of data checks (previously described), the relay collects information regarding the 255 most recent communications errors. Each record contains at least the following fields:

- DATE—Date when the dropout occurred
- TIME—Time when the dropout occurred
- RECOVERY_DATE—Date when the channel returned to service (if the channel is currently failed, it is displayed and included in the calculations, as if its recovery were to occur at the time the report was requested)
- RECOVERY_TIME—Time when the channel returned to service (if the channel is currently failed, it is displayed and included in the calculations, as if its recovery were to occur at the time the report was requested)
- DURATION—Time elapsed during dropout
- CAUSE—Reason for dropout (see *Message Decoding and Integrity Checks on page J.2*)

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 currently failed, it is displayed and included in the calculations, as if its recovery were to occur at the time the report was requested.

NOTE: Combine error conditions including RBADA, RBADB, CBADA, and CBADB with other alarm conditions using SELOGIC control equations. You can use these alarm conditions to program the relay to take appropriate action when it detects a communications channel failure.

When the duration of an outage on Channel A or B exceeds a user-definable threshold, the relay asserts a user-accessible Relay Word bit, RBADA or RBADB. When channel unavailability exceeds a user-definable threshold for Channel A or B, the relay asserts a user-accessible Relay Word bit, CBADA or CBADB. Use the **COMM** command to generate a long or summary report of the communications errors.

Use the RBADPU setting to determine how long a channel error must last before the meter 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 meter element CBADA is asserted. The times used in the calculation are those that are available in the COM records. See *COMMUNICATIONS Command* in *Section 7: Communications* for more information.

MIRRORED BITS Protocol for the Pulsar 9600 Modem

To use a Pulsar MBT modem, set setting PROTO := MBTA or MBTB (Port settings). Setting PROTO := MBTA or MBTB hides setting SPEED (forces the data rate to 9600), hides setting PARITY (forces parity to a value of 0), hides setting RTSCTS (forces RTSCTS to a value of N), and forces the transmit time to be faster than double the power system cycle. *Table J.4* shows the difference in message transmission periods when not using the Pulsar modem (PROTO ≠ MBTA or MBTB), and using the Pulsar MBT modem (PROTO = MBTA or MBTB).

NOTE: You must consider the idle time in calculations of data transfer latency through a Pulsar MBT modem system.

Table J.4 MIRRORED BITS Communications Message Transmission Period

Data Rate	PROTO ≠ MBTA or MBTB	PROTO = MBTA or MBTB
38400	4 times a power system cycle	n/a
19200	4 times a power system cycle	n/a
9600	4 times a power system cycle	2 times a power system cycle
4800	7.5 ms	n/a

The relay sets RTS to a negative voltage at the EIA-232 connector to signify that MIRRORED BITS communications matches this specification.

Settings

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. The standard MIRRORED BITS protocols MBA and MBB use a 6-data bit format for data encoding. The MB8 protocols MB8A and MB8B use an 8-data bit format, which allows MIRRORED BITS to operate on communications channels requiring an 8-data bit format. *Table J.5* shows the MIRRORED BITS protocol port settings, ranges, and default settings for Port F, Port 3, and Port 4.

Table J.5 MIRRORED BITS Protocol Settings (Sheet 1 of 2)

Setting Prompt	Setting Description	Factory-Default Settings
TXID	MIRRORED BITS ID of This Device (1–4)	2
RXID	MIRRORED BITS ID of Device Receiving From (1–4)	1
RBADPU	Outage Duration to Set RBAD (1–10000 seconds)	60
CBADPU	Channel Unavailability to Set CBAD (1–10000 ppm)	1000
RXDFLT	8 char string of 1s, 0s, or Xs	XXXXXXXX
RMB1PU	RMB1 Pickup Debounce Messages (1–8 messages)	1

Table J.5 MIRRORED BITS Protocol Settings (Sheet 2 of 2)

Setting Prompt	Setting Description	Factory-Default Settings
RMB1DO	RMB1 Dropout Debounce Messages (1–8 messages)	1
RMB2PU	RMB2 Pickup Debounce Messages (1–8 messages)	1
RMB2DO	RMB2 Dropout Debounce Messages (1–8 messages)	1
RMB3PU	RMB3 Pickup Debounce Messages (1–8 messages)	1
RMB3DO	RMB3 Dropout Debounce Messages (1–8 messages)	1
RMB4PU	RMB4 Pickup Debounce Messages (1–8 messages)	1
RMB4DO	RMB4 Dropout Debounce Messages (1–8 messages)	1
RMB5PU	RMB5 Pickup Debounce Messages (1–8 messages)	1
RMB5DO	RMB5 Dropout Debounce Messages (1–8 messages)	1
RMB6PU	RMB6 Pickup Debounce Messages (1–8 messages)	1
RMB6DO	RMB6 Dropout Debounce Messages (1–8 messages)	1
RMB7PU	RMB7 Pickup Debounce Messages (1–8 messages)	1
RMB7DO	RMB7 Dropout Debounce Messages (1–8 messages)	1
RMB8PU	RMB8 Pickup Debounce Messages (1–8 messages)	1
RMB8DO	RMB8 Dropout Debounce Messages (1–8 messages)	1

Appendix K
Synchrophasors

Overview

The SEL-787 Transformer Protection Relay provides phasor measurement unit (PMU) capabilities when connected to an IRIG-B time source with an accuracy of ±10 µs or better. Synchrophasor data are available via the **MET PM** ASCII command and the IEEE C37.118 protocol.

Synchrophasor measurement refers to the concept of providing measurements taken on a synchronized schedule in multiple locations. A high-accuracy clock, commonly called a 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 SEL-787 relays, to synchronize the gathering of power system data. The accurate clock allows precise event report triggering and other offline analysis functions. 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.

The SEL-787 Global settings class contains the synchrophasor settings, including the choice of transmitted synchrophasor data set. The Port settings class selects which serial port(s) or Ethernet port can be used for synchrophasor protocol use. See *Settings for Synchrophasors on page K.4*.

The SEL-787 timekeeping function generates status Relay Word bits and time-quality information that is important for synchrophasor measurement. Some protection SELOGIC variables and programmable digital trigger information is also added to the Relay Word bits for synchrophasors. See *Synchrophasor Relay Word Bits on page K.12*.

When synchrophasor measurement is enabled, the SEL-787 creates the synchrophasor data set at a user-defined rate. Synchrophasor data are available in ASCII format over a serial port set to PROTO = SEL. See *View Synchrophasors Using the MET PM Command on page K.15*.

The value of synchrophasor data increases greatly when the data can be shared over a communications network in real time. A synchrophasor protocol is available in the SEL-787 that allows for a centralized device to collect data efficiently from several PMUs. Some possible uses of a system-wide synchrophasor system include the following:

- Power-system state measurement
- Generator model validation
- Wide-area network protection and control schemes
- Small-signal analysis
- Power-system disturbance analysis

The SEL-3373 is a phasor data concentrator (PDC) designed to interface with PMUs, other PDCs, and synchrophasor vector processors (SVPs). The SEL-3373 has two primary functions. The first is to collect and correlate synchrophasor data from multiple PMUs. The second is to then compact and transmit synchrophasor data either to a data historian for post-analysis or to visualization software (SEL-5078-2 SYNCHROWAVE Central Visualization and Analysis Software) for real-time viewing of a power system.

SYNCHROWAVE Central quickly translates power system data into visual information. It is a powerful, yet easy-to-use solution for displaying and analyzing real-time streaming data, archived data, and relay event data, and provides a time-synchronized wide-area view of your system. SYNCHROWAVE Central includes Event Viewer, providing engineers and operators with the ability to view PMU data and perform event analysis by viewing relay event reports directly from SYNCHROWAVE Central.

The SEL-3378 Synchrophasor Vector Processor (SVP) is a real-time synchrophasor programmable logic controller. Use the SVP to collect synchrophasor messages from relays and PMUs. The SVP time-aligns incoming messages, processes these messages with an internal logic engine, and sends control command to external devices to perform user-defined actions. Additionally, the SVP can send calculated or derived data to devices such as other SVPs, PDCs, and monitoring systems.

The SEL-787 supports the protocol portion of the IEEE C37.118, Standard for Synchrophasors for Power Systems. In the SEL-787, this protocol is referred to as C37.118. See *Settings Affect Message Contents on page K.16*.

Synchrophasor Measurement

The PMU in the SEL-787 measures voltages and currents on a constant-time basis. These samples are time-stamped with the IRIG time source. The relay then filters the measured samples according to Global setting PMAPP := Fast or Narrow (see *PMAPP on page K.5*).

The phase angle is measured relative to an absolute time reference, which is represented by a cosine function in *Figure K.1*. The time-of-day is shown for the two time marks. The reference is consistent with the phase reference defined in the IEEE C37.118 standard. During steady-state conditions, the SEL-787 synchrophasor values can be directly compared to values from other PMUs that conform to IEEE C37.118.

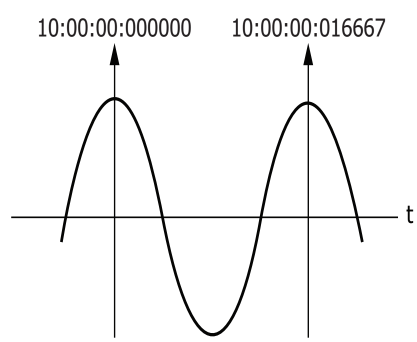

Figure K.1 Phase Reference

The TSOK Relay Word bit asserts when the SEL-787 has determined that the IRIG-B time source has sufficient accuracy and the synchrophasor data meets the specified accuracy. Synchrophasors are still measured if the time source threshold is not met, as indicated by Relay Word bit TSOK = logical 0. The **MET PM** command is not available in this case.

The instrumentation transformers (PTs or CTs) and the interconnecting cables may introduce a time shift in the measured signal. Global settings VCOMP, VSCOMP, and IW*n*COMP (where *n* = 1, 2, 3, or 4), entered in degrees, are added to the measured phasor angles to create the corrected phasor angles, as shown in *Figure K.2*, *Figure K.3*, and *Equation K.1*. The VCOMP, VSCOMP, and IW*n*COMP settings may be positive or negative values. The corrected angles are displayed in the **MET PM** command and transmitted as part of synchrophasor messages.

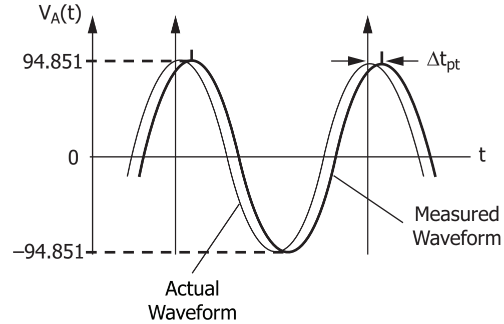

Figure K.2 Waveform at Relay Terminals May Have a Phase Shift

$$\text{Compensation Angle} = \frac{\Delta t_{pt}}{\left(\frac{1}{\text{freq}_{\text{nominal}}}\right)} \cdot 360°$$
$$= \Delta t_{pt} \cdot \text{freq}_{\text{nominal}} \cdot 360°$$

Equation K.1

If the time shift on the PT measurement path Δt_{pt} = 0.784 ms and the nominal frequency, $\text{freq}_{\text{nominal}}$ = 60Hz, use *Equation K.2* to obtain the correction angle:

$$0.784 \cdot 10^{-3}\text{s} \cdot 60\text{s}^{-1} \cdot 360° = 16.934°$$

Equation K.2

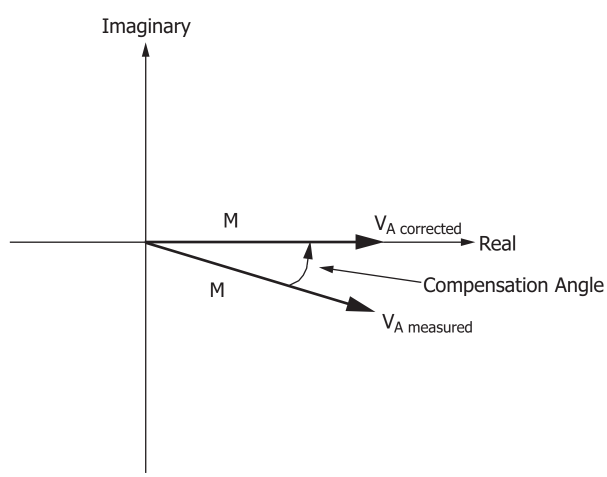

Figure K.3 Correction of Measured Phase Angle

The phasors are rms values scaled in primary units, as determined by Group settings PTR, PTRS (for synchronism-check input), CTR*n* (where *n* = 1, 2, 3, or 4), and CTRN.

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 almost always shows 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 Synchrophasors

The PMU settings are listed in *Table K.1*. Modify these settings when you want to use the IEEE C37.118 synchrophasor protocol.

The Global enable setting EPMU must be set to Y before the remaining SEL-787 synchrophasor settings are available. No synchrophasor data collection can take place when EPMU := N.

You must make the serial port settings in *Table K.5* or Ethernet port settings in *Table K.6* to transmit data with a synchrophasor protocol. It is possible to set EPMU := Y without using any ports for synchrophasor protocols. For example, the port **MET PM** ASCII command can still be used.

NOTE: Synchrophasors are not supported in the SEL-787 models that have a combination of LEA and conventional cards in Slot E and Slot Z. EMPU is forced to N in these models.

Table K.1 PMU Settings in the SEL-787 for IEEE C37.118 Protocol in Global Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE SYNCHRONIZED PHASOR MEASUREMENT	Y, N	EPMU := N[a]
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	MRATE := 10
PMU APPLICATION	Fast := Fast Response, Narrow := Narrow Bandwidth	PMAPP := NARROW
FREQUENCY-BASED PHASOR COMPENSATION	Y, N	PHCOMP := Y
STATION NAME	16 characters	PMSTN := SEL-787 XFRMR1
PMU HARDWARE ID	1–65534	PMID := 1
PHASOR DATA SET, VOLTAGES	V1, ALL, NA	PHDATAV := V1
VOLTAGE ANGLE COMP FACTOR	–179.99 to 180.00 deg	VCOMP := 0.00
VS VOLTAGE ANGLE COMP FACTOR	–179.99 to 180.00 deg	VSCOMP := 0.00
PHASOR DATA SET, CURRENTS	I1, ALL, NA	PHDATAI := I1
CURRENT SOURCE	IW1, IW2, IW3, IW4, ALL	PHCURR := IW1
CURRENT ANGLE COMP FACTOR	–179.99 to 180.00 deg (where *n* = 1, 2, 3, or 4)	IW*n*COMP := 0.00

Table K.1 PMU Settings in the SEL-787 for IEEE C37.118 Protocol in Global Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
NUMBER OF ANALOG VALUES	0–4	NUMANA := 0
NUMBER OF 16-BIT DIGITAL STATUS WORDS	0, 1	NUMDSW := 0
TRIGGER REASON BIT 1	SELOGIC	TREA1 := TRIP OR ER
TRIGGER REASON BIT 2	SELOGIC	TREA2 := 0
TRIGGER REASON BIT 3	SELOGIC	TREA3 := 0
TRIGGER REASON BIT 4	SELOGIC	TREA4 := 0
TRIGGER	SELOGIC	PMTRIG := TREA1 OR TREA2 OR TREA3 OR TREA4
IRIG-B CONTROL BITS DEFINITION	NONE, C37.118	IRIGC := NONE

[a] Set EPMU := Y to access the remaining settings.

Certain settings in *Table K.1* are hidden, depending on the status of other settings. For example, if PHDATAI := NA, the IW*n*COMP settings are hidden to limit the number of settings for your synchrophasor application. Definitions for the settings in *Table K.1* are as follows:

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 seven settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size. See *Communications Bandwidth on page K.16* 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 one-quarter 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-787 synchrophasor data with other PMU data that do not employ frequency compensation.

PMSTN and PMID

Defines the name and number of the PMU. The PMSTN setting is an ASCII string with as many as 16 characters. The PMID setting is a numeric value. Use your utility or synchrophasor data concentrator naming convention to determine these settings.

PHDATAV, VCOMP, 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 seven settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth on page K.16* for detailed information.

- ➤ PHDATAV := V1 transmits only positive-sequence voltage, V_1
- ➤ PHDATAV := ALL transmits V_1, V_A, V_B, V_C, and V_S (if available). VAB, VBC, VCA are transmitted if DELTA_Y := DELTA.
- ➤ PHDATAV := NA does not transmit any voltages

Table K.2 describes the order of synchrophasors inside the data packet.

The VCOMP and VSCOMP settings allow correction for any steady-state voltage phase errors (from the potential transformers or wiring characteristics). See *Synchrophasor Measurement on page K.2* for details on this setting.

PHDATAI and IWnCOMP

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 the seven settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth on page K.16* for detailed information.

- ➤ PHDATAI := I1 transmits only positive-sequence current, I_1 (for the winding(s) selected by the PHCURR setting)
- ➤ PHDATAI := ALL transmits I_1, I_A, I_B, and I_C (for the winding(s) selected by the PHCURR setting)
- ➤ PHDATAI := NA does not transmit any currents

The IW*n*COMP setting (where *n* = Winding 1, 2, 3, or 4) allows correction for any steady-state phase errors (from the current transformers or wiring characteristics). Note that the relay uses the IW3COMP setting for Winding 3 currents as well as the neutral current (IN). See *Synchrophasor Measurement on page K.2* for details on these settings.

Table K.2 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. Real values are transmitted first and imaginary 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, selected phase voltages are transmitted first, followed by VS input voltage (if your relay includes the VS option), positive-sequence voltage, and positive-sequence current.

PHCURR

PHCURR selects which currents (W1, W2, W3, W4, or ALL) 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 the seven settings that determines the minimum port SPEED necessary to support the synchrophasor data packet rate and size. See *Communications Bandwidth on page K.16* for detailed information.

Table K.2 describes the order of synchrophasors inside the data packet.

Table K.2 Synchrophasor Order in Data Stream (Voltages and Currents)

Synchrophasors[a, b, c] Rectangular Real	Synchrophasors[a, b, c] Rectangular Imaginary	Included When Global Settings Are as Follows:
V1	V1	PHDATAV := V1 or ALL
VA	VA	PHDATAV := ALL
VB	VB	
VC	VC	
VS	VS	
I1W1	I1W1	PHDATAI := I1 or ALL (if selected by the PHCURR setting)
I1W2	I1W2	
I1W3	I1W3	
I1W4	I1W4	
IAW1	IAW1	PHDATAI := ALL (if selected by the PHCURR setting)
IBW1	IBW1	
ICW1	ICW1	
IAW2	IAW2	
IBW2	IBW2	
ICW2	ICW2	
IAW3	IAW3	
IBW3	IBW3	
ICW3	ICW3	
IAW4	IAW4	
IBW4	IBW4	
ICW4	ICW4	

[a] Synchrophasors are included in the order shown (for example, voltages, if selected, always precede currents).
[b] Synchrophasors are transmitted as primary values. Relay settings CTRn (where n = 1, 2, 3, or 4), CTRN, PTR, PTRS are used to scale the values. If wye-connected CTs are used, the relay calculates the primary currents from the secondary values by multiplying them with the corresponding CT ratio. If delta-connected CTs are used, the relay calculates the primary currents from the secondary values by multiplying them with the corresponding CT ratio and dividing them by the $\sqrt{3}$. The angles are not compensated. For more details, refer to Delta-Connected CTs on page 5.3.
[c] When PHDATAV := ALL and DELTA_Y := WYE, phase voltages VA, VB, and VC are transmitted. Phase voltages VAB, VBC, and VCAX are transmitted when DELTA_Y := DELTA.

NUMANA

Selects the number of user-definable analog values to be included in the synchrophasor data stream. This setting is one of seven settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size. See *Communications Bandwidth on page K.16* for detailed information.

The choices for this setting depend on the synchrophasor system design.

- ➤ Setting NUMANA := 0 sends no user-definable analog values.
- ➤ Setting NUMANA := 1–4 sends the user-definable analog values, as listed in *Table K.3*.

The format of the user-defined analog data is always floating point, and each value occupies four bytes.

Table K.3 User-Defined Analog Values Selected by the NUMANA Setting

NUMANA Setting	Analog Quantities Sent	Total Number of Bytes Used for Analog Values
0	None	0
1	MV29	4
2	Above, plus MV30	8
3	Above, plus MV31	12
4	Above, plus MV32	16

NUMDSW

Selects the number of user-definable digital status words to be included in the synchrophasor data stream. This setting is one of seven settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size. See *Communications Bandwidth on page K.16* for detailed information.

The choices for this setting depend on the synchrophasor system design. The inclusion of binary data can help indicate breaker status or other operational data to the synchrophasor processor.

- ➤ Setting NUMDSW := 0 sends no user-definable binary status words.
- ➤ Setting NUMDSW := 1 sends the user-definable binary status words, as listed in *Table K.4*.

Table K.4 User-Defined Digital Status Words Selected by the NUMDSW Setting

NUMDSW Setting	Digital Status Words Sent	Total Number of Bytes Used for Digital Values
0	None	0
1	[SV32, SV31…SV17]	2

TREA1, TREA2, TREA3, TREA4, and PMTRIG

Defines the programmable trigger bits as allowed by IEEE C37.118.

Each of the four Trigger Reason settings, TREA1–TREA4, and the PMU Trigger setting, PMTRIG, are SELOGIC control equations in the Global settings class. The SEL-787 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-787 Event Report Trigger ER, a SELOGIC control equation in the Report settings class.

The trigger reason equations represent the Trigger Reason bits in the STAT field of the data packet. After the trigger reason bits are set to convey a message, the PMTRIG Equation should be asserted for a reasonable amount of time, to allow the synchrophasor processor to read the TREA1–TREA4 fields.

The SEL-787 automatically sets the TREA1–TREA4 or PMTRIG Relay Word bits based on their default SELOGIC control equation. To change the operation of these bits they must be programmed.

These bits may be used to send various messages at a low bandwidth via the synchrophasor message stream. Digital Status Words may also be used to send binary information directly, without the need to manage the coding of the trigger reason messages in SELOGIC.

Use these Trigger Reason bits if your synchrophasor system design requires these bits. The SEL-787 synchrophasor processing and protocol transmission are not affected by the status of these bits.

IRIGC

NOTE: Set IRIGC = C37.118 only when an IRIG-B000 signal is connected to the relay. Set IRIGC = NONE when an IRIG-B002 (standard IRIG) signal is connected.

Defines if IEEE C37.118 control bit extensions are in use. Control bit extensions contain information such as leap second, UTC, daylight-saving time (DST), and time quality. When your satellite-synchronized clock provides these extensions your relay is able to adjust the synchrophasor time stamp accordingly.

- IRIGC := NONE ignores bit extensions
- IRIGC := C37.118 extracts bit extensions and corrects synchrophasor time accordingly

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 K.5*.

Table K.5 SEL-787 Serial Port Settings for Synchrophasors

Setting Prompt	Setting Range	Setting Name := Factory Default
PROTOCOL	SEL, MOD, DNET, DNP, EVMSG, PMU, MBA, MBB, MB8A, MB8B, MBTA, MBTB[a]	PROTO := SEL[b]
DATA SPEED	300 to 38400	SPEED := 9600
STOP BITS	1, 2	STOPBIT := 1
HDWR HANDSHAKING	Y, N	RTSCTS := N

[a] Some of the other PROTO setting choices may not be available.
[b] Set PROTO = PMU to enable IEEE C37.118 synchrophasor protocol on this port.

The serial port settings for PROTO := PMU, shown in *Table K.5*, do not include the settings BITS and PARITY; these two settings are internally fixed as BITS := 8, PARITY := N.

To enable IEEE C37.118 synchrophasor protocol on the serial port, set the Global setting EPMU := Y and set the corresponding serial Port setting PROTO := PMU.

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 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 K.6*.

Ethernet port setting EPMIP cannot be set when Global setting EPMU := N. Synchrophasors must be enabled (EPMU := Y) before EPMIP can be set.

Table K.6 SEL-787 Ethernet Port Settings for Synchrophasors

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE PMU PROCESSING[a]	0–2	EPMIP := 0[b]
PMU OUTPUT 1 TRANSPORT SCHEME	OFF, TCP, UDP_S, UDP_T, UDP_U	PMOTS1 := OFF
PMU OUTPUT 1 CLIENT IP (REMOTE) ADDRESS	www.xxx.yyy.zzz[c, d]	PMOIPA1 := 192.168.1.3
PMU OUTPUT 1 TCP/IP (LOCAL) PORT NUMBER	1–65534[c, d]	PMOTCP1 := 4712
PMU OUTPUT 1 UDP/IP DATA (REMOTE) PORT NUMBER	1–65534[c, e, f]	PMOUDP1 := 4713
PMU OUTPUT 2 TRANSPORT SCHEME	OFF, TCP, UDP_S, UDP_T, UDP_U	PMOTS2 := OFF
PMU OUTPUT 2 CLIENT IP (REMOTE) ADDRESS	www.xxx.yyy.zzz[g]	PMOIPA2 := 192.168.1.4
PMU OUTPUT 2 TCP/IP (LOCAL) PORT NUMBER	1–65534[d, g]	PMOTCP2 := 4722
PMU OUTPUT 2 UDP/IP DATA (REMOTE) PORT NUMBER	1–65534[f, g, h]	PMOUDP2 := 4713

[a] Setting is hidden when EPMU := N.
[b] Set EPMIP := 1 or 2 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.
[c] Setting hidden when PMOTS1 := OFF.
[d] Port number must be unique.
[e] Setting is hidden when PMOTS1 := TCP.
[f] Port numbers must be unique for PMOUDP1, PMOUDP2, and DNPUDP1–3, if active.
[g] Setting is hidden when PMOTS2 := OFF.
[h] Setting is hidden when PMOTS2 := TCP.

Definitions for some of the settings in *Table K.6* are discussed in the following text.

PMOTS1 and PMOTS2

These settings select the PMU Output Transport Scheme for Session 1 and Session 2, respectively.

PMOTSn := TCP

This setting establishes a single, persistent TCP socket for transmitting and receiving synchrophasor messages (both commands and data), as illustrated in *Figure K.4*.

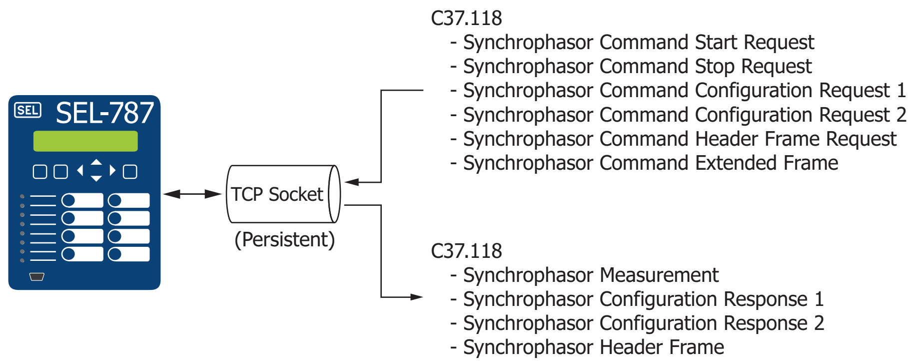

Figure K.4 TCP Connection

PMOTSn := UDP_T

This setting establishes two socket connections. A non-persistent TCP connection is used for receiving synchrophasor command messages as well as synchrophasor configuration and header response messages. A persistent UDP connection is used to transmit synchrophasor data messages. *Figure K.5* depicts the UDP_T connection.

PMOTSn := UDP_U

This setting uses the same connection scheme as the UDP_T setting, except that the synchrophasor configuration and header response messages are sent over the UDP connection, as shown in *Figure K.5*.

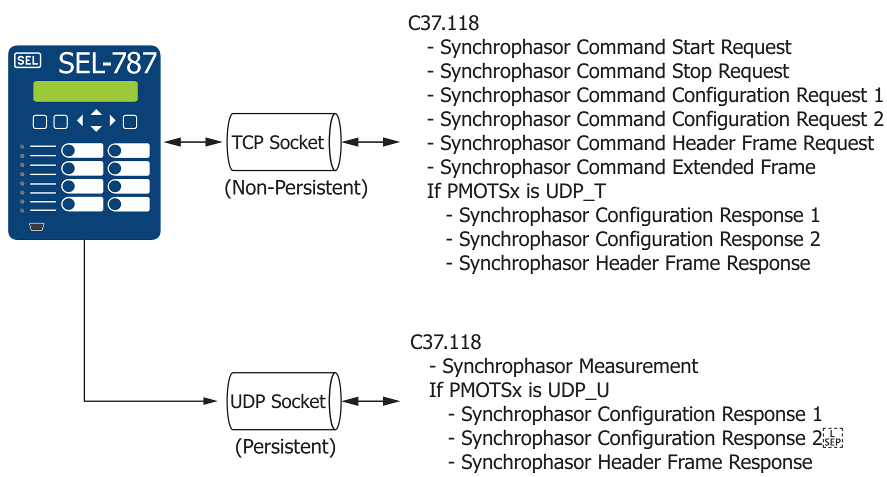

Figure K.5 UDP_T and UDP_U Connections

PMOTSn := UDP_S

NOTE: The UDP setting options (UDP_T, UDP_U, and UDP_S) allow for both Multicast and Unicast IP addresses.

This setting establishes a single persistent UDP socket to transmit synchrophasor messages. Synchrophasor data are transmitted whenever new data are read. With this communications scheme, the relay sends a “Synchrophasor Configuration Response 2” once every minute, as shown in *Figure K.6*.

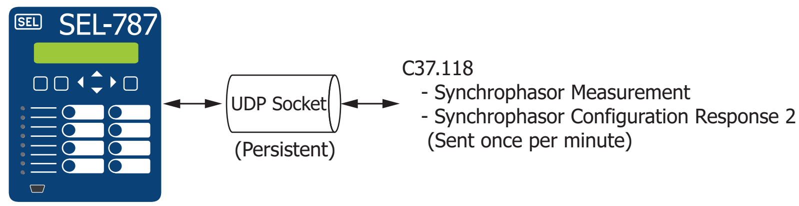

Figure K.6 UDP_S Connection

PMOIPA1 and PMOIPA2

Defines the PMU Output Client IP Address for Session 1 and Session 2, respectively.

PMOTCP1 and PMOTCP2

Defines the TCP/IP (Local) Port Number for Session 1 and Session 2, respectively. The TCP port numbers must all be unique.

PMOUDP1 and PMOUDP2

Defines the UDP/IP (Remote) Port Number for Session 1 and Session 2, respectively. The TCP port numbers must all be unique.

Synchrophasor Relay Word Bits

Table K.7 and *Table K.8* list the SEL-787 Relay Word bits that are related to synchrophasor measurement. The Synchrophasor Trigger Relay Word bits in *Table K.7* follow the state of the SELOGIC control equations of the same name, listed at the bottom of *Table K.1*. These Relay Word bits are included in the IEEE C37.118 synchrophasor data frame STAT field. See *Table K.4* for standard definitions for these settings.

Table K.7 Synchrophasor Trigger Relay Word Bits

Name	Description
PMTRIG	Trigger (SELOGIC)
TREA4	Trigger Reason Bit 4 (SELOGIC)
TREA3	Trigger Reason Bit 3 (SELOGIC)
TREA2	Trigger Reason Bit 2 (SELOGIC)
TREA1	Trigger Reason Bit 1 (SELOGIC)

Time Quality of the IRIG Source

The time-synchronization Relay Word bits in *Table K.8* indicate the present status of the timekeeping function of the SEL-787.

Table K.8 Time-Synchronization Relay Word Bits

Name	Description
IRIGOK	Asserts while relay time is based on IRIG-B time source.
TSOK	Time synchronization OK. Asserts while time is based on an IRIG-B time source of sufficient accuracy for synchrophasor measurement.
PMDOK	Phasor measurement data OK. Asserts when the SEL-787 is enabled, synchrophasors are enabled (Global setting EPMU = Y), Relay Word bit TSOK = 1, the frequency is 40–70 Hz, and the positive-sequence voltage(s) V1 > 10 V secondary. The SEL-787-4X model uses the positive-sequence current I1 > 0.1 • I_{NOM} secondary, instead of the positive-sequence voltage.

The Relay Word bit TSOK provides the indication that the time synchronization is OK. The SEL-787 determines the suitability of the IRIG-B signal for normal accuracy by applying several tests:

- Seconds, minutes, and day fields are in range
- Time from two consecutive messages differs by one second, except for leap second or DST transitions
- When IRIGC = C37.118, the signal contains the correct parity bit

The SEL-787 determines the suitability of the IRIG-B signal for high-accuracy timekeeping by applying two additional tests:

NOTE: The jitter measurement for the IRIG signal could take as long as 15 seconds to determine. During this time TSOK is not asserted.

- 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 = NONE, the relay asserts TSOK when only the first test is met. When IRIGC = C37.118 and an appropriate IRIG-B signal is connected, Relay Word bit TSOK only asserts when these two tests are met. The time error information in the IRIG-B control field is mapped to the TQUAL bits in the relay. *Table K.9* provides the information for the TQUAL bits and how they translate to time quality. The values 0 (Locked) and 4 (1 microsecond) indicate that the relay is receiving high accuracy IRIG.

When the IRIG signal is lost, IRIGOK deasserts. However, TSOK remains asserted for a holdover period of 15 seconds. If the IRIG signal is not restored within 15 seconds, TSOK also deasserts.

Table K.9 TQUAL Bits Translation to Time Quality (Sheet 1 of 2)

TQUAL8	TQUAL4	TQUAL2	TQUAL1	Value	Time Quality
0	0	0	0	0	Locked
0	0	0	1	1	1 nanosecond
0	0	1	0	2	10 nanoseconds
0	0	1	1	3	100 nanoseconds
0	1	0	0	4	1 microsecond
0	1	0	1	5	10 microseconds
0	1	1	0	6	100 microseconds
0	1	1	1	7	1 millisecond

Table K.9 TQUAL Bits Translation to Time Quality (Sheet 2 of 2)

TQUAL8	TQUAL4	TQUAL2	TQUAL1	Value	Time Quality
1	0	0	0	8	10 milliseconds
1	0	0	1	9	100 milliseconds
1	0	1	0	10	1 second
1	0	1	1	11	10 seconds
1	1	0	0	12	100 seconds
1	1	0	1	13	1000 seconds
1	1	1	0	14	10000 seconds
1	1	1	1	15	Fault

The Relay Word bit PMDOK provides the indication that the phasor measurement data are acceptable. Based on the SEL-787 model, PMDOK asserts under the following conditions.

For the SEL-787-3E and SEL-787-3S models:

1. The relay is enabled
2. EPMU = Y
3. IRIGOK = 1
4. TSOK = 1
5. The synchrophasor filter buffers are fully primed
6. The magnitude of the positive-sequence voltage, |V1| > 10 V
7. The frequency is 40–70 Hz

For the SEL-787-4X models:

1. The relay is enabled
2. EPMU = Y
3. IRIGOK = 1
4. TSOK = 1
5. The synchrophasor filter buffers are fully primed
6. The magnitude of the positive-sequence current, $|I1| > 0.1 * I_{NOM}$ (I_{NOM} =1 A or 5 A of Winding 1 based on the Model Option Table)
7. The frequency is FNOM (50/60 Hz)

PMDOK takes 15 seconds to assert when the relay is first powered, after any of the settings in *Table K.1* are changed, or when an IRIG-B time signal is first connected. This is because of the delay in time qualification (TSOK to assert).

View Synchrophasors Using the MET PM Command

The **MET PM** serial port ASCII command may be used to view the SEL-787 synchrophasor measurements. See *MET Command (Metering Data) on page 7.56* 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 and to compare it with similar data captured in other PMU(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 PHDATAV and PHDATAI. The **MET PM** command can function even when no serial ports are sending synchrophasor data—it is unaffected by serial port setting PROTO.

NOTE: To have the MET PM xx:yy:zz response transmitted from a serial port, the corresponding port must have the AUTO setting set to Y (YES).

The **MET PM** command only operates when the SEL-787 is in the IRIG timekeeping mode, as indicated by Relay Word bit TSOK = logical 1.

Figure K.7 shows a sample **MET PM** command response. The synchrophasor data are also available via the **HMI > Meter PM** menu in QuickSet, and has a similar format to *Figure K.7*.

The **MET PM** ***time*** command can be used to direct the SEL-787 to display the synchrophasor for an exact specified time, in 24-hour format. For example, entering the command **MET PM 14:14:12** results in a response similar to *Figure K.7* occurring just after 14:14:12, with the time stamp 14:14:12.000. See *Section 7: Communications* for complete command options and error messages.

```
=>>MET PM <Enter>

SEL-787-3S                                  Date: 08/26/2013   Time: 10:20:17.000
TRNSFRMR RELAY                              Time Source: External

Time Quality   Maximum time synchronization error:    0.000 (ms)  TSOK = 1

Synchrophasors

                     Phase Voltages             Pos. Sequence Voltage
                 VA        VB        VC                 V1
MAG (kV)         11.65     17.47     22.78               3.19
ANG (DEG)       115.15    115.48    116.03             -34.59

                 VS
MAG (V)           1.20
ANG (DEG)        90.00

                     Phase Currents             Pos. Sequence Current
                 IAW1      IBW1      ICW1               I1W1
MAG (A)          99.15    197.92    298.93              57.32
ANG (DEG)       109.44    110.40    110.77             -38.27

                 IAW2      IBW2      ICW2               I1W2
MAG (A)        3973.19   4997.14   6016.55             586.00
ANG (DEG)       111.17    111.48    111.96             -36.67

                 IAW3      IBW3      ICW3               I1W3
MAG (A)        6910.09   7960.45   8919.38             574.28
ANG (DEG)       112.91    113.23    113.73             -35.07

FREQ (Hz) 59.989
Rate-of-change of FREQ (Hz/s)   -0.01
```

Figure K.7 Sample MET PM Command Response

```
Digitals

SV24    SV23    SV22    SV21    SV20    SV19    SV18    SV17
 0       0       0       0       0       0       0       0
SV32    SV31    SV30    SV29    SV28    SV27    SV26    SV25
 0       0       0       0       0       0       0       0

Analogs

MV29      0.000  MV30      0.000  MV31      0.000  MV32      0.000

=>>
```

Figure K.7 Sample MET PM Command Response (Continued)

IEEE C37.118 Synchrophasor Protocol

The SEL-787 complies with IEEE C37.118, Standard for Synchrophasors for Power Systems. The protocol is available on serial Ports 2, 3, 4, and F by setting the corresponding port setting PROTO := PMU. In addition, synchrophasor data can be accessed through the Ethernet port when the EPMIP setting is enabled.

This section does not cover the details of the protocol, but highlights some of the important features and options that are available.

Settings Affect Message Contents

The SEL-787 allows several options for transmitting synchrophasor data. These are controlled by Global settings described in *Settings for Synchrophasors on page K.4*. You can select how often to transmit the synchrophasor messages (MRATE) and which synchrophasors to transmit (PHDATAV and PHDATAI). The SEL-787 automatically includes the frequency and rate-of-change-of-frequency in the synchrophasor messages.

The relay can include as many as four user-programmable analog values in the synchrophasor message, as controlled by Global setting NUMANA, and 0 or 16 digital status values, as controlled by Global setting NUMDSW.

The SEL-787 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.

Communications Bandwidth

A PMU that is configured to transmit a single synchrophasor (positive-sequence voltage, for example) at a message rate of once per second places little burden on the communications channel. As more synchrophasors, analog values, or digital status words are added, or if the message rate is increased, some communications channel restrictions come into play.

The IEEE C37.118 synchrophasor message format always includes 18 bytes for the message header and terminal ID, time information, status bits, and CRC value. The selection of synchrophasor, programmable analog, and programmable digital data adds to the byte requirements. *Table K.10* can be used to calculate the number of bytes in a synchrophasor message.

Table K.10 Size of a IEEE C37.118 Synchrophasor Message

Item	Possible Number of Quantities	Bytes per Quantity	Number of Bytes	
			Minimum	Maximum
Fixed			18	18
Synchrophasors	0–17	4	0	68
Frequency/DFDT	2 (fixed)	2	4	4
Analog Values	0–4	4	0	16
Digital Status Words	0–1	2	0	2
Total (Minimum and Maximum)			22	108

Table K.11 lists the data rate settings available on any SEL-787 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 K.11 Serial Port Bandwidth for Synchrophasors (in Bytes)

Global Setting MRATE	Port Setting SPEED								
	300	600	1200	2400	4800	9600	19200	38400	57600
1	21	42	85	170	340	680	1360	2720	4080
2		21	42	85	170	340	680	1360	2040
4 (60 Hz only)			21	42	85	170	340	680	1020
5				34	68	136	272	544	816
10					34	68	136	272	408
12 (60 Hz only)					28	56	113	226	340
15 (60 Hz only)					21	45	90	181	272
20 (60 Hz only)						34	68	136	204
25 (50 Hz only)						27	54	108	163
30 (60 Hz only)						22	45	90	136
50 (50 Hz only)							27	54	81
60 (60 Hz only)							22	45	68

Referring to *Table K.10* and *Table K.11*, it is clear that the lower SPEED settings are very restrictive.

The smallest practical synchrophasor message would be comprised of one digital status word, and this message would consume 24 bytes (includes frequency and DFDT). This type of message could be sent at any message rate (MRATE = 60) when SPEED := 38400, to MRATE := 5 when SPEED := 2400, and to MRATE := 1 when SPEED := 600.

Another example application has messages comprised of nine synchrophasors, one digital status word, and two analog values. This type of message would consume 68 bytes. The 68-byte message could be sent at any message rate less than or equal to ten (MRATE) when SPEED := 9600.

Protocol Operation

The SEL-787 only transmits synchrophasor messages over serial ports that have setting PROTO := PMU or Ethernet ports that have setting EPMIP enabled. The connected device is typically a synchrophasor processor, such as the SEL-3373. The synchrophasor processor controls the PMU functions of the SEL-787, 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.

The SEL-787 does not begin transmitting synchrophasors until an enable message is received from the synchrophasor processor. The relay stops synchrophasor transmission when the appropriate command is received from the synchrophasor processor. The SEL-787 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-787 only responds to configuration block request messages when it is in the non-transmitting mode.

IEEE C37.118 PMU Setting Example

A utility is upgrading its distribution system to use the SEL-787 for transformer protection and power-system state measurement. The utility also wants to install 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 and positive-sequence current from Winding 1
- 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-787, an SEL-2407 Satellite-Synchronized Clock, and an SEL-3373 Phasor Data Concentrator in each substation.

This example covers the PMU settings in the SEL-787 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 synchrophasor data use Port 3, and the maximum data rate allowed is 19200.
- The system designer specifies integer numeric representation for the synchrophasor data, and rectangular coordinates.
- The system designer specifies integer numeric representation for the frequency data.
- The system designer specifies IEEE C37.118 synchrophasor response, because the data are being used for system monitoring.

The protection settings are not shown.

The protection engineer performs a bandwidth check, using *Table K.10*, and determines the required message size. The system requirements, in order of appearance in *Table K.10*, are:

- 5 Synchrophasors, in integer representation
- Integer representation for the frequency data
- 3 digital status bits, which require one status word

The message size is 18 + 5 • 4 + 2 • 2 + 1 • 2 = 44 bytes. Using *Table K.11*, the engineer verifies that the port data rate of 9600 is adequate for the message, at 10 messages per second.

The Protection SELOGIC Variables SV14, SV15, and SV16 are used to transmit the breaker status, loss-of-potential alarm, and frequency measurement status, respectively. Make the Global settings as shown in *Table K.12*.

Table K.12 Example Synchrophasor Global Settings

Setting Prompt	Setting Range	Setting Name := Example Setting Value
NOMINAL SYSTEM FREQUENCY	50, 60 Hz	FNOM := 60
ENABLE SYNCHRONIZED PHASOR MEASUREMENT	Y, N	EPMU := Y
MESSAGES PER SECOND	1, 2, 4, 5, 10, 12, 15, 20, 30, 60	MRATE := 10
PMU APPLICATION	F := Fast Response, N := Narrow Bandwidth	PMAPP := FAST
FREQUENCY-BASED PHASOR COMPENSATION	Y, N	PHCOMP := Y
STATION NAME	16 characters	PMSTN := SAMPLE1
PMU HARDWARE ID	1–65534	PMID := 14
PHASOR DATA SET, VOLTAGES	V1, ALL, NA	PHDATAV := V1
PHASE VOLTAGE ANGLE COMPENSATION FACTOR	–179.99 to 180.00 degrees	VCOMP := 4.20
PHASOR DATA SET, CURRENTS	I1, ALL, NA	PHDATAI := ALL
CURRENT SOURCE	IW1, IW2, IW3, IW4, ALL	PHCURR := IW1
PHASE CURRENT ANGLE COMPENSATION FACTOR	–179.99 to 180.00 degrees	IW1COMP := 3.50
NUMBER OF 16-BIT DIGITAL STATUS WORDS	0 or 1	NUMDSW := 1

Table K.13 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 K.14* in all the settings groups.

Table K.14 Example Synchrophasor SELOGIC Settings

Setting	Value
SV30	52A1
SV31	LOP
SV32	FREQTRK

Make the *Table K.15* settings for serial port 3, using the **SET P 3** command.

Table K.15 Example Synchrophasor Port Settings

Setting Prompt	Setting Range	Setting Name := Example Setting Value
PROTOCOL	SEL, MOD, DNP, EVMSG, PMU, MBA, MBB, MB8A, MB8B, MBTA, MBTB	PROTO := PMU
DATA SPEED	300 to 38400	SPEED := 19200
STOP BITS	1, 2 bits	STOPBIT := 1
ENABLE HARDWARE HANDSHAKING	Y, N	RTSCTS := N

Appendix L
Relay Word Bits

Overview

The protection and control element results are represented by Relay Word bits in the SEL-787 Transformer Protection Relay. Each Relay Word bit has a label name and can be in either of the following states:

- ➤ 1 (logical 1)
- ➤ 0 (logical 0)

Logical 1 represents an element being picked up or otherwise asserted. Logical 0 represents an element being dropped out or otherwise deasserted.

Table L.1 and *Table L.2* show a list of Relay Word bits and corresponding descriptions. The Relay Word bit row numbers correspond to the row numbers used in the **TAR** command (see *TARGET Command (Display Relay Word Bit Status)*).

Any Relay Word bit (except Row 0) can be used in SELOGIC control equations (see *Section 4: Protection and Logic Functions*) and the Sequential Events Recorder (SER) trigger list settings (see *Section 10: Analyzing Events*).

Table L.1 SEL-787 Relay Word Bits (Sheet 1 of 7)

Bit/Row	Relay Word Bits							
	7	6	5	4	3	2	1	0
TAR 0	ENABLED	TRIP_LED	TLED_01	TLED_02	TLED_03	TLED_04	TLED_05	TLED_06
1	50P11T	50P12T	50P13T	50P14T	50P21T	50P22T	50P23T	50P24T
2	50P31T	50P32T	50P33T	50P34T	50P41T	50P42T	50P43T	50P44T
3	50G11T	50G12T	50G21T	50G22T	50G31T	50G32T	50G41T	50G42T
4	50Q11T	50Q12T	50Q21T	50Q22T	50Q31T	50Q32T	50Q41T	50Q42T
5	51P1T	51P2T	51P3T	51P4T	51Q1T	51Q2T	51Q3T	51Q4T
6	51G1T	51G2T	51G3T	51G4T	[a]	[a]	[a]	87Q
7	REMTRIP	PFLEAD	[a]	[a]	[a]	[a]	ORED50T	ORED51T
8	50P11P	50P12P	50P13P	50P14P	50P21P	50P22P	50P23P	50P24P
9	50P31P	50P32P	50P33P	50P34P	50P41P	50P42P	50P43P	50P44P
10	50G11P	50G12P	50G21P	50G22P	50G31P	50G32P	50G41P	50G42P
11	50Q11P	50Q12P	50Q21P	50Q22P	50Q31P	50Q32P	50Q41P	50Q42P
12	51P1P	51P2P	51P3P	51P4P	51Q1P	51Q2P	51Q3P	51Q4P
13	51G1P	51G2P	51G3P	51G4P	[a]	[a]	[a]	[a]
14	51P1R	51P2R	51P3R	51P4R	51Q1R	51Q2R	51Q3R	51Q4R

Table L.1 SEL-787 Relay Word Bits (Sheet 2 of 7)

Bit/Row	Relay Word Bits							
	7	6	5	4	3	2	1	0
15	51G1R	51G2R	51G3R	51G4R	a	a	a	a
16	50N11P	50N12P	50N11T	50N12T	51N1T	a	51N1P	51N1R
17	50P31AP	50P31AT	50P31BP	50P31BT	50P31CP	50P31CT	a	a
18	50P32AP	50P32AT	50P32BP	50P32BT	50P32CP	50P32CT	a	a
19	51P3AP	51P3AT	51P3BP	51P3BT	51P3CP	51P3CT	a	a
20	51P3AR	51P3BR	51P3CR	a	51PC12R	51PC34R	51GC12R	51GC34R
21	51PC12P	51PC34P	51GC12P	51GC34P	51PC12T	51PC34T	51GC12T	51GC34T
22	TH5	87AP	TH5T	87AT	52A1	52A2	52A3	52A4
23	87U1	87U2	87U3	87U	87R1	87R2	87R3	87R
24	2_4HB1	2_4HB2	2_4HB3	2_4HBL	5HB1	5HB2	5HB3	5HBL
25	87BL1	87BL2	87BL3	87HB	87HR1	87HR2	87HR3	87HR
26	REF1E	REF1BY	REF1F	REF1R	REF1FP	REF1RP	50NREF1	50GREF1
27	REF3AE	REF3ABY	REF3AF	REF3AR	REF3AFP	REF3ARP	50NREF3A	50GREF3A
28	REF3BE	REF3BBY	REF3BF	REF3BR	REF3BFP	REF3BRP	50NREF3B	50GREF3B
29	24D1	24D1T	24C2	24C2T	24CR	a	a	a
30	3PWR1P	3PWR2P	3PWR1T	3PWR2T	a	a	DCHI	DCLO
31	59P1	59P2	59P1T	59P2T	59PP1	59PP2	59PP1T	59PP2T
32	59G1	59G2	59G1T	59G2T	59Q1	59Q2	59Q1T	59Q2T
33	59S1	59S2	59S1T	59S2T	a	a	3P59	a
34	27P1	27P2	27P1T	27P2T	27PP1	27PP2	27PP1T	27PP2T
35	27S1	27S2	27S1T	27S2T	3P27	a	a	a
36	TRIP	OUT101	OUT102	OUT103	a	a	a	a
37	OUT301	OUT302	OUT303	OUT304	OUT305	OUT306	OUT307	OUT308
38	OUT401	OUT402	OUT403	OUT404	OUT405	OUT406	OUT407	OUT408
39	REF1PP	REF1P	REF3APP	REF3AP	REF3BPP	REF3BP	a	a
40	REF1PR	REF3APR	REF3BPR	a	a	a	a	a
41	IN101	IN102	a	a	a	a	a	a
42	IN301	IN302	IN303	IN304	IN305	IN306	IN307	IN308
43	IN401	IN402	IN403	IN404	IN405	IN406	IN407	IN408
44	IN501	IN502	IN503	IN504	IN505	IN506	IN507	IN508
45	BFI1	BFI2	BFI3	BFI4	BFT1	BFT2	BFT3	BFT4
46	RTDT	AMBALRM	AMBTRIP	OTHALRM	OTHTRIP	a	a	a
47	LINKA	LINKB	PMDOK	SALARM	WARNING	TSOK	IRIGOK	FAULT
48	COMMIDLE	COMMLOSS	COMMFLT	CFGFLT	LINKFAIL	PASEL	PBSEL	LOP
49	81D1T	81D2T	81D3T	81D4T	LINK1	STORMDET	a	a
50	FREQTRK	ER	FREQFZ	a	RSTENRGY	RSTMXMN	RSTDEM	RSTPKDEM
51	RTDFLT	RTDIN	TRGTR	RTDA	a	DSABLSET	RSTTRGT	HALARM
52	RTD1A	RTD1T	RTD2A	RTD2T	RTD3A	RTD3T	RTD4A	RTD4T
53	RTD5A	RTD5T	RTD6A	RTD6T	RTD7A	RTD7T	RTD8A	RTD8T

Table L.1 SEL-787 Relay Word Bits (Sheet 3 of 7)

Bit/Row	Relay Word Bits							
	7	6	5	4	3	2	1	0
54	RTD9A	RTD9T	RTD10A	RTD10T	RTD11A	RTD11T	RTD12A	RTD12T
55	CLOSE1	CLOSE2	CLOSE3	CLOSE4	a	a	a	a
56	SG1	SG2	SG3	SG4	TREA1	TREA2	TREA3	TREA4
57	TR1	TR2	TR3	TR4	TRIP1	TRIP2	TRIP3	TRIP4
58	ULTRIP1	ULTRIP2	ULTRIP3	ULTRIP4	ULCL1	ULCL2	ULCL3	ULCL4
59	OC1	OC2	OC3	OC4	CL1	CL2	CL3	CL4
60	CC1	CC2	CC3	CC4	CF1	CF2	CF3	CF4
61	PMTRIG	ULTRXFMR	TRXFMR	TRIPXFMR	a	a	a	a
62	PB01	PB02	PB03	PB04	PB05	PB06	PB07	PB08
63	PB01_PUL	PB02_PUL	PB03_PUL	PB04_PUL	PB05_PUL	PB06_PUL	PB07_PUL	PB08_PUL
64	PB1A_LED	PB1B_LED	PB2A_LED	PB2B_LED	PB3A_LED	PB3B_LED	PB4A_LED	PB4B_LED
65	PB5A_LED	PB5B_LED	PB6A_LED	PB6B_LED	PB7A_LED	PB7B_LED	PB8A_LED	PB8B_LED
66	a	a	T01_LED	T02_LED	T03_LED	T04_LED	T05_LED	T06_LED
67	DNAUX1	DNAUX2	DNAUX3	DNAUX4	DNAUX5	DNAUX6	DNAUX7	DNAUX8
68	DNAUX9	DNAUX10	DNAUX11	RELAY_EN	a	INR1	INR2	INR3
69	PHDEM	3I2DEM	GNDEM	a	a	TFLTALA	TFLTALB	TFLTALC
70	LB01	LB02	LB03	LB04	LB05	LB06	LB07	LB08
71	LB09	LB10	LB11	LB12	LB13	LB14	LB15	LB16
72	LB17	LB18	LB19	LB20	LB21	LB22	LB23	LB24
73	LB25	LB26	LB27	LB28	LB29	LB30	LB31	LB32
74	RB01	RB02	RB03	RB04	RB05	RB06	RB07	RB08
75	RB09	RB10	RB11	RB12	RB13	RB14	RB15	RB16
76	RB17	RB18	RB19	RB20	RB21	RB22	RB23	RB24
77	RB25	RB26	RB27	RB28	RB29	RB30	RB31	RB32
78	SV01	SV02	SV03	SV04	SV05	SV06	SV07	SV08
79	SV01T	SV02T	SV03T	SV04T	SV05T	SV06T	SV07T	SV08T
80	SV09	SV10	SV11	SV12	SV13	SV14	SV15	SV16
81	SV09T	SV10T	SV11T	SV12T	SV13T	SV14T	SV15T	SV16T
82	SV17	SV18	SV19	SV20	SV21	SV22	SV23	SV24
83	SV17T	SV18T	SV19T	SV20T	SV21T	SV22T	SV23T	SV24T
84	SV25	SV26	SV27	SV28	SV29	SV30	SV31	SV32
85	SV25T	SV26T	SV27T	SV28T	SV29T	SV30T	SV31T	SV32T
86	LT01	LT02	LT03	LT04	LT05	LT06	LT07	LT08
87	LT09	LT10	LT11	LT12	LT13	LT14	LT15	LT16
88	LT17	LT18	LT19	LT20	LT21	LT22	LT23	LT24
89	LT25	LT26	LT27	LT28	LT29	LT30	LT31	LT32
90	SC01QU	SC02QU	SC03QU	SC04QU	SC05QU	SC06QU	SC07QU	SC08QU
91	SC01QD	SC02QD	SC03QD	SC04QD	SC05QD	SC06QD	SC07QD	SC08QD
92	SC09QU	SC10QU	SC11QU	SC12QU	SC13QU	SC14QU	SC15QU	SC16QU

Table L.1 SEL-787 Relay Word Bits (Sheet 4 of 7)

Bit/Row	Relay Word Bits							
	7	6	5	4	3	2	1	0
93	SC09QD	SC10QD	SC11QD	SC12QD	SC13QD	SC14QD	SC15QD	SC16QD
94	SC17QU	SC18QU	SC19QU	SC20QU	SC21QU	SC22QU	SC23QU	SC24QU
95	SC17QD	SC18QD	SC19QD	SC20QD	SC21QD	SC22QD	SC23QD	SC24QD
96	SC25QU	SC26QU	SC27QU	SC28QU	SC29QU	SC30QU	SC31QU	SC32QU
97	SC25QD	SC26QD	SC27QD	SC28QD	SC29QD	SC30QD	SC31QD	SC32QD
98	RMB8A	RMB7A	RMB6A	RMB5A	RMB4A	RMB3A	RMB2A	RMB1A
99	TMB8A	TMB7A	TMB6A	TMB5A	TMB4A	TMB3A	TMB2A	TMB1A
100	RMB8B	RMB7B	RMB6B	RMB5B	RMB4B	RMB3B	RMB2B	RMB1B
101	TMB8B	TMB7B	TMB6B	TMB5B	TMB4B	TMB3B	TMB2B	TMB1B
102	LBOKB	CBADB	RBADB	ROKB	LBOKA	CBADA	RBADA	ROKA
103	VB001	VB002	VB003	VB004	VB005	VB006	VB007	VB008
104	VB009	VB010	VB011	VB012	VB013	VB014	VB015	VB016
105	VB017	VB018	VB019	VB020	VB021	VB022	VB023	VB024
106	VB025	VB026	VB027	VB028	VB029	VB030	VB031	VB032
107	VB033	VB034	VB035	VB036	VB037	VB038	VB039	VB040
108	VB041	VB042	VB043	VB044	VB045	VB046	VB047	VB048
109	VB049	VB050	VB051	VB052	VB053	VB054	VB055	VB056
110	VB057	VB058	VB059	VB060	VB061	VB062	VB063	VB064
111	VB065	VB066	VB067	VB068	VB069	VB070	VB071	VB072
112	VB073	VB074	VB075	VB076	VB077	VB078	VB079	VB080
113	VB081	VB082	VB083	VB084	VB085	VB086	VB087	VB088
114	VB089	VB090	VB091	VB092	VB093	VB094	VB095	VB096
115	VB097	VB098	VB099	VB100	VB101	VB102	VB103	VB104
116	VB105	VB106	VB107	VB108	VB109	VB110	VB111	VB112
117	VB113	VB114	VB115	VB116	VB117	VB118	VB119	VB120
118	VB121	VB122	VB123	VB124	VB125	VB126	VB127	VB128
119	AILW1	AILW2	AILAL	[a]	AIHW1	AIHW2	AIHAL	[a]
120	AI301LW1	AI301LW2	AI301LAL	[a]	AI301HW1	AI301HW2	AI301HAL	[a]
121	AI302LW1	AI302LW2	AI302LAL	[a]	AI302HW1	AI302HW2	AI302HAL	[a]
122	AI303LW1	AI303LW2	AI303LAL	[a]	AI303HW1	AI303HW2	AI303HAL	[a]
123	AI304LW1	AI304LW2	AI304LAL	[a]	AI304HW1	AI304HW2	AI304HAL	[a]
124	AI401LW1	AI401LW2	AI401LAL	[a]	AI401HW1	AI401HW2	AI401HAL	[a]
125	AI402LW1	AI402LW2	AI402LAL	[a]	AI402HW1	AI402HW2	AI402HAL	[a]
126	AI403LW1	AI403LW2	AI403LAL	[a]	AI403HW1	AI403HW2	AI403HAL	[a]
127	AI404LW1	AI404LW2	AI404LAL	[a]	AI404HW1	AI404HW2	AI404HAL	
128	DI_A1	DI_B1	DI_C1	DI_A2	DI_B2	DI_C2	TESTDB	MATHERR
129	DI_A3	DI_B3	DI_C3	DI_A4	DI_B4	DI_C4	[a]	[a]
130	TQUAL1	TQUAL2	TQUAL4	TQUAL8	DST	DSTP	LPSEC	LPSECP
131	TSNTPB	TSNTPP	TUTCS	TUTC1	TUTC2	TUTC4	TUTC8	TUTCH
132	BCW1A	BCW1B	BCW1C	BCW1	BCW2A	BCW2B	BCW2C	BCW2

Table L.1 SEL-787 Relay Word Bits (Sheet 5 of 7)

Bit/Row	Relay Word Bits							
	7	6	5	4	3	2	1	0
133	BCW3A	BCW3B	BCW3C	BCW3	BCW4A	BCW4B	BCW4C	BCW4
134	59VP	59VS	SF	25A1	25A2	a	a	a
135	OUT501	OUT502	OUT503	OUT504	OUT505	OUT506	OUT507	OUT508
136	a	a	a	a	a	a	a	a
137	[IN109]	a	a	a	a	a	a	a
138	IN309	IN310	IN311	IN312	IN313	IN314	a	a
139	IN409	IN410	IN411	IN412	IN413	IN414	a	a
140	IN509	IN510	IN511	IN512	IN513	IN514	a	a
141	AI501LW1	AI501LW2	AI501LAL	a	AI501HW1	AI501HW2	AI501HAL	a
142	AI502LW1	AI502LW2	AI502LAL	a	AI502HW1	AI502HW2	AI502HAL	a
143	AI503LW1	AI503LW2	AI503LAL	a	AI503HW1	AI503HW2	AI503HAL	a
144	AI504LW1	AI504LW2	AI504LAL	a	AI504HW1	AI504HW2	AI504HAL	a
145	89A2P1	89B2P1	89CL2P1	89OP2P1	89A2P2	89B2P2	89CL2P2	89OP2P2
146	89A2P3	89B2P3	89CL2P3	89OP2P3	89A2P4	89B2P4	89CL2P4	89OP2P4
147	89A2P5	89B2P5	89CL2P5	89OP2P5	89A2P6	89B2P6	89CL2P6	89OP2P6
148	89A2P7	89B2P7	89CL2P7	89OP2P7	89A2P8	89B2P8	89CL2P8	89OP2P8
149	89A2P9	89B2P9	89CL2P9	89OP2P9	89A2P10	89B2P10	89CL2P10	89OP2P10
150	89A2P11	89B2P11	89CL2P11	89OP2P11	89A2P12	89P2P12	89CL2P12	89OP2P12
151	89A2P13	89B2P13	89CL2P13	89OP2P13	89A2P14	89B2P14	89CL2P14	89OP2P14
152	89A2P15	89B2P15	89CL2P15	89OP2P15	89A2P16	89B2P16	89CL2P16	89OP2P16
153	89AL2P1	89AL2P2	89AL2P3	89AL2P4	89AL2P5	89AL2P6	89AL2P7	89AL2P8
154	89AL2P9	89AL2P10	89AL2P11	89AL2P12	89AL2P13	89AL2P14	89AL2P15	89AL2P16
155	52B1	52B2	52B3	52B4	ENLRC	LOCAL	BKJMP	a
156	27I1	27I1T	27I1RS	27I1TC	27I2	27I2T	27I2RS	27I2TC
157	59I1	59I1T	59I1RS	59I1TC	59I2	59I2T	59I2RS	59I2TC
158	59I3	59I3T	59I3RS	59I3TC	59I4	59I4T	59I4RS	59I4TC
159	a	a	a	a	a	a	a	a
160	89O2P1	89OS2P1	89OI2P1	89OE2P1	89C2P1	89CS2P1	89CI2P1	89CE2P1
161	89O2P2	89OS2P2	89OI2P2	89OE2P2	89C2P2	89CS2P2	89CI2P2	89CE2P2
162	89O2P3	89OS2P3	89OI2P3	89OE2P3	89C2P3	89CS2P3	89CI2P3	89CE2P3
163	89O2P4	89OS2P4	89OI2P4	89OE2P4	89C2P4	89CS2P4	89CI2P4	89CE2P4
164	89O2P5	89OS2P5	89OI2P5	89OE2P5	89C2P5	89CS2P5	89CI2P5	89CE2P5
165	89O2P6	89OS2P6	89OI2P6	89OE2P6	89C2P6	89CS2P6	89CI2P6	89CE2P6
166	89O2P7	89OS2P7	89OI2P7	89OE2P7	89C2P7	89CS2P7	89CI2P7	89CE2P7
167	89O2P8	89OS2P8	89OI2P8	89OE2P8	89C2P8	89CS2P8	89CI2P8	89CE2P8
168	89O2P9	89OS2P9	89OI2P9	89OE2P9	89C2P9	89CS2P9	89CI2P9	89CE2P9
169	89O2P10	89OS2P10	89OI2P10	89OE2P10	89C2P10	89CS2P10	89CI2P10	89CE2P10
170	89O2P11	89OS2P11	89OI2P11	89OE2P11	89C2P11	89CS2P11	89CI2P11	89CE2P11
171	89O2P12	89OS2P12	89OI2P12	89OE2P12	89C2P12	89CS2P12	89CI2P12	89CE2P12
172	89O2P13	89OS2P13	89OI2P13	89OE2P13	89C2P13	89CS2P13	89CI2P13	89CE2P13

Table L.1 SEL-787 Relay Word Bits (Sheet 6 of 7)

Bit/Row	Relay Word Bits							
	7	6	5	4	3	2	1	0
173	89O2P14	89OS2P14	89OI2P14	89OE2P14	89C2P14	89CS2P14	89CI2P14	89CE2P14
174	89O2P15	89OS2P15	89OI2P15	89OE2P15	89C2P15	89CS2P15	89CI2P15	89CE2P15
175	89O2P16	89OS2P16	89OI2P16	89OE2P16	89C2P16	89CS2P16	89CI2P16	89CE2P16
176	89OC2P1	89RO2P1	89OM2P1	a	89CC2P1	89RC2P1	89CM2P1	a
177	89OC2P2	89RO2P2	89OM2P2	a	89CC2P2	89RC2P2	89CM2P2	a
178	89OC2P3	89RO2P3	89OM2P3	a	89CC2P3	89RC2P3	89CM2P3	a
179	89OC2P4	89RO2P4	89OM2P4	a	89CC2P4	89RC2P4	89CM2P4	a
180	89OC2P5	89RO2P5	89OM2P5	a	89CC2P5	89RC2P5	89CM2P5	a
181	89OC2P6	89RO2P6	89OM2P6	a	89CC2P6	89RC2P6	89CM2P6	a
182	89OC2P7	89RO2P7	89OM2P7	a	89CC2P7	89RC2P7	89CM2P7	a
183	89OC2P8	89RO2P8	89OM2P8	a	89CC2P8	89RC2P8	89CM2P8	a
184	89OC2P9	89RO2P9	89OM2P9	a	89CC2P9	89RC2P9	89CM2P9	a
185	89OC2P10	89RO2P10	89OM2P10	a	89CC2P10	89RC2P10	89CM2P10	a
186	89OC2P11	89RO2P11	89OM2P11	a	89CC2P11	89RC2P11	89CM2P11	a
187	89OC2P12	89RO2P12	89OM2P12	a	89CC2P12	89RC2P12	89CM2P12	a
188	89OC2P13	89RO2P13	89OM2P13	a	89CC2P13	89RC2P13	89CM2P13	a
189	89OC2P14	89RO2P14	89OM2P14	a	89CC2P14	89RC2P14	89CM2P14	a
190	89OC2P15	89RO2P15	89OM2P15	a	89CC2P15	89RC2P15	89CM2P15	a
191	89OC2P16	89RO2P16	89OM2P16	a	89CC2P16	89RC2P16	89CM2P16	a
192	89OC3PL1	89RO3PL1	89OM3PL1	a	89CC3PL1	89RC3PL1	89CM3PL1	a
193	89OC3PE1	89RO3PE1	89OM3PE1	a	89CC3PE1	89RC3PE1	89CM3PE1	a
194	89OC3PL2	89RO3PL2	89OM3PL2	a	89CC3PL2	89RC3PL2	89CM3PL2	a
195	89OC3PE2	89RO3PE2	89OM3PE2	a	89CC3PE2	89RC3PE2	89CM3PE2	a
196	a	a	a	a	a	a	a	a
197	a	a	a	a	a	a	a	a
198	a	a	a	a	a	a	a	a
199	a	a	a	a	a	a	a	a
200	89IP2P1	89IP2P2	89IP2P3	89IP2P4	89IP2P5	89IP2P6	89IP2P7	89IP2P8
201	89IP2P9	89IP2P10	89IP2P11	89IP2P12	89IP2P13	89IP2P14	89IP2P15	89IP2P16
202	89A3PL1	89B3PL1	89CL3PL1	89OP3PL1	89AL3PL1	89IP3PL1	89AL	a
203	89A3PE1	89B3PE1	89CL3PE1	89OP3PE1	89AL3PE1	89IP3PE1	89IP	a
204	89A3PL2	89B3PL2	89CL3PL2	89OP3PL2	89AL3PL2	89IP3PL2	a	a
205	89A3PE2	89B3PE2	89CL3PE2	89OP3PE2	89AL3PE2	89IP3PE2	a	a
206	89O3PL1	89OS3PL1	89OI3PL1	89OE3PL1	89C3PL1	89CS3PL1	89CI3PL1	89CE3PL1
207	89O3PE1	89OS3PE1	89OI3PE1	89OE3PE1	89C3PE1	89CS3PE1	89CI3PE1	89CE3PE1
208	89O3PL2	89OS3PL2	89OI3PL2	89OE3PL2	89C3PL2	89CS3PL2	89CI3PL2	89CE3PL2
209	89O3PE2	89OS3PE2	89OI3PE2	89OE3PE2	89C3PE2	89CS3PE2	89CI3PE2	89CE3PE2
210	a	a	a	a	a	a	a	a
211	a	a	a	a	a	a	a	a
212	a	a	a	a	a	a	a	a

Table L.1 SEL-787 Relay Word Bits (Sheet 7 of 7)

Bit/Row	Relay Word Bits							
	7	6	5	4	3	2	1	0
213	a	a	a	a	a	a	a	a
214	SCBK1BC	SCBK1BO	BKENC1	BKENO1	SCBK2BC	SCBK2BO	BKENC2	BKENO2
215	SCBK3BC	SCBK3BO	BKENC3	BKENO3	SCBK4BC	SCBK4BO	BKENC4	BKENO4
216	50P121P	50P122P	50P341P	50P342P	50P231P	50P232P	a	a
217	50P121T	50P122T	50P341T	50P342T	50P231P	50P232T	a	a
218	50G121P	50P122P	50G341P	50G342P	50G231P	50G232P	a	a
219	50G121T	50G122T	50G341T	50G342T	50G231T	50G232T	a	a
220	51PC23P	51PC23T	51PC23R	51GC23P	51GC23T	51GC23R	a	a
221	a	a	a	a	a	a	a	a
222	87QP	87QBLK	DRDOPT	DRDOPT1	DRDOPT2	DRDOPT3		
• • •	• • •	• • •	• • •	• • •	• • •	• • •	• • •	• • •
224	a	a	a	a	a	a	a	a
225	PTP_TIM	PTP_OK	PTPSYNC	PTPA	PTPB	a	a	a
226	LPHDSIM	a	a	a	a	a	a	a
227	SC850TM	SC850BM	SC850SM	SC850LS	LOC	MLTLEV	LOCSTA	OREDLOC
228	BFTR1	BFTR2	BFTR3	BFTR4	BFULTR1	BFULTR2	BFULTR3	BFULTR4
229	BFRT1	BFRT2	BFRT3	BFRT4	50BF1	50BF2	50BF3	50BF4
230	50BFG1	50BFG2	50BFG3	50BFG4	BFTRIP1	BFTRIP2	BFTRIP3	BFTRIP4
231	REF1OCT	FLTP1	REF1RBK	REF1FBK	REF3AOCT	FLTP3A	REF3ARBK	REF3AFBK
232	a	a	a	a	REF3BOCT	FLTP3B	REF3BRBK	REF3BFBK
• • •	• • •	• • •	• • •	• • •	• • •	• • •	• • •	• • •
240	a	a	a	a	a	a	a	a

[a] Reserved for future use.

Definitions

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 1 of 31)

Bit	Definition	Row
2_4HB1	Second- or fourth-harmonic block asserted for Differential Element 1	24
2_4HB2	Second- or fourth-harmonic block asserted for Differential Element 2	24
2_4HB3	Second- or fourth-harmonic block asserted for Differential Element 3	24
2_4HBL	Second- or fourth-harmonic block asserted (2_4HB1 OR 2_4HB2 OR 2_4HB3)	24
24C2	Level 2 volts/hertz composite element pickup	29
24C2T	Level 2 volts/hertz composite element timed out	29

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 2 of 31)

Bit	Definition	Row
24CR	Level 2 volts/hertz element fully reset	29
24D1	Level 1 volts/hertz instantaneous pickup	29
24D1T	Level 1 volts/hertz definite-time element timed out	29
25A1	Intertie slip/breaker-time compensated phase angle less than 25ANG1 setting	134
25A2	Intertie slip/breaker-time compensated phase angle less than 25ANG2 setting	134
27I1	Level 1 inverse undervoltage element pickup	156
27I1RS	Level 1 inverse undervoltage element reset	156
27I1T	Level 1 inverse undervoltage element time out	156
27I1TC	Level 1 inverse undervoltage element torque control	156
27I2	Level 2 inverse undervoltage element pickup	156
27I2RS	Level 2 inverse undervoltage element reset	156
27I2T	Level 2 inverse undervoltage element time out	156
27I2TC	Level 2 inverse undervoltage element torque control	156
27P1	Level 1 phase undervoltage element pickup	34
27P1T	Level 1 phase undervoltage element trip	34
27P2	Level 2 phase undervoltage element pickup	34
27P2T	Level 2 phase undervoltage element trip	34
27PP1	Level 1 phase-to-phase undervoltage element pickup	34
27PP1T	Level 1 phase-to-phase undervoltage element trip	34
27PP2	Level 2 phase-to-phase undervoltage element pickup	34
27PP2T	Level 2 phase-to-phase undervoltage element trip	34
27S1	Level 1 VS channel undervoltage element pickup	35
27S1T	Level 1 VS channel undervoltage element trip	35
27S2	Level 2 VS channel undervoltage element pickup	35
27S2T	Level 2 VS channel undervoltage element trip	35
3I2DEM	Negative-sequence current demand pickup	69
3P27	Three-phase undervoltage pickup when all three phases are below 27P1P	35
3P59	Three-phase overvoltage pickup when all three phases are above 59P1P	33
3PWR1P	Three-Phase Power Element 1 pickup	30
3PWR1T	Three-Phase Power Element 1 trip	30
3PWR2P	Three-Phase Power Element 2 pickup	30
3PWR2T	Three-Phase Power Element 2 trip	30
50BF1	Breaker 1 failure current detector	229
50BF2	Breaker 2 failure current detector	229

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 3 of 31)

Bit	Definition	Row
50BF3	Breaker 3 failure current detector	229
50BF4	Breaker 4 failure current detector	229
50BFG1	Breaker 1 failure residual current detector	230
50BFG2	Breaker 2 failure residual current detector	230
50BFG3	Breaker 3 failure residual current detector	230
50BFG4	Breaker 4 failure residual current detector	230
50G11P	Level 1 residual-ground instantaneous overcurrent element pickup—Winding 1	10
50G11T	Level 1 residual-ground instantaneous overcurrent element trip—Winding 1	3
50G121P	Level 1 residual-ground instantaneous overcurrent element pickup—Winding 1 & Winding 2	218
50G121T	Level 1 residual-ground instantaneous overcurrent element trip—Winding 1 & Winding 2	219
50G12P	Level 2 residual-ground instantaneous overcurrent element pickup—Winding 1	10
50G122P	Level 2 residual-ground instantaneous overcurrent element pickup—Winding 1 & Winding 2	218
50G122T	Level 2 residual-ground instantaneous overcurrent element trip—Winding 1 & Winding 2	219
50G12T	Level 2 residual-ground instantaneous overcurrent element trip—Winding 1	3
50G21P	Level 1 residual-ground instantaneous overcurrent element pickup—Winding 2	10
50G21T	Level 1 residual-ground instantaneous overcurrent element trip—Winding 2	3
50G22P	Level 2 residual-ground instantaneous overcurrent element pickup—Winding 2	10
50G22T	Level 2 residual-ground instantaneous overcurrent element trip—Winding 2	3
50G231P	Level 1 residual-ground instantaneous overcurrent element pickup—Winding 2 & Winding 3	218
50G231T	Level 1 residual-ground instantaneous overcurrent element trip—Winding 2 & Winding 3	219
50G232P	Level 2 residual-ground instantaneous overcurrent element pickup—Winding 2 & Winding 3	218
50G232T	Level 2 residual-ground instantaneous overcurrent element trip—Winding 2 & Winding 3	219
50G31P	Level 1 residual-ground instantaneous overcurrent element pickup—Winding 3	10
50G31T	Level 1 residual-ground instantaneous overcurrent element trip—Winding 3	3
50G32P	Level 2 residual-ground instantaneous overcurrent element pickup—Winding 3	10
50G32T	Level 2 residual-ground instantaneous overcurrent element trip—Winding 3	3
50G341P	Level 1 residual-ground instantaneous overcurrent element pickup—Winding 3 & Winding 4	218
50G341T	Level 1 residual-ground instantaneous overcurrent element trip—Winding 3 & Winding 4	219
50G342P	Level 2 residual-ground instantaneous overcurrent element pickup—Winding 3 & Winding 4	218
50G342T	Level 2 residual-ground instantaneous overcurrent element trip—Winding 3 & Winding 4	219
50G41P	Level 1 residual-ground instantaneous overcurrent element pickup—Winding 4	10

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 4 of 31)

Bit	Definition	Row
50G41T	Level 1 residual-ground instantaneous overcurrent element trip—Winding 4	3
50G42P	Level 2 residual-ground instantaneous overcurrent element pickup—Winding 4	10
50G42T	Level 2 residual-ground instantaneous overcurrent element trip—Winding 4	3
50GREF1	REF1 element normalized polarization quantity sensitivity threshold exceeded	26
50GREF3A	REF3A element normalized polarization quantity sensitivity threshold exceeded	27
50GREF3B	REF3B element normalized polarization quantity sensitivity threshold exceeded	28
50N11P	Level 1 neutral-ground instantaneous overcurrent element pickup—Input 1	16
50N11T	Level 1 neutral-ground instantaneous overcurrent element trip—Input 1	16
50N12P	Level 2 neutral-ground instantaneous overcurrent element pickup—Input 1	16
50N12T	Level 2 neutral-ground instantaneous overcurrent element trip—Input 1	16
50NREF1	REF1 element normalized operate quantity sensitivity threshold exceeded	26
50NREF3A	REF3A element normalized operate quantity sensitivity threshold exceeded	27
50NREF3B	REF3B element normalized operate quantity sensitivity threshold exceeded	28
50P11P	Level 1 phase instantaneous overcurrent element pickup—Winding 1	8
50P11T	Level 1 phase instantaneous overcurrent element trip—Winding 1	1
50P121P	Level 1 phase instantaneous overcurrent element pickup—Winding 1 & Winding 2	216
50P121T	Level 1 phase instantaneous overcurrent element trip—Winding 1 & Winding 2	217
50P122P	Level 2 phase instantaneous overcurrent element pickup—Winding 1 & Winding 2	216
50P122T	Level 2 phase instantaneous overcurrent element trip—Winding 1 & Winding 2	217
50P12P	Level 2 phase instantaneous overcurrent element pickup—Winding 1	8
50P12T	Level 2 phase instantaneous overcurrent element trip—Winding 1	1
50P13P	Level 3 phase instantaneous overcurrent element pickup—Winding 1	8
50P13T	Level 3 phase instantaneous overcurrent element trip—Winding 1	1
50P14P	Level 4 phase instantaneous overcurrent element pickup—Winding 1	8
50P14T	Level 4 phase instantaneous overcurrent element trip—Winding 1	1
50P21P	Level 1 phase instantaneous overcurrent element pickup—Winding 2	8
50P21T	Level 1 phase instantaneous overcurrent element trip—Winding 2	1
50P22P	Level 2 phase instantaneous overcurrent element pickup—Winding 2	8
50P22T	Level 2 phase instantaneous overcurrent element trip—Winding 2	1
50P231P	Level 1 phase instantaneous overcurrent element pickup—Winding 2 & Winding 3	216
50P231T	Level 1 phase instantaneous overcurrent element trip—Winding 2 & Winding 3	217
50P232P	Level 2 phase instantaneous overcurrent element pickup—Winding 2 & Winding 3	216
50P232T	Level 2 phase instantaneous overcurrent element trip—Winding 2 & Winding 3	217
50P23P	Level 3 phase instantaneous overcurrent element pickup—Winding 2	8

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 5 of 31)

Bit	Definition	Row
50P23T	Level 3 phase instantaneous overcurrent element trip—Winding 2	1
50P24P	Level 4 phase instantaneous overcurrent element pickup—Winding 2	8
50P24T	Level 4 phase instantaneous overcurrent element trip—Winding 2	1
50P31AP	Level 1 phase instantaneous overcurrent element pickup—Phase A of Winding 3	17
50P31AT	Level 1 phase instantaneous overcurrent element trip—Phase A of Winding 3	17
50P31BP	Level 1 phase instantaneous overcurrent element pickup—Phase B of Winding 3	17
50P31BT	Level 1 phase instantaneous overcurrent element trip—Phase B of Winding 3	17
50P31CP	Level 1 phase instantaneous overcurrent element pickup—Phase C of Winding 3	17
50P31CT	Level 1 phase instantaneous overcurrent element trip—Phase C of Winding 3	17
50P31P	Level 1 phase instantaneous overcurrent element pickup—Winding 3	9
50P31T	Level 1 phase instantaneous overcurrent element trip—Winding 3	2
50P32AP	Level 2 phase instantaneous overcurrent element pickup—Phase A of Winding 3	18
50P32AT	Level 2 phase instantaneous overcurrent element trip—Phase A of Winding 3	18
50P32BP	Level 2 phase instantaneous overcurrent element pickup—Phase B of Winding 3	18
50P32BT	Level 2 phase instantaneous overcurrent element trip—Phase B of Winding 3	18
50P32CP	Level 2 phase instantaneous overcurrent element pickup—Phase C of Winding 3	18
50P32CT	Level 2 phase instantaneous overcurrent element trip—Phase C of Winding 3	18
50P32P	Level 2 phase instantaneous overcurrent element pickup—Winding 3	9
50P32T	Level 2 phase instantaneous overcurrent element trip—Winding 3	2
50P33P	Level 3 phase instantaneous overcurrent element pickup—Winding 3	9
50P33T	Level 3 phase instantaneous overcurrent element trip—Winding 3	2
50P341P	Level 1 phase instantaneous overcurrent element pickup—Winding 3 & Winding 4	216
50P341T	Level 1 phase instantaneous overcurrent element trip—Winding 2 & Winding 3	217
50P342P	Level 2 phase instantaneous overcurrent element pickup—Winding 3 & Winding 4	216
50P342T	Level 2 phase instantaneous overcurrent element trip—Winding 2 & Winding 3	217
50P34P	Level 4 phase instantaneous overcurrent element pickup—Winding 3	9
50P34T	Level 4 phase instantaneous overcurrent element trip—Winding 3	2
50P41P	Level 1 phase instantaneous overcurrent element pickup—Winding 4	9
50P41T	Level 1 phase instantaneous overcurrent element trip—Winding 4	2
50P42P	Level 2 phase instantaneous overcurrent element pickup—Winding 4	9
50P42T	Level 2 phase instantaneous overcurrent element trip—Winding 4	2
50P43P	Level 3 phase instantaneous overcurrent element pickup—Winding 4	9
50P43T	Level 3 phase instantaneous overcurrent element trip—Winding 4	2
50P44P	Level 4 phase instantaneous overcurrent element pickup—Winding 4	9

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 6 of 31)

Bit	Definition	Row
50P44T	Level 4 phase instantaneous overcurrent element trip—Winding 4	2
50Q11P	Level 1 negative-sequence instantaneous overcurrent element pickup—Winding 1	11
50Q11T	Level 1 negative-sequence instantaneous overcurrent element trip—Winding 1	4
50Q12P	Level 2 negative-sequence instantaneous overcurrent element pickup—Winding 1	11
50Q12T	Level 2 negative-sequence instantaneous overcurrent element trip—Winding 1	4
50Q21P	Level 1 negative-sequence instantaneous overcurrent element pickup—Winding 2	11
50Q21T	Level 1 negative-sequence instantaneous overcurrent element trip—Winding 2	4
50Q22P	Level 2 negative-sequence instantaneous overcurrent element pickup—Winding 2	11
50Q22T	Level 2 negative-sequence instantaneous overcurrent element trip—Winding 2	4
50Q31P	Level 1 negative-sequence instantaneous overcurrent element pickup—Winding 3	11
50Q31T	Level 1 negative-sequence instantaneous overcurrent element trip—Winding 3	4
50Q32P	Level 2 negative-sequence instantaneous overcurrent element pickup—Winding 3	11
50Q32T	Level 2 negative-sequence instantaneous overcurrent element trip—Winding 3	4
50Q41P	Level 1 negative-sequence instantaneous overcurrent element pickup—Winding 4	11
50Q41T	Level 1 negative-sequence instantaneous overcurrent element trip—Winding 4	4
50Q42P	Level 2 negative-sequence instantaneous overcurrent element pickup—Winding 4	11
50Q42T	Level 2 negative-sequence instantaneous overcurrent element trip—Winding 4	4
51G1P	Residual-ground time-overcurrent element pickup—Winding 1	13
51G1R	Residual-ground time-overcurrent element reset—Winding 1	15
51G1T	Residual-ground time-overcurrent element trip—Winding 1	6
51G2P	Residual-ground time-overcurrent element pickup—Winding 2	13
51G2R	Residual-ground time-overcurrent element reset—Winding 2	15
51G2T	Residual-ground time-overcurrent element trip—Winding 2	6
51G3P	Residual-ground time-overcurrent element pickup—Winding 3	13
51G3R	Residual-ground time-overcurrent element reset—Winding 3	15
51G3T	Residual-ground time-overcurrent element trip—Winding 3	6
51G4P	Residual-ground time-overcurrent element pickup—Winding 4	13
51G4R	Residual-ground time-overcurrent element reset—Winding 4	15
51G4T	Residual-ground time-overcurrent element trip—Winding 4	6
51GC12P	Residual-ground time-overcurrent element pickup—Combined Winding 1 and Winding 2	21
51GC12R	Residual-ground time-overcurrent element reset—Combined Winding 1 and Winding 2	20
51GC12T	Residual-ground time-overcurrent element trip—Combined Winding 1 and Winding 2	21
51GC23P	Residual-ground time-overcurrent element pickup—Combined Winding 2 & Winding 3	220
51GC23T	Residual-ground time-overcurrent element trip—Combined Winding 2 & Winding 3	220

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 7 of 31)

Bit	Definition	Row
51GC23R	Residual-ground time-overcurrent element reset—Combined Winding 2 & Winding 3	220
51GC34P	Residual-ground time-overcurrent element pickup—Combined Winding 3 and Winding 4	21
51GC34R	Residual-ground time-overcurrent element reset—Combined Winding 3 and Winding 4	20
51GC34T	Residual-ground time-overcurrent element trip—Combined Winding 3 and Winding 4	21
51N1P	Neutral-ground time-overcurrent element pickup—Input 1	16
51N1R	Neutral-ground time-overcurrent element reset—Input 1	16
51N1T	Neutral-ground time-overcurrent element trip—Input 1	16
51P1P	Maximum phase time-overcurrent element pickup—Winding 1	12
51P1R	Maximum phase time-overcurrent element reset—Winding 1	14
51P1T	Maximum phase time-overcurrent element trip—Winding 1	5
51P2P	Maximum phase time-overcurrent element pickup—Winding 2	12
51P2R	Maximum phase time-overcurrent element reset—Winding 2	14
51P2T	Maximum phase time-overcurrent element trip—Winding 2	5
51P3AP	Phase time-overcurrent element pickup—Phase A of Winding 3	19
51P3AR	Phase time-overcurrent element reset—Phase A of Winding 3	20
51P3AT	Phase time-overcurrent element trip—Phase A of Winding 3	19
51P3BP	Phase time-overcurrent element pickup—Phase B of Winding 3	19
51P3BR	Phase time-overcurrent element reset—Phase B of Winding 3	20
51P3BT	Phase time-overcurrent element trip—Phase B of Winding 3	19
51P3CP	Phase time-overcurrent element pickup—Phase C of Winding 3	19
51P3CR	Phase time-overcurrent element reset—Phase C of Winding 3	20
51P3CT	Phase time-overcurrent element trip—Phase C of Winding 3	19
51P3P	Maximum phase time-overcurrent element pickup—Winding 3	12
51P3R	Maximum phase time-overcurrent element reset—Winding 3	14
51P3T	Maximum phase time-overcurrent element trip—Winding 3	5
51P4P	Maximum phase time-overcurrent element pickup—Winding 4	12
51P4R	Maximum phase time-overcurrent element reset—Winding 4	14
51P4T	Maximum phase time-overcurrent element trip—Winding 4	5
51PC12P	Maximum phase time-overcurrent element pickup—Combined Winding 1 and Winding 2	21
51PC12R	Maximum phase time-overcurrent element reset—Combined Winding 1 and Winding 2	20
51PC12T	Maximum phase time-overcurrent element trip—Combined Winding 1 and Winding 2	21
51PC23P	Maximum phase time-overcurrent element pickup—Combined Winding 2 & Winding 3	220
51PC23T	Maximum phase time-overcurrent element trip—Combined Winding 2 & Winding 3	220
51PC23R	Maximum phase time-overcurrent element reset—Combined Winding 2 & Winding 3	220

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 8 of 31)

Bit	Definition	Row
51PC34P	Maximum phase time-overcurrent element pickup—Combined Winding 3 and Winding 4	21
51PC34R	Maximum phase time-overcurrent element reset—Combined Winding 3 and Winding 4	20
51PC34T	Maximum phase time-overcurrent element trip—Combined Winding 3 and Winding 4	21
51Q1P	Negative-sequence time-overcurrent element pickup—Winding 1	12
51Q1R	Negative-sequence time-overcurrent element reset—Winding 1	14
51Q1T	Negative-sequence time-overcurrent element trip—Winding 1	5
51Q2P	Negative-sequence time-overcurrent element pickup—Winding 2	12
51Q2R	Negative-sequence time-overcurrent element reset—Winding 2	14
51Q2T	Negative-sequence time-overcurrent element trip—Winding 2	5
51Q3P	Negative-sequence time-overcurrent element pickup—Winding 3	12
51Q3R	Negative-sequence time-overcurrent element reset—Winding 3	14
51Q3T	Negative-sequence time-overcurrent element trip—Winding 3	5
51Q4P	Negative-sequence time-overcurrent element pickup—Winding 4	12
51Q4R	Negative-sequence time-overcurrent element reset—Winding 4	14
51Q4T	Negative-sequence time-overcurrent element trip—Winding 4	5
52A1	Circuit Breaker 1, Contact A	22
52A2	Circuit Breaker 2, Contact A	22
52A3	Circuit Breaker 3, Contact A	22
52A4	Circuit Breaker 4, Contact A	22
52B1	Circuit Breaker 1, N/C contact	155
52B2	Circuit Breaker 2, N/C contact	155
52B3	Circuit Breaker 3, N/C contact	155
52B4	Circuit Breaker 4, N/C contact	155
59G1	Level 1 zero-sequence overvoltage element pickup	32
59G1T	Level 1 zero-sequence overvoltage element trip	32
59G2	Level 2 zero-sequence overvoltage element pickup	32
59G2T	Level 2 zero-sequence overvoltage element trip	32
59I1	Level 1 inverse overvoltage element pickup	157
59I1RS	Level 1 inverse overvoltage element reset	157
59I1T	Level 1 inverse overvoltage element time out	157
59I1TC	Level 1 inverse overvoltage element torque control	157
59I2	Level 2 inverse overvoltage element pickup	157
59I2RS	Level 2 inverse overvoltage element reset	157
59I2T	Level 2 inverse overvoltage element time out	157

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 9 of 31)

Bit	Definition	Row
59I2TC	Level 2 inverse overvoltage element torque control	157
59I3	Level 3 inverse overvoltage element pickup	158
59I3RS	Level 3 inverse overvoltage element reset	158
59I3T	Level 3 inverse overvoltage element time out	158
59I3TC	Level 3 inverse overvoltage element torque control	158
59I4	Level 4 inverse overvoltage element pickup	158
59I4RS	Level 4 inverse overvoltage element reset	158
59I4T	Level 4 inverse overvoltage element time out	158
59I4TC	Level 4 inverse overvoltage element torque control	158
59P1	Level 1 phase overvoltage element pickup	31
59P1T	Level 1 phase overvoltage element trip	31
59P2	Level 2 phase overvoltage element pickup	31
59P2T	Level 2 phase overvoltage element trip	31
59PP1	Level 1 phase-to-phase overvoltage element pickup	31
59PP1T	Level 1 phase-to-phase overvoltage element trip	31
59PP2	Level 2 phase-to-phase overvoltage element pickup	31
59PP2T	Level 2 phase-to-phase overvoltage element trip	31
59Q1	Level 1 negative-sequence overvoltage element pickup	32
59Q1T	Level 1 negative-sequence overvoltage element trip	32
59Q2	Level 2 negative-sequence overvoltage element pickup	32
59Q2T	Level 2 negative-sequence overvoltage element trip	32
59S1	Level 1 VS channel overvoltage element pickup	33
59S1T	Level 1 VS channel overvoltage element trip	33
59S2	Level 2 VS channel overvoltage element pickup	33
59S2T	Level 2 VS channel overvoltage element trip	33
59VP	Phase voltage window element (selected phase voltage [VP] between settings 25VLO and 25VHI)	134
59VS	VS channel voltage window element (selected phase voltage [VS] between settings 25VLO and 25VHI)	134
5HB1	Fifth-harmonic block asserted for Differential Element 1	24
5HB2	Fifth-harmonic block asserted for Differential Element 2	24
5HB3	Fifth-harmonic block asserted for Differential Element 3	24
5HBL	Fifth-harmonic block asserted (5HB1 OR 5HB2 OR 5HB3)	24
81D1T	Level 1 definite-time over-/underfrequency trip	49
81D2T	Level 2 definite-time over-/underfrequency trip	49

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 10 of 31)

Bit	Definition	Row
81D3T	Level 3 definite-time over-/underfrequency trip	49
81D4T	Level 4 definite-time over-/underfrequency trip	49
87AP	Differential current alarm element pickup	22
87AT	Differential current alarm element trip	22
87BL1	Harmonic block asserted for Differential Element 1	25
87BL2	Harmonic block asserted for Differential Element 2	25
87BL3	Harmonic block asserted for Differential Element 3	25
87HB	Harmonic block differential element asserted	25
87HR	Harmonic restrained element (HR1 OR HR2 OR HR3) AND harmonic restrain enable	25
87HR1	Harmonic Restrained Element 1	25
87HR2	Harmonic Restrained Element 2	25
87HR3	Harmonic Restrained Element 3	25
87Q	Negative-sequence differential element trip	6
87QBLK	Negative-sequence differential element blocked	222
87QP	Negative-sequence differential element pickup	222
87R	Restrained differential element trip (87HR OR 87HB)	23
87R1	Restrained Differential Element 1 (not considering harmonic blocks)	23
87R2	Restrained Differential Element 2 (not considering harmonic blocks)	23
87R3	Restrained Differential Element 3 (not considering harmonic blocks)	23
87U	Unrestrained differential element trip (87U1 OR 87U2 OR 87U3)	23
87U1	Unrestrained Differential Element 1 trip	23
87U2	Unrestrained Differential Element 2 trip	23
87U3	Unrestrained Differential Element 3 trip	23
89A2P1	Two-Position Disconnect 1 N/O contact	145
89A2P2	Two-Position Disconnect 2 N/O contact	145
89A2P3	Two-Position Disconnect 3 N/O contact	146
89A2P4	Two-Position Disconnect 4 N/O contact	146
89A2P5	Two-Position Disconnect 5 N/O contact	147
89A2P6	Two-Position Disconnect 6 N/O contact	147
89A2P7	Two-Position Disconnect 7 N/O contact	148
89A2P8	Two-Position Disconnect 8 N/O contact	148
89A2P9	Two-Position Disconnect 9 N/O contact	149
89A2P10	Two-Position Disconnect 10 N/O contact	149
89A2P11	Two-Position Disconnect 11 N/O contact	150

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 11 of 31)

Bit	Definition	Row
89A2P12	Two-Position Disconnect 12 N/O contact	150
89A2P13	Two-Position Disconnect 13 N/O contact	151
89A2P14	Two-Position Disconnect 14 N/O contact	151
89A2P15	Two-Position Disconnect 15 N/O contact	152
89A2P16	Two-Position Disconnect 16 N/O contact	152
89A3PE1	Three-Position Earthing Disconnect 1 N/O auxiliary contact	203
89A3PE2	Three-Position Earthing Disconnect 2 N/O auxiliary contact	205
89A3PL1	Three-Position In-Line Disconnect 1 N/O auxiliary contact	202
89A3PL2	Three-Position In-Line Disconnect 2 N/O auxiliary contact	204
89AL	Any two-position or three-position disconnect in alarm	202
89AL2P1	Two-Position Disconnect 1 alarm	153
89AL2P2	Two-Position Disconnect 2 alarm	153
89AL2P3	Two-Position Disconnect 3 alarm	153
89AL2P4	Two-Position Disconnect 4 alarm	153
89AL2P5	Two-Position Disconnect 5 alarm	153
89AL2P6	Two-Position Disconnect 6 alarm	153
89AL2P7	Two-Position Disconnect 7 alarm	153
89AL2P8	Two-Position Disconnect 8 alarm	153
89AL2P9	Two-Position Disconnect 9 alarm	154
89AL2P10	Two-Position Disconnect 10 alarm	154
89AL2P11	Two-Position Disconnect 11 alarm	154
89AL2P12	Two-Position Disconnect 12 alarm	154
89AL2P13	Two-Position Disconnect 13 alarm	154
89AL2P14	Two-Position Disconnect 14 alarm	154
89AL2P15	Two-Position Disconnect 15 alarm	154
89AL2P16	Two-Position Disconnect 16 alarm	154
89AL3PE1	Three-Position Earthing Disconnect 1 alarm	203
89AL3PE2	Three-Position Earthing Disconnect 2 alarm	205
89AL3PL1	Three-Position In-Line Disconnect 1 alarm	202
89AL3PL2	Three-Position In-Line Disconnect 2 alarm	204
89B2P1	Two-Position Disconnect 1 N/C contact	145
89B2P2	Two-Position Disconnect 2 N/C contact	145
89B2P3	Two-Position Disconnect 3 N/C contact	146
89B2P4	Two-Position Disconnect 4 N/C contact	146

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 12 of 31)

Bit	Definition	Row
89B2P5	Two-Position Disconnect 5 N/C contact	147
89B2P6	Two-Position Disconnect 6 N/C contact	147
89B2P7	Two-Position Disconnect 7 N/C contact	148
89B2P8	Two-Position Disconnect 8 N/C contact	148
89B2P9	Two-Position Disconnect 9 N/C contact	149
89B2P10	Two-Position Disconnect 10 N/C contact	149
89B2P11	Two-Position Disconnect 11 N/C contact	150
89B2P12	Two-Position Disconnect 12 N/C contact	150
89B2P13	Two-Position Disconnect 13 N/C contact	151
89B2P14	Two-Position Disconnect 14 N/C contact	151
89B2P15	Two-Position Disconnect 15 N/C contact	152
89B2P16	Two-Position Disconnect 16 N/C contact	152
89B3PE1	Three-Position Earthing Disconnect 1 N/C auxiliary contact	203
89B3PE2	Three-Position Earthing Disconnect 2 N/C auxiliary contact	205
89B3PL1	Three-Position In-Line Disconnect 1 N/C auxiliary contact	202
89B3PL2	Three-Position In-Line Disconnect 2 N/C auxiliary contact	204
89C2P1	Two-Position Disconnect 1 close output	160
89C2P10	Two-Position Disconnect 10 close output	169
89C2P11	Two-Position Disconnect 11 close output	170
89C2P12	Two-Position Disconnect 12 close output	171
89C2P13	Two-Position Disconnect 13 close output	172
89C2P14	Two-Position Disconnect 14 close output	173
89C2P15	Two-Position Disconnect 15 close output	174
89C2P16	Two-Position Disconnect 16 close output	175
89C2P2	Two-Position Disconnect 2 close output	161
89C2P3	Two-Position Disconnect 3 close output	162
89C2P4	Two-Position Disconnect 4 close output	163
89C2P5	Two-Position Disconnect 5 close output	164
89C2P6	Two-Position Disconnect 6 close output	165
89C2P7	Two-Position Disconnect 7 close output	166
89C2P8	Two-Position Disconnect 8 close output	167
89C2P9	Two-Position Disconnect 9 close output	168
89C3PE1	Three-Position Earthing Disconnect 1 close output	207
89C3PE2	Three-Position Earthing Disconnect 2 close output	209

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 13 of 31)

Bit	Definition	Row
89C3PL1	Three-Position In-Line Disconnect 1 close output	206
89C3PL2	Three-Position In-Line Disconnect 2 close output	208
89CC2P1	Two-Position Disconnect 1 close command for control via communication protocols	176
89CC2P10	Two-Position Disconnect 10 close command for control via communication protocols	185
89CC2P11	Two-Position Disconnect 11 close command for control via communication protocols	186
89CC2P12	Two-Position Disconnect 12 close command for control via communication protocols	187
89CC2P13	Two-Position Disconnect 13 close command for control via communication protocols	188
89CC2P14	Two-Position Disconnect 14 close command for control via communication protocols	189
89CC2P15	Two-Position Disconnect 15 close command for control via communication protocols	190
89CC2P16	Two-Position Disconnect 16 close command for control via communication protocols	191
89CC2P2	Two-Position Disconnect 2 close command for control via communication protocols	177
89CC2P3	Two-Position Disconnect 3 close command for control via communication protocols	178
89CC2P4	Two-Position Disconnect 4 close command for control via communication protocols	179
89CC2P5	Two-Position Disconnect 5 close command for control via communication protocols	180
89CC2P6	Two-Position Disconnect 6 close command for control via communication protocols	181
89CC2P7	Two-Position Disconnect 7 close command for control via communication protocols	182
89CC2P8	Two-Position Disconnect 8 close command for control via communication protocols	183
89CC2P9	Two-Position Disconnect 9 close command for control via communication protocols	184
89CC3PE1	Three-Position Earthing Disconnect 1 close command for control via communication protocols	193
89CC3PE2	Three-Position Earthing Disconnect 2 close command for control via communication protocols	195
89CC3PL1	Three-Position In-Line Disconnect 1 close command for control via communication protocols	192
89CC3PL2	Three-Position In-Line Disconnect 2 close command for control via communication protocols	194
89CE2P1	Two-Position Disconnect 1 close enable	160
89CE2P10	Two-Position Disconnect 10 close enable	169
89CE2P11	Two-Position Disconnect 11 close enable	170
89CE2P12	Two-Position Disconnect 12 close enable	171
89CE2P13	Two-Position Disconnect 13 close enable	172
89CE2P14	Two-Position Disconnect 14 close enable	173
89CE2P15	Two-Position Disconnect 15 close enable	174
89CE2P16	Two-Position Disconnect 16 close enable	175
89CE2P2	Two-Position Disconnect 2 close enable	161
89CE2P3	Two-Position Disconnect 3 close enable	162

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 14 of 31)

Bit	Definition	Row
89CE2P4	Two-Position Disconnect 4 close enable	163
89CE2P5	Two-Position Disconnect 5 close enable	164
89CE2P6	Two-Position Disconnect 6 close enable	165
89CE2P7	Two-Position Disconnect 7 close enable	166
89CE2P8	Two-Position Disconnect 8 close enable	167
89CE2P9	Two-Position Disconnect 9 close enable	168
89CE3PE1	Three-Position Earthing Disconnect 1 close enable	207
89CE3PE2	Three-Position Earthing Disconnect 2 close enable	209
89CE3PL1	Three-Position In-Line Disconnect 1 close enable	206
89CE3PL2	Three-Position In-Line Disconnect 2 close enable	208
89CI2P1	Two-Position Disconnect 1 close immobility timer timed out	160
89CI2P10	Two-Position Disconnect 10 close immobility timer timed out	169
89CI2P11	Two-Position Disconnect 11 close immobility timer timed out	170
89CI2P12	Two-Position Disconnect 12 close immobility timer timed out	171
89CI2P13	Two-Position Disconnect 13 close immobility timer timed out	172
89CI2P14	Two-Position Disconnect 14 close immobility timer timed out	173
89CI2P15	Two-Position Disconnect 15 close immobility timer timed out	174
89CI2P16	Two-Position Disconnect 16 close immobility timer timed out	175
89CI2P2	Two-Position Disconnect 2 close immobility timer timed out	161
89CI2P3	Two-Position Disconnect 3 close immobility timer timed out	162
89CI2P4	Two-Position Disconnect 4 close immobility timer timed out	163
89CI2P5	Two-Position Disconnect 5 close immobility timer timed out	164
89CI2P6	Two-Position Disconnect 6 close immobility timer timed out	165
89CI2P7	Two-Position Disconnect 7 close immobility timer timed out	166
89CI2P8	Two-Position Disconnect 8 close immobility timer timed out	167
89CI2P9	Two-Position Disconnect 9 close immobility timer timed out	168
89CI3PE1	Three-Position Earthing Disconnect 1 close immobility timer timed out	207
89CI3PE2	Three-Position Earthing Disconnect 2 close immobility timer timed out	209
89CI3PL1	Three-Position In-Line Disconnect 1 close immobility timer timed out	206
89CI3PL2	Three-Position In-Line Disconnect 2 close immobility timer timed out	208
89CL2P1	Two-Position Disconnect 1 closed	145
89CL2P2	Two-Position Disconnect 2 closed	145
89CL2P3	Two-Position Disconnect 3 closed	146
89CL2P4	Two-Position Disconnect 4 closed	146

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 15 of 31)

Bit	Definition	Row
89CL2P5	Two-Position Disconnect 5 closed	147
89CL2P6	Two-Position Disconnect 6 closed	147
89CL2P7	Two-Position Disconnect 7 closed	148
89CL2P8	Two-Position Disconnect 8 closed	148
89CL2P9	Two-Position Disconnect 9 closed	149
89CL2P10	Two-Position Disconnect 10 closed	149
89CL2P11	Two-Position Disconnect 11 closed	150
89CL2P12	Two-Position Disconnect 12 closed	150
89CL2P13	Two-Position Disconnect 13 closed	151
89CL2P14	Two-Position Disconnect 14 closed	151
89CL2P15	Two-Position Disconnect 15 closed	152
89CL2P16	Two-Position Disconnect 16 closed	152
89CL3PE1	Three-Position Earthing Disconnect 1 closed	203
89CL3PE2	Three-Position Earthing Disconnect 2 closed	205
89CL3PL1	Three-Position In-Line Disconnect 1 closed	202
89CL3PL2	Three-Position In-Line Disconnect 2 closed	204
89CM2P1	Two-Position Disconnect 1 close command for control via front panel HMI	176
89CM2P10	Two-Position Disconnect 10 close command for control via front panel HMI	185
89CM2P11	Two-Position Disconnect 11 close command for control via front panel HMI	186
89CM2P12	Two-Position Disconnect 12 close command for control via front panel HMI	187
89CM2P13	Two-Position Disconnect 13 close command for control via front panel HMI	188
89CM2P14	Two-Position Disconnect 14 close command for control via front panel HMI	189
89CM2P15	Two-Position Disconnect 15 close command for control via front panel HMI	190
89CM2P16	Two-Position Disconnect 16 close command for control via front panel HMI	191
89CM2P2	Two-Position Disconnect 2 close command for control via front panel HMI	177
89CM2P3	Two-Position Disconnect 3 close command for control via front panel HMI	178
89CM2P4	Two-Position Disconnect 4 close command for control via front panel HMI	179
89CM2P5	Two-Position Disconnect 5 close command for control via front panel HMI	180
89CM2P6	Two-Position Disconnect 6 close command for control via front panel HMI	181
89CM2P7	Two-Position Disconnect 7 close command for control via front panel HMI	182
89CM2P8	Two-Position Disconnect 8 close command for control via front panel HMI	183
89CM2P9	Two-Position Disconnect 9 close command for control via front panel HMI	184
89CM3PE1	Three-Position Earthing Disconnect 1 close command for control via front panel HMI	193
89CM3PE2	Three-Position Earthing Disconnect 2 close command for control via front panel HMI	195

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 16 of 31)

Bit	Definition	Row
89CM3PL1	Three-Position In-Line Disconnect 1 close command for control via front panel HMI	192
89CM3PL2	Three-Position In-Line Disconnect 2 close command for control via front panel HMI	194
89CS2P1	Two-Position Disconnect 1 close seal-in timer timed out	160
89CS2P10	Two-Position Disconnect 10 close seal-in timer timed out	169
89CS2P11	Two-Position Disconnect 11 close seal-in timer timed out	170
89CS2P12	Two-Position Disconnect 12 close seal-in timer timed out	171
89CS2P13	Two-Position Disconnect 13 close seal-in timer timed out	172
89CS2P14	Two-Position Disconnect 14 close seal-in timer timed out	173
89CS2P15	Two-Position Disconnect 15 close seal-in timer timed out	174
89CS2P16	Two-Position Disconnect 16 close seal-in timer timed out	175
89CS2P2	Two-Position Disconnect 2 close seal-in timer timed out	161
89CS2P3	Two-Position Disconnect 3 close seal-in timer timed out	162
89CS2P4	Two-Position Disconnect 4 close seal-in timer timed out	163
89CS2P5	Two-Position Disconnect 5 close seal-in timer timed out	164
89CS2P6	Two-Position Disconnect 6 close seal-in timer timed out	165
89CS2P7	Two-Position Disconnect 7 close seal-in timer timed out	166
89CS2P8	Two-Position Disconnect 8 close seal-in timer timed out	167
89CS2P9	Two-Position Disconnect 9 close seal-in timer timed out	168
89CS3PE1	Three-Position Earthing Disconnect 1 close seal-in timer timed out	207
89CS3PE2	Three-Position Earthing Disconnect 2 close seal-in timer timed out	209
89CS3PL1	Three-Position In-Line Disconnect 1 close seal-in timer timed out	206
89CS3PL2	Three-Position In-Line Disconnect 2 close seal-in timer timed out	208
89IP	Any two-position or three-position disconnect operation in-progress	203
89IP2P1	Two-Position Disconnect 1 operation in-progress	201
89IP2P10	Two-Position Disconnect 10 operation in-progress	201
89IP2P11	Two-Position Disconnect 11 operation in-progress	201
89IP2P12	Two-Position Disconnect 12 operation in-progress	201
89IP2P13	Two-Position Disconnect 13 operation in-progress	201
89IP2P14	Two-Position Disconnect 14 operation in-progress	201
89IP2P15	Two-Position Disconnect 15 operation in-progress	201
89IP2P16	Two-Position Disconnect 16 operation in-progress	201
89IP2P2	Two-Position Disconnect 2 operation in-progress	200
89IP2P3	Two-Position Disconnect 3 operation in-progress	200
89IP2P4	Two-Position Disconnect 4 operation in-progress	200

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 17 of 31)

Bit	Definition	Row
89IP2P5	Two-Position Disconnect 5 operation in-progress	200
89IP2P6	Two-Position Disconnect 6 operation in-progress	200
89IP2P7	Two-Position Disconnect 7 operation in-progress	200
89IP2P8	Two-Position Disconnect 8 operation in-progress	200
89IP2P9	Two-Position Disconnect 9 operation in-progress	201
89IP3PE1	Three-Position Earthing Disconnect 1 operation in-progress	203
89IP3PE2	Three-Position Earthing Disconnect 2 operation in-progress	205
89IP3PL1	Three-Position In-Line Disconnect 1 operation in-progress	202
89IP3PL2	Three-Position In-Line Disconnect 2 operation in-progress	204
89O2P1	Two-Position Disconnect 1 open output	160
89O2P10	Two-Position Disconnect 10 open output	169
89O2P11	Two-Position Disconnect 11 open output	170
89O2P12	Two-Position Disconnect 12 open output	171
89O2P13	Two-Position Disconnect 13 open output	172
89O2P14	Two-Position Disconnect 14 open output	173
89O2P15	Two-Position Disconnect 15 open output	174
89O2P16	Two-Position Disconnect 16 open output	175
89O2P2	Two-Position Disconnect 2 open output	161
89O2P3	Two-Position Disconnect 3 open output	162
89O2P4	Two-Position Disconnect 4 open output	163
89O2P5	Two-Position Disconnect 5 open output	164
89O2P6	Two-Position Disconnect 6 open output	165
89O2P7	Two-Position Disconnect 7 open output	166
89O2P8	Two-Position Disconnect 8 open output	167
89O2P9	Two-Position Disconnect 9 open output	168
89O3PE1	Three-Position Earthing Disconnect 1 open output	207
89O3PE2	Three-Position Earthing Disconnect 2 open output	209
89O3PL1	Three-Position In-Line Disconnect 1 open output	206
89O3PL2	Three-Position In-Line Disconnect 2 open output	208
89OC2P1	Two-Position Disconnect 1 open command for control via communication protocols	176
89OC2P10	Two-Position Disconnect 10 open command for control via communication protocols	185
89OC2P11	Two-Position Disconnect 11 open command for control via communication protocols	186
89OC2P12	Two-Position Disconnect 12 open command for control via communication protocols	187
89OC2P13	Two-Position Disconnect 13 open command for control via communication protocols	188

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 18 of 31)

Bit	Definition	Row
89OC2P14	Two-Position Disconnect 14 open command for control via communication protocols	189
89OC2P15	Two-Position Disconnect 15 open command for control via communication protocols	190
89OC2P16	Two-Position Disconnect 16 open command for control via communication protocols	191
89OC2P2	Two-Position Disconnect 2 open command for control via communication protocols	177
89OC2P3	Two-Position Disconnect 3 open command for control via communication protocols	178
89OC2P4	Two-Position Disconnect 4 open command for control via communication protocols	179
89OC2P5	Two-Position Disconnect 5 open command for control via communication protocols	180
89OC2P6	Two-Position Disconnect 6 open command for control via communication protocols	181
89OC2P7	Two-Position Disconnect 7 open command for control via communication protocols	182
89OC2P8	Two-Position Disconnect 8 open command for control via communication protocols	183
89OC2P9	Two-Position Disconnect 9 open command for control via communication protocols	184
89OC3PE1	Three-Position Earthing Disconnect 1 open command for control via communication protocols	193
89OC3PE2	Three-Position Earthing Disconnect 2 open command for control via communication protocols	195
89OC3PL1	Three-Position In-Line Disconnect 1 open command for control via communication protocols	192
89OC3PL2	Three-Position In-Line Disconnect 2 open command for control via communication protocols	194
89OE2P1	Two-Position Disconnect 1 open enable	160
89OE2P10	Two-Position Disconnect 10 open enable	169
89OE2P11	Two-Position Disconnect 11 open enable	170
89OE2P12	Two-Position Disconnect 12 open enable	171
89OE2P13	Two-Position Disconnect 13 open enable	172
89OE2P14	Two-Position Disconnect 14 open enable	173
89OE2P15	Two-Position Disconnect 15 open enable	174
89OE2P16	Two-Position Disconnect 16 open enable	175
89OE2P2	Two-Position Disconnect 2 open enable	161
89OE2P3	Two-Position Disconnect 3 open enable	162
89OE2P4	Two-Position Disconnect 4 open enable	163
89OE2P5	Two-Position Disconnect 5 open enable	164
89OE2P6	Two-Position Disconnect 6 open enable	165
89OE2P7	Two-Position Disconnect 7 open enable	166
89OE2P8	Two-Position Disconnect 8 open enable	167
89OE2P9	Two-Position Disconnect 9 open enable	168
89OE3PE1	Three-Position Earthing Disconnect 1 open enable	207

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 19 of 31)

Bit	Definition	Row
89OE3PE2	Three-Position Earthing Disconnect 2 open enable	209
89OE3PL1	Three-Position In-Line Disconnect 1 open enable	206
89OE3PL2	Three-Position In-Line Disconnect 2 open enable	208
89OI2P1	Two-Position Disconnect 1 open immobility timer timed out	160
89OI2P10	Two-Position Disconnect 10 open immobility timer timed out	169
89OI2P11	Two-Position Disconnect 11 open immobility timer timed out	170
89OI2P12	Two-Position Disconnect 12 open immobility timer timed out	171
89OI2P13	Two-Position Disconnect 13 open immobility timer timed out	172
89OI2P14	Two-Position Disconnect 14 open immobility timer timed out	173
89OI2P15	Two-Position Disconnect 15 open immobility timer timed out	174
89OI2P16	Two-Position Disconnect 16 open immobility timer timed out	175
89OI2P2	Two-Position Disconnect 2 open immobility timer timed out	161
89OI2P3	Two-Position Disconnect 3 open immobility timer timed out	162
89OI2P4	Two-Position Disconnect 4 open immobility timer timed out	163
89OI2P5	Two-Position Disconnect 5 open immobility timer timed out	164
89OI2P6	Two-Position Disconnect 6 open immobility timer timed out	165
89OI2P7	Two-Position Disconnect 7 open immobility timer timed out	166
89OI2P8	Two-Position Disconnect 8 open immobility timer timed out	167
89OI2P9	Two-Position Disconnect 9 open immobility timer timed out	168
89OI3PE1	Three-Position Earthing Disconnect 1 open immobility timer timed out	207
89OI3PE2	Three-Position Earthing Disconnect 2 open immobility timer timed out	209
89OI3PL1	Three-Position In-Line Disconnect 1 open immobility timer timed out	206
89OI3PL2	Three-Position In-Line Disconnect 2 open immobility timer timed out	208
89OM2P1	Two-Position Disconnect 1 open command for control via front panel HMI	176
89OM2P10	Two-Position Disconnect 10 open command for control via front panel HMI	185
89OM2P11	Two-Position Disconnect 11 open command for control via front panel HMI	186
89OM2P12	Two-Position Disconnect 12 open command for control via front panel HMI	187
89OM2P13	Two-Position Disconnect 13 open command for control via front panel HMI	188
89OM2P14	Two-Position Disconnect 14 open command for control via front panel HMI	189
89OM2P15	Two-Position Disconnect 15 open command for control via front panel HMI	190
89OM2P16	Two-Position Disconnect 16 open command for control via front panel HMI	191
89OM2P2	Two-Position Disconnect 2 open command for control via front panel HMI	177
89OM2P3	Two-Position Disconnect 3 open command for control via front panel HMI	178
89OM2P4	Two-Position Disconnect 4 open command for control via front panel HMI	179

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Bit	Definition	Row
89OM2P5	Two-Position Disconnect 5 open command for control via front panel HMI	180
89OM2P6	Two-Position Disconnect 6 open command for control via front panel HMI	181
89OM2P7	Two-Position Disconnect 7 open command for control via front panel HMI	182
89OM2P8	Two-Position Disconnect 8 open command for control via front panel HMI	183
89OM2P9	Two-Position Disconnect 9 open command for control via front panel HMI	184
89OM3PE1	Three-Position Earthing Disconnect 1 open command for control via front panel HMI	193
89OM3PE2	Three-Position Earthing Disconnect 2 open command for control via front panel HMI	195
89OM3PL1	Three-Position In-Line Disconnect 1 open command for control via front panel HMI	192
89OM3PL2	Three-Position In-Line Disconnect 2 open command for control via front panel HMI	194
89OP2P1	Two-Position Disconnect 1 open	145
89OP2P2	Two-Position Disconnect 2 open	145
89OP2P3	Two-Position Disconnect 3 open	146
89OP2P4	Two-Position Disconnect 4 open	146
89OP2P5	Two-Position Disconnect 5 open	147
89OP2P6	Two-Position Disconnect 6 open	147
89OP2P7	Two-Position Disconnect 7 open	148
89OP2P8	Two-Position Disconnect 8 open	148
89OP2P9	Two-Position Disconnect 9 open	149
89OP2P10	Two-Position Disconnect 10 open	149
89OP2P11	Two-Position Disconnect 11 open	150
89OP2P12	Two-Position Disconnect 12 open	150
89OP2P13	Two-Position Disconnect 13 open	151
89OP2P14	Two-Position Disconnect 14 open	151
89OP2P15	Two-Position Disconnect 15 open	152
89OP2P16	Two-Position Disconnect 16 open	152
89OP3PE1	Three-Position Earthing Disconnect 1 open	203
89OP3PE2	Three-Position Earthing Disconnect 2 open	205
89OP3PL1	Three-Position In-Line Disconnect 1 open	202
89OP3PL2	Three-Position In-Line Disconnect 2 open	204
89OS2P1	Two-Position Disconnect 1 open seal-in timer timed out	160
89OS2P10	Two-Position Disconnect 10 open seal-in timer timed out	169
89OS2P11	Two-Position Disconnect 11 open seal-in timer timed out	170
89OS2P12	Two-Position Disconnect 12 open seal-in timer timed out	171
89OS2P13	Two-Position Disconnect 13 open seal-in timer timed out	172

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 21 of 31)

Bit	Definition	Row
89OS2P14	Two-Position Disconnect 14 open seal-in timer timed out	173
89OS2P15	Two-Position Disconnect 15 open seal-in timer timed out	174
89OS2P16	Two-Position Disconnect 16 open seal-in timer timed out	175
89OS2P2	Two-Position Disconnect 2 open seal-in timer timed out	161
89OS2P3	Two-Position Disconnect 3 open seal-in timer timed out	162
89OS2P4	Two-Position Disconnect 4 open seal-in timer timed out	163
89OS2P5	Two-Position Disconnect 5 open seal-in timer timed out	164
89OS2P6	Two-Position Disconnect 6 open seal-in timer timed out	165
89OS2P7	Two-Position Disconnect 7 open seal-in timer timed out	166
89OS2P8	Two-Position Disconnect 8 open seal-in timer timed out	167
89OS2P9	Two-Position Disconnect 9 open seal-in timer timed out	168
89OS3PE1	Three-Position Earthing Disconnect 1 open seal-in timer timed out	207
89OS3PE2	Three-Position Earthing Disconnect 2 open seal-in timer timed out	209
89OS3PL1	Three-Position In-Line Disconnect 1 open seal-in timer timed out	206
89OS3PL2	Three-Position In-Line Disconnect 2 open seal-in timer timed out	208
89RC2P1	Two-Position Disconnect 1 remote close control SELOGIC control equation	176
89RC2P10	Two-Position Disconnect 10 remote close control SELOGIC control equation	185
89RC2P11	Two-Position Disconnect 11 remote close control SELOGIC control equation	186
89RC2P12	Two-Position Disconnect 12 remote close control SELOGIC control equation	187
89RC2P13	Two-Position Disconnect 13 remote close control SELOGIC control equation	188
89RC2P14	Two-Position Disconnect 14 remote close control SELOGIC control equation	189
89RC2P15	Two-Position Disconnect 15 remote close control SELOGIC control equation	190
89RC2P16	Two-Position Disconnect 16 remote close control SELOGIC control equation	191
89RC2P2	Two-Position Disconnect 2 remote close control SELOGIC control equation	177
89RC2P3	Two-Position Disconnect 3 remote close control SELOGIC control equation	178
89RC2P4	Two-Position Disconnect 4 remote close control SELOGIC control equation	179
89RC2P5	Two-Position Disconnect 5 remote close control SELOGIC control equation	180
89RC2P6	Two-Position Disconnect 6 remote close control SELOGIC control equation	181
89RC2P7	Two-Position Disconnect 7 remote close control SELOGIC control equation	182
89RC2P8	Two-Position Disconnect 8 remote close control SELOGIC control equation	183
89RC2P9	Two-Position Disconnect 9 remote close control SELOGIC control equation	184
89RC3PE1	Three-Position Earthing Disconnect 1 remote close control SELOGIC control equation	193
89RC3PE2	Three-Position Earthing Disconnect 2 remote close control SELOGIC control equation	195
89RC3PL1	Three-Position In-Line Disconnect 1 remote close control SELOGIC control equation	192

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 22 of 31)

Bit	Definition	Row
89RC3PL2	Three-Position In-Line Disconnect 2 remote close control SELOGIC control equation	194
89RO2P1	Two-Position Disconnect 1 remote open control SELOGIC control equation	176
89RO2P10	Two-Position Disconnect 10 remote open control SELOGIC control equation	185
89RO2P11	Two-Position Disconnect 11 remote open control SELOGIC control equation	186
89RO2P12	Two-Position Disconnect 12 remote open control SELOGIC control equation	187
89RO2P13	Two-Position Disconnect 13 remote open control SELOGIC control equation	188
89RO2P14	Two-Position Disconnect 14 remote open control SELOGIC control equation	189
89RO2P15	Two-Position Disconnect 15 remote open control SELOGIC control equation	190
89RO2P16	Two-Position Disconnect 16 remote open control SELOGIC control equation	191
89RO2P2	Two-Position Disconnect 2 remote open control SELOGIC control equation	177
89RO2P3	Two-Position Disconnect 3 remote open control SELOGIC control equation	178
89RO2P4	Two-Position Disconnect 4 remote open control SELOGIC control equation	179
89RO2P5	Two-Position Disconnect 5 remote open control SELOGIC control equation	180
89RO2P6	Two-Position Disconnect 6 remote open control SELOGIC control equation	181
89RO2P7	Two-Position Disconnect 7 remote open control SELOGIC control equation	182
89RO2P8	Two-Position Disconnect 8 remote open control SELOGIC control equation	183
89RO2P9	Two-Position Disconnect 9 remote open control SELOGIC control equation	184
89RO3PE1	3-Position Earthing Disconnect 1 remote open control SELOGIC control equation	193
89RO3PE2	3-Position Earthing Disconnect 2 remote open control SELOGIC control equation	195
89RO3PL1	3-Position In-Line Disconnect 1 remote open control SELOGIC control equation	192
89RO3PL2	3-Position In-Line Disconnect 2 remote open control SELOGIC control equation	194
AI*nnn*HAL	Analog Inputs 301–504 warnings/alarms (where *nnn* = 301–504) high alarm limit	120–144
AI*nnn*HW1	Analog Inputs 301–504 warnings/alarms (where *nnn* = 301–504) high warning, Level 1	120–144
AI*nnn*HW2	Analog Inputs 301–504 warnings/alarms (where *nnn* = 301–504) high warning, Level 2	120–144
AI*nnn*LAL	Analog Inputs 301–504 warnings/alarms (where *nnn* = 301–504) low alarm limit	120–144
AI*nnn*LW1	Analog Inputs 301–504 warnings/alarms (where *nnn* = 301–504) low warning, Level 1	120–144
AI*nnn*LW2	Analog Inputs 301–504 warnings/alarms (where *nnn* = 301–504) low warning, Level 2	120–144
AIHAL	Analog inputs high alarm limit. If any AI*xxx*HAL = 1, then AIHAL = 1.	119
AIHW1	Analog inputs high warning, Level 1. If any AI*xxx*HW1 = 1, then AIHW1 = 1.	119
AIHW2	Analog inputs high warning, Level 2. If any AI*xxx*HW2 = 1, then AIHW2 = 1.	119
AILAL	Analog inputs low alarm limit. If any AI*xxx*LAL = 1, then AILAL = 1.	119
AILW1	Analog inputs low warning, Level 1. If any AI*xxx*LW1 = 1, then AILW1 = 1.	119
AILW2	Analog inputs low warning, Level 2. If any AI*xxx*LW2 = 1, then AILW2 = 1.	119
AMBALRM	Ambient temperature alarm. AMBALRM asserts if the healthy Ambient RTD temperature exceeds its alarm set point.	46

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Bit	Definition	Row
AMBTRIP	Ambient temperature trip. AMBTRIP asserts when the healthy Ambient RTD temperature exceeds its trip set point.	46
BCW1	BCW1A OR BCW1B OR BCW1C	132
BCW1A	Breaker 1, Phase A contact wear has reached the 100 percent wear level	132
BCW1B	Breaker 1, Phase B contact wear has reached the 100 percent wear level	132
BCW1C	Breaker 1, Phase C contact wear has reached the 100 percent wear level	132
BCW2	BCW2A OR BCW2B OR BCW2C	132
BCW2A	Breaker 2, Phase A contact wear has reached the 100 percent wear level	132
BCW2B	Breaker 2, Phase B contact wear has reached the 100 percent wear level	132
BCW2C	Breaker 2, Phase C contact wear has reached the 100 percent wear level	132
BCW3	BCW3A OR BCW3B OR BCW3C	133
BCW3A	Breaker 3, Phase A contact wear has reached the 100 percent wear level	133
BCW3B	Breaker 3, Phase B contact wear has reached the 100 percent wear level	133
BCW3C	Breaker 3, Phase C contact wear has reached the 100 percent wear level	133
BCW4	BCW4A OR BCW4B OR BCW4C	133
BCW4A	Breaker 4, Phase A contact wear has reached the 100 percent wear level	133
BCW4B	Breaker 4, Phase B contact wear has reached the 100 percent wear level	133
BCW4C	Breaker 4, Phase C contact wear has reached the 100 percent wear level	133
BFI1–BFI4	Breaker failure logic for Breaker 1–Breaker 4 initiated	45
BFT1–BFT4	Breaker failure timer for Breaker 1–Breaker 4 timed out	45
BFRT1	Breaker 1 failure retrip	229
BFRT2	Breaker 2 failure retrip	229
BFRT3	Breaker 3 failure retrip	229
BFRT4	Breaker 4 failure retrip	229
BFTR1	SELOGIC Breaker 1 failure trip equation	228
BFTR2	SELOGIC Breaker 2 failure trip equation	228
BFTR3	SELOGIC Breaker 3 failure trip equation	228
BFTR4	SELOGIC Breaker 4 failure trip equation	228
BFTRIP1	Breaker 1 failure trip logic output	230
BFTRIP2	Breaker 2 failure trip logic output	230
BFTRIP3	Breaker 3 failure trip logic output	230
BFTRIP4	Breaker 4 failure trip logic output	230
BFULTR1	SELOGIC Breaker 1 failure unlatch trip equation	228
BFULTR2	SELOGIC Breaker 2 failure unlatch trip equation	228
BFULTR3	SELOGIC Breaker 3 failure unlatch trip equation	228

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Bit	Definition	Row
BFULTR4	SELOGIC Breaker 4 failure unlatch trip equation	228
BKENC1	SELOGIC control for Breaker 1 close interlocking supervision	214
BKENC2	SELOGIC control for Breaker 2 close interlocking supervision	214
BKENC3	SELOGIC control for Breaker 3 close interlocking supervision	215
BKENC4	SELOGIC control for Breaker 4 close interlocking supervision	215
BKENO1	SELOGIC control for Breaker 1 open interlocking supervision	214
BKENO2	SELOGIC control for Breaker 2 open interlocking supervision	214
BKENO3	SELOGIC control for Breaker 3 open interlocking supervision	215
BKENO4	SELOGIC control for Breaker 4 open interlocking supervision	215
BKJMP	Asserts if breaker control jumper is installed on main board	155
CBADA	Channel A, channel unavailability over threshold	102
CBADB	Channel B, channel unavailability over threshold	102
CC1–CC4	**CLOSE** command—asserts when a communications command is issued to close Breaker 1–Breaker 4	60
CF1–CF4	Breaker 1–Breaker 4 close condition failure ON	60
CFGFLT	Asserts on failed settings interdependency check during Modbus setting change	48
CL1–CL4	Close SELOGIC Control Equation CL1–CL4	59
CLOSE1–CLOSE4	Close logic output for Breaker 1–Breaker 4	55
COMMFLT	Time out of internal communication between CPU board and DeviceNet board	48
COMMIDLE	DeviceNet card in programming mode	48
COMMLOSS	DeviceNet communication failure	48
DCHI	Station dc battery instantaneous overvoltage element	30
DCLO	Station dc battery instantaneous undervoltage element	30
DI_A1	Distortion index wdg1—Phase A	128
DI_A2	Distortion index wdg2—Phase A	128
DI_A3	Distortion index wdg3—Phase A	129
DI_A4	Distortion index wdg4—Phase A	129
DI_B1	Distortion index wdg1—Phase B	128
DI_B2	Distortion index wdg2—Phase B	128
DI_B3	Distortion index wdg3—Phase B	129
DI_B4	Distortion index wdg4—Phase B	129
DI_C1	Distortion index wdg1—Phase C	128
DI_C2	Distortion index wdg2—Phase C	128
DI_C3	Distortion index wdg3—Phase C	129
DI_C4	Distortion index wdg4—Phase C	129

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Bit	Definition	Row
DNAUX1–DNAUX8	DeviceNet/Modbus AUX1–DNAUX8 assert bits	67
DNAUX9–DNAUX11	DeviceNet/Modbus AUX9–DNAUX11 assert bits	68
DRDOPT	External fault detected	222
DRDOPT1	External fault detected—Element 1	222
DRDOPT2	External fault detected—Element 2	222
DRDOPT3	External fault detected—Element 3	222
DSABLSET	SELOGIC control equation: do not allow settings changes from front-panel interface when asserted	51
DST	Daylight-saving time	130
DSTP	Daylight-saving time pending	130
ENABLED	**ENABLE** LED	0
ENLRC	Asserted when Local/Remote is enabled by EN_LRC=Y	155
ER	Event report trigger SELOGIC control equation	50
FAULT	Indicates fault condition. Asserts when SELOGIC Control Equation FAULT results in a logical 1.	47
FLTP1	REF1 element, external phase-to-phase fault detected	231
FLTP3A	REF3A element, external phase-to-phase fault detected	231
FLTP3B	REF3B element, external phase-to-phase fault detected	232
FREQFZ	Synchrophasor frequency calculation—calculation disabled when bit is asserted	50
FREQTRK	Frequency tracking enable bit—tracking enabled when bit is asserted	50
GNDEM	Zero-sequence current demand pickup	69
HALARM	Diagnostics failure	51
IN101–IN102	Contact Inputs IN101 and IN102	41
IN301–IN308	Contact Inputs IN301–IN308 (available only with optional I/O module)	42
IN309–IN314	Contact Inputs IN309–IN314 (available only with optional I/O module)	138
IN401–IN408	Contact Inputs IN401–IN408 (available only with optional I/O module)	43
IN409–IN414	Contact Inputs IN409–IN414 (available only with optional I/O module)	139
IN501–IN508	Contact Inputs IN501–IN508 (available only with optional I/O module)	44
IN509–IN514	Contact Inputs IN509–IN514 (available only with optional I/O module)	140
INR1	87-1 element in high security mode	68
INR2	87-2 element in high security mode	68
INR3	87-3 element in high security mode	68
IRIGOK	IRIG-B time sync input data are valid	47
LB01–LB08	Local Bits 01–08	70
LB09–LB16	Local Bits 09–16	71

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Bit	Definition	Row
LB17–LB24	Local Bits 17–24	72
LB25–LB32	Local Bits 25–32	73
LBOKA	Channel A, looped back OK	102
LBOKB	Channel B, looped back OK	102
LINK1	Asserted when a valid link is detected on Port 1	49
LINKA	Assert if Ethernet Port A detects link	47
LINKB	Assert if Ethernet Port B detects link	47
LINKFAIL	Failure of active Ethernet port link	48
LOC	SELOGIC control for control authority as local/bay level	227
LOCAL	Asserted when relay control configuration is in Local mode	155
LOCSTA	SELOGIC control for control authority at station level	227
LOP	Loss of potential	48
LPHDSIM	IEC 61850 simulation mode	226
LPSEC	Direction of the upcoming leap second. During the time that LPSECP is asserted, if LPSEC is asserted, the upcoming leap second is deleted; otherwise, the leap second is added.	130
LPSECP	Leap second pending	130
LT01–LT08	Latch Bits 01–08	86
LT09–LT16	Latch Bits 09–16	87
LT17–LT24	Latch Bits 17–24	88
LT25–LT32	Latch Bits 25–32	89
MATHERR	SELOGIC math error bit asserted for divide-by-zero, etc., in SELOGIC math functions	128
MLTLEV	SELOGIC control for multilevel mode of control authority	227
OC1–OC4	**OPEN** command—asserts when a communications command is issued to open Breaker 1–Breaker 4	59
ORED50T	Logical OR of all the instantaneous overcurrent elements tripped outputs	7
ORED51T	Logical OR of all the time overcurrent elements tripped outputs	7
OREDLOC	Logical OR of LOC and LOCAL Relay Word bits	227
OTHALRM	Other temperature alarm. OTHALRM asserts when one or more healthy Other RTD temperatures exceed their alarm set points.	46
OTHTRIP	Other temperature trip. OTHTRIP asserts when one or more healthy Other RTD temperatures exceed their trip set points.	46
OUT101–OUT103	Control equation for Contact Output OUT101–OUT103	36
OUT301–OUT308	Control equation for Contact Output OUT301–OUT308 (available only with optional I/O module)	37
OUT401–OUT408	Control equation for Contact Output OUT401–OUT408 (available only with optional I/O module)	38

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 27 of 31)

Bit	Definition	Row
OUT501–OUT508	Control equation for Contact Outputs OUT501–OUT508 (available only with optional I/O module)	135
PASEL	Ethernet Port A is selected for communication	48
PB01–PB08	Front-Panel Pushbutton 1–8 bit (asserted when PB01–PB08 is pressed)	62
PB01_PUL–PB08_PUL	Front-Panel Pushbutton 1–8 pulse bit (asserted for one processing interval when PB01–PB08 is pressed)	63
PB1A_LED–PB4A_LED	SELOGIC control equation: Drives LED PB1A–LED PB4A	64
PB1B_LED–PB4B_LED	SELOGIC control equation: Drives LED PB1B–LED PB4B	64
PB5A_LED–PB8A_LED	SELOGIC control equation: Drives LED PB5A–LED PB8A	65
PB5B_LED–PB8B_LED	SELOGIC control equation: Drives LED PB5B–LED PB8B	65
PBSEL	Ethernet Port B is selected for communication	48
PFLEAD	Three-phase power factor lead indication	7
PHDEM	Phase current demand pickup	69
PMDOK	Phasor measurement data OK	47
PMTRIG	Trigger for synchrophasors	61
PTPA	Asserts when PTP is enabled in PRP mode and the relay is receiving PTP messages on Port 1A	225
PTPB	Asserts when PTP is enabled in PRP mode and the relay is receiving PTP messages on Port 1B	225
PTPSYNC	Asserts if the relay is using PTP time to do time sync	225
PTP_OK	Asserts if PTP time is within the 4 ms local offset	225
PTP_TIM	Asserts if a valid PTP time source is detected	225
RB01–RB08	Remote Bits 01–08	74
RB09–RB16	Remote Bits 09–16	75
RB17–RB24	Remote Bits 17–24	76
RB25–RB32	Remote Bits 25–32	77
RBADA	Channel A, outage duration over threshold	102
RBADB	Channel B, outage duration over threshold	102
REF1BY	REF1 element bypass logic output asserted	26
REF1E	REF1 element enabled	26
REF1F	REF1 element forward (internal fault) declaration	26
REF1FBK	Block REF1F element	231
REF1FP	REF1 element torque output forward (internal fault) declaration	26
REF1OCT	REF1 element open CT, wiring, or setting error detected	231

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Bit	Definition	Row
REF1P	REF1 inverse-time O/C element timed out	39
REF1PP	REF1 inverse-time O/C element picked up	39
REF1PR	REF1 inverse-time O/C element reset	40
REF1R	REF1 element reverse (external fault) declaration	26
REF1RBK	Block REF1R element	231
REF1RP	REF1 element torque output reverse (external fault) declaration	26
REF3ABY	REF3A element bypass logic output asserted	27
REF3AE	REF3A element enabled	27
REF3AF	REF3A element forward (internal fault) declaration	27
REF3AFBK	Block REF3AF element	231
REF3AFP	REF3A element torque output forward (internal fault) declaration	27
REF3AOCT	REF3A element open CT, wiring, or setting error detected	231
REF3AP	REF3A inverse-time O/C element timed out	39
REF3APP	REF3A inverse-time O/C element picked up	39
REF3APR	REF3A inverse-time O/C element reset	40
REF3AR	REF3A element reverse (external) fault declaration	27
REF3ARBK	Block REF3AR element	231
REF3ARP	REF3A element torque output reverse (external) declaration	27
REF3BBY	REF3B element bypass logic output asserted	28
REF3BE	REF3B element enabled	28
REF3BF	REF3B element forward (internal) fault declaration	28
REF3BFBK	Block REF3BF element	232
REF3BFP	REF3B element torque output forward (internal) declaration	28
REF3BOCT	REF3A element open CT, wiring, or setting error detected	232
REF3BP	REF3B inverse-time O/C element timed out	39
REF3BPP	REF3B inverse-time O/C element picked up	39
REF3BPR	REF3B inverse-time O/C element reset	40
REF3BR	REF3B element reverse (external) fault declaration	28
REF3BRBK	Block REF3BR element	232
REF3BRP	REF3B element torque output reverse (external) declaration	28
RELAY_EN	Relay OK flag. RELAY_EN status follows the **ENABLED** LED status.	68
REMTRIP	Remote trip	7
RMB1A–RMB8A	Channel A receive MIRRORED BITS RMB1A through RMB8A	98
RMB1B–RMB8B	Channel B receive MIRRORED BITS RMB1B through RMB8B	100

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 29 of 31)

Bit	Definition	Row
ROKA	Channel A, received data OK	102
ROKB	Channel B, received data OK	102
RSTDEM	Reset demand metering	50
RSTENRGY	Reset energy metering. Assert when the SELOGIC Control Equation RSTENRG result is logical 1.	50
RSTMXMN	Reset max/min metering. Assert when the SELOGIC Control Equation RSTMXMN result is logical 1.	50
RSTPKDEM	Reset peak demand metering	50
RSTTRGT	SELOGIC control equation: reset trip logic and targets when asserted	51
RTD1A–RTD4A RTD1T–RTD4T	RTD1 through RTD4: alarms and trips	52
RTD5A–RTD8A RTD5T–RTD8T	RTD5 through RTD8: alarms and trips	53
RTD9A–RTD12A RTD9T–RTD12T	RTD9 through RTD12: alarms and trips	54
RTDA	Asserts when any RTD alarm (RTD_A) is asserted	51
RTDFLT	Asserts when an open or short-circuit condition is detected on any enabled RTD input, or when communication with the external RTD module has been interrupted	51
RTDIN	Indicates status of contact connected to SEL-2600A RTD Module	51
RTDT	Asserts when any RTD trip (RTD_T) is asserted	46
SALARM	Software alarms: invalid password, changing access levels, settings changes, active group change, copy command, and password change	47
SC01QD–SC08QD	SELOGIC Counters 01 through 08 asserted when counter = 0	91
SC01QU–SC08QU	SELOGIC Counters 01 through 08 asserted when counter = preset value	90
SC09QD–SC16QD	SELOGIC Counters 09 through 16 asserted when counter = 0	93
SC09QU–SC16QU	SELOGIC Counters 09 through 16 asserted when counter = preset value	92
SC17QD–SC24QD	SELOGIC Counters 17 through 24 asserted when counter = 0	95
SC17QU–SC24QU	SELOGIC Counters 17 through 24 asserted when counter = preset value	94
SC25QD–SC32QD	SELOGIC Counters 25 through 32 asserted when counter = 0	97
SC25QU–SC32QU	SELOGIC Counters 25 through 32 asserted when counter = preset value	96
SC850BM	SELOGIC control for IEC 61850 Block Mode	227
SC850TM	SELOGIC control for IEC 61850 Test Mode	227
SCBK1BC	SELOGIC control for Breaker 1 close interlocking supervision equation	214
SCBK2BC	SELOGIC control for Breaker 2 close interlocking supervision equation	214
SCBK3BC	SELOGIC control for Breaker 3 close interlocking supervision equation	215
SCBK4BC	SELOGIC control for Breaker 4 close interlocking supervision equation	215
SCBK1BO	SELOGIC control for Breaker 1 open interlocking supervision equation	214

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Bit	Definition	Row
SCBK2BO	SELOGIC control for Breaker 2 open interlocking supervision equation	214
SCBK3BO	SELOGIC control for Breaker 3 open interlocking supervision equation	215
SCBK4BO	SELOGIC control for Breaker 4 open interlocking supervision equation	215
SF	Slip frequency is within acceptable bounds (between 25SLO and 25SHI settings)	134
SC850SM	SELOGIC control for IEC 61850 simulation mode	227
SC850LS	SELOGIC control for control authority at station level	227
SG1	Asserts when Setting Group 1 is active	56
SG2	Asserts when Setting Group 2 is active	56
SG3	Asserts when Setting Group 3 is active	56
SG4	Asserts when Setting Group 4 is active	56
STORMDET	Asserts if a network storm has been detected	49
SV01–SV08	SELOGIC Control Equation Variables SV01 through SV08	78
SV01T–SV08T	SELOGIC Control Equation Variables SV01T through SV08T with settable pickup and dropout time delay	79
SV09–SV16	SELOGIC Control Equation Variables SV09 through SV16	80
SV09T–SV16T	SELOGIC Control Equation Variables SV09T through SV16T with settable pickup and dropout time delay	81
SV17–SV24	SELOGIC Control Equation Variables SV17 through SV24	82
SV17T–SV24T	SELOGIC Control Equation Variables SV17T through SV24T with settable pickup and dropout time delay	83
SV25–SV32	SELOGIC Control Equation Variables SV25 through SV32	84
SV25T–SV32T	SELOGIC Control Equation Variables SV25T through SV32T with settable pickup and dropout time delay	85
T01_LED–T06_LED	SELOGIC control equation: drives T01_LED–T06_LED	66
TESTDB	Asserts when reported analog and digital values are overridden using the **TEST DB** command.	128
TFLTALA	Through fault alarm, Phase A	69
TFLTALB	Through fault alarm, Phase B	69
TFLTALC	Through fault alarm, Phase C	69
TH5	Fifth-harmonic alarm threshold exceeded	22
TH5T	Fifth-harmonic alarm threshold exceeded for longer than TH5D	22
TLED_01–TLED_06	Target LED 1–Target LED 6	0
TMB1A–TMB8A	Channel A transmit MIRRORED BITS TMB1A through TMB8A	99
TMB1B–TMB8B	Channel B transmit MIRRORED BITS TMB1B through TMB8B	101
TQUAL1	Time quality bit, add 1 when asserted	130
TQUAL2	Time quality bit, add 2 when asserted	130

Table L.2 Relay Word Bit Definitions for the SEL-787 (Sheet 31 of 31)

Bit	Definition	Row
TQUAL4	Time quality bit, add 4 when asserted	130
TQUAL8	Time quality bit, add 8 when asserted	130
TR1–TR4	Trip SELOGIC Control Equations TR1–TR4 (also has been referred to as TRIPEQ1–TRIPEQ4)	57
TREA1–TREA4	Trigger Reason Bits 1–4 for synchrophasors	56
TRGTR	Target reset. Asserts for one quarter-cycle when you execute a front-panel, serial port target reset command, or Modbus target reset.	51
TRIP	Trip logic output	36
TRIP_LED	TRIP LED	0
TRIP1–TRIP4	TRIP1–TRIP4 logic outputs	57
TRIPXFMR	TripXFMR logic output	61
TRXFMR	Trip SELOGIC Control Equation TRXFMR (Also has been referred to as TRXFMREQ)	61
TSNTPB	SNTP secondary server is active	131
TSNTPP	SNTP primary server is active	131
TSOK	Assert if current time source accuracy is sufficient for synchronized phasor measurements	47
TUTC1	Offset hours from UTC, binary, add 1 if asserted	131
TUTC2	Offset hours from UTC, binary, add 2 if asserted	131
TUTC4	Offset hours from UTC, binary, add 4 if asserted	131
TUTC8	Offset hours from UTC, binary, add 8 if asserted	131
TUTCH	Offset half-hour from UTC, binary, add 0.5 if asserted	131
TUTCS	Offset hours sign from UTC, subtract the UTC offset if TUTCS is asserted; otherwise, add	131
ULCL1–ULCL4	Unlatch close conditions SELOGIC Control Equations CL1–CL4 state	58
ULTRIP1–ULTRIP4	Unlatch (auto reset) trip from SELOGIC Control Equations TR1–TR4	58
ULTRXFMR	Unlatch (auto reset) trip from SELOGIC Control Equation TRXFMR	61
VB*xxx*	Virtual bits used for incoming GOOSE messages (*xxx* = 1–128)	103–118
WARNING	Warning bit asserts for possible warning conditions, as shown in *Table 8.3*. These conditions also trigger a flashing TRIP LED.	47

Appendix M
Analog Quantities

The SEL-787 Transformer Protection Relay contains several analog quantities that can be used for more than one function. The actual analog quantities available depend on the part number of the relay you use. Analog quantities are typically generated and used by a primary function, such as metering, and selected quantities are made available for one or more supplemental functions, for example, the load profile.

Note that all analog quantities available for use in SELOGIC control equations are processed every 25 ms and may not be suitable for fast-response control and protection applications. Analog quantities for rms data are determined through the use of data averaged over the previous 8 cycles.

Table M.1 lists analog quantities that can be used in the following specific functions:

- Display points (see *Section 8: Front-Panel Operations*)
- SELOGIC control equations (see *Section 4: Protection and Logic Functions*)
- Load profile recorder (see *Section 5: Metering and Monitoring*)
- DNP (see *Appendix D: DNP3 Communications*)
- Fast Message Read
- IEC 60870-5-103 (See *Appendix H: IEC 60870-5-103 Communications*)
- EtherNet/IP (see *Appendix F: EtherNet/IP Communications*)
- Modbus (see *Appendix E: Modbus Communications*)
- Fast Meter (see *Appendix C: SEL Communications Processors*)
- IEC 61850 (see *Appendix G: IEC 61850 Communications*)

Table M.1 Analog Quantities (Sheet 1 of 18)

Name	Description	Units	Display Points	SELOGIC	Load Profile	DNP3/Fast Message Read/ IEC 60870-5-103/EtherNet/IP	Modbus[a]	Fast Meter	IEC 61850[b, c]
Fundamental Instantaneous Metering									
IAW1_MAG	Winding 1 current, A-phase, magnitude	A pri	x	x	x	x	x	x	x
IAW1_ANG	Winding 1 current, A-phase, angle	degrees	x	x	x	x	x		x
IBW1_MAG	Winding 1 current, B-phase, magnitude	A pri	x	x	x	x	x	x	x

Table M.1 Analog Quantities (Sheet 2 of 18)

Name	Description	Units	Display Points	SELOGIC	Load Profile	DNP3/Fast Message Read/ IEC 60870-5-103/EtherNet/IP	Modbus[a]	Fast Meter	IEC 61850[b, c]
IBW1_ANG	Winding 1 current, B-phase, angle	degrees	x	x	x	x	x		x
ICW1_MAG	Winding 1 current, C-phase, magnitude	A pri	x	x	x	x	x	x	x
ICW1_ANG	Winding 1 current, C-phase, angle	degrees	x	x	x	x	x		x
I1W1_MAG	Winding 1 current, positive-sequence, magnitude	A pri	x	x	x	x	x		x
I1W1_ANG	Winding 1 current, positive-sequence, angle	degrees	x	x	x	x	x		x
IGW1_MAG	Winding 1 current, calculated-residual, magnitude	A pri	x	x	x	x	x		x
IGW1_ANG	Winding 1 current, calculated-residual, angle	degrees	x	x	x	x	x		x
3I2W1MAG	Winding 1 current, negative-sequence, magnitude	A pri	x	x	x	x	x		x
3I2W1ANG	Winding 1 current, negative-sequence, angle	degrees	x	x	x	x	x		x
IAW2_MAG	Winding 2 current, A-phase, magnitude	A pri	x	x	x	x	x	x	x
IAW2_ANG	Winding 2 current, A-phase, angle	degrees	x	x	x	x	x		x
IBW2_MAG	Winding 2 current, B-phase, magnitude	A pri	x	x	x	x	x	x	x
IBW2_ANG	Winding 2 current, B-phase, angle	degrees	x	x	x	x	x		x
ICW2_MAG	Winding 2 current, C-phase, magnitude	A pri	x	x	x	x	x	x	x
ICW2_ANG	Winding 2 current, C-phase, angle	degrees	x	x	x	x	x		x
I1W2_MAG	Winding 2 current, positive-sequence, magnitude	A pri	x	x	x	x	x		x
I1W2_ANG	Winding 2 current, positive-sequence, angle	degrees	x	x	x	x	x		x
IGW2_MAG	Winding 2 current, calculated-residual, magnitude	A pri	x	x	x	x	x		x
IGW2_ANG	Winding 2 current, calculated-residual, angle	degrees	x	x	x	x	x		x
3I2W2MAG	Winding 2 current, negative-sequence, magnitude	A pri	x	x	x	x	x		x
3I2W2ANG	Winding 2 current, negative-sequence, angle	degrees	x	x	x	x	x		x
IAW3_MAG	Winding 3 current, A-phase, magnitude	A pri	x	x	x	x	x	x	x
IAW3_ANG	Winding 3 current, A-phase, angle	degrees	x	x	x	x	x		x

Table M.1 Analog Quantities (Sheet 3 of 18)

Name	Description	Units	Display Points	SELogic	Load Profile	DNP3/Fast Message Read/ IEC 60870-5-103/EtherNet/IP	Modbus[a]	Fast Meter	IEC 61850[b, c]
IBW3_MAG	Winding 3 current, B-phase, magnitude	A pri	x	x	x	x	x	x	x
IBW3_ANG	Winding 3 current, B-phase, angle	degrees	x	x	x	x	x		x
ICW3_MAG	Winding 3 current, C-phase, magnitude	A pri	x	x	x	x	x	x	x
ICW3_ANG	Winding 3 current, C-phase, angle	degrees	x	x	x	x	x		x
I1W3_MAG	Winding 3 current, positive-sequence, magnitude	A pri	x	x	x	x	x		x
I1W3_ANG	Winding 3 current, positive-sequence, angle	degrees	x	x	x	x	x		x
IGW3_MAG	Winding 3 current, calculated-residual, magnitude	A pri	x	x	x	x	x		x
IGW3_ANG	Winding 3 current, calculated-residual, angle	degrees	x	x	x	x	x		x
3I2W3MAG	Winding 3 current, negative-sequence, magnitude	A pri	x	x	x	x	x		x
3I2W3ANG	Winding 3 current, negative-sequence, angle	degrees	x	x	x	x	x		x
IAW4_MAG	Winding 4 current, A-phase, magnitude	A pri	x	x	x	x	x	x	x
IAW4_ANG	Winding 4 current, A-phase, angle	degrees	x	x	x	x	x		x
IBW4_MAG	Winding 4 current, B-phase, magnitude	A pri	x	x	x	x	x	x	x
IBW4_ANG	Winding 4 current, B-phase, angle	degrees	x	x	x	x	x		x
ICW4_MAG	Winding 4 current, C-phase, magnitude	A pri	x	x	x	x	x	x	x
ICW4_ANG	Winding 4 current, C-phase, angle	degrees	x	x	x	x	x		x
I1W4_MAG	Winding 4 current, positive-sequence, magnitude	A pri	x	x	x	x	x		x
I1W4_ANG	Winding 4 current, positive-sequence, angle	degrees	x	x	x	x	x		x
IGW4_MAG	Winding 4 current, calculated-residual, magnitude	A pri	x	x	x	x	x		x
IGW4_ANG	Winding 4 current, calculated-residual, angle	degrees	x	x	x	x	x		x
3I2W4MAG	Winding 4 current, negative-sequence, magnitude	A pri	x	x	x	x	x		x
3I2W4ANG	Winding 4 current, negative-sequence, angle	degrees	x	x	x	x	x		x

Table M.1 Analog Quantities (Sheet 4 of 18)

Name	Description	Units	Display Points	SELogic	Load Profile	DNP3/Fast Message Read/ IEC 60870-5-103/EtherNet/IP	Modbus[a]	Fast Meter	IEC 61850[b, c]
IAW12MAG	Winding 1 and Winding 2 combined current, A-phase, magnitude	A pri	x	x	x	x	x		x
IAW12ANG	Winding 1 and Winding 2 combined current, A-phase, angle	degrees	x	x	x	x	x		x
IBW12MAG	Winding 1 and Winding 2 combined current, B-phase, magnitude	A pri	x	x	x	x	x		x
IBW12ANG	Winding 1 and Winding 2 combined current, B-phase, angle	degrees	x	x	x	x	x		x
ICW12MAG	Winding 1 and Winding 2 combined current, C-phase, magnitude	A pri	x	x	x	x	x		x
ICW12ANG	Winding 1 and Winding 2 combined current, C-phase, angle	degrees	x	x	x	x	x		x
I1W12MAG	Winding 1 and Winding 2 combined current, positive-sequence, magnitude	A pri	x	x	x	x	x		x
I1W12ANG	Winding 1 and Winding 2 combined current, positive-sequence, angle	degrees	x	x	x	x	x		x
IGW12MAG	Winding 1 and Winding 2 combined current, calculated-residual, magnitude	A pri	x	x	x	x	x		x
IGW12ANG	Winding 1 and Winding 2 combined current, calculated-residual, angle	degrees	x	x	x	x	x		x
3I2W12MG	Winding 1 and Winding 2 combined current, negative-sequence, magnitude	A pri	x	x	x	x	x		x
3I2W12AG	Winding 1 and Winding 2 combined current, negative-sequence, angle	degrees	x	x	x	x	x		x
IAW34MAG	Winding 3 and Winding 4 combined current, A-phase, magnitude	A pri	x	x	x	x	x		x
IAW34ANG	Winding 3 and Winding 4 combined current, A-phase, angle	degrees	x	x	x	x	x		x
IBW34MAG	Winding 3 and Winding 4 combined current, B-phase, magnitude	A pri	x	x	x	x	x		x
IBW34ANG	Winding 3 and Winding 4 combined current, B-phase, angle	degrees	x	x	x	x	x		x
ICW34MAG	Winding 3 and Winding 4 combined current, C-phase, magnitude	A pri	x	x	x	x	x		x
ICW34ANG	Winding 3 and Winding 4 combined current, C-phase, angle	degrees	x	x	x	x	x		x
I1W34MAG	Winding 3 and Winding 4 combined current, positive-sequence, magnitude	A pri	x	x	x	x	x		x

Table M.1 Analog Quantities (Sheet 5 of 18)

Name	Description	Units	Display Points	SELogic	Load Profile	DNP3/Fast Message Read/ IEC 60870-5-103/EtherNet/IP	Modbus[a]	Fast Meter	IEC 61850[b, c]
I1W34ANG	Winding 3 and Winding 4 combined current, positive-sequence, angle	degrees	x	x	x	x	x		x
IGW34MAG	Winding 3 and Winding 4 combined current, calculated-residual, magnitude	A pri	x	x	x	x	x		x
IGW34ANG	Winding 3 and Winding 4 combined current, calculated-residual, angle	degrees	x	x	x	x	x		x
3I2W34MG	Winding 3 and Winding 4 combined current, negative-sequence, magnitude	A pri	x	x	x	x	x		x
3I2W34AG	Winding 3 and Winding 4 combined current, negative-sequence, angle	degrees	x	x	x	x	x		x
IAW23MAG	Winding 2 and Winding 3 combined current, A-phase, magnitude	A pri	x	x	x	x	x		x
IAW23ANG	Winding 2 and Winding 3 combined current, A-phase, angle	degrees	x	x	x	x	x		x
IBW23MAG	Winding 2 and Winding 3 combined current, B-phase, magnitude	A pri	x	x	x	x	x		x
IBW23ANG	Winding 2 and Winding 3 combined current, B-phase, angle	degrees	x	x	x	x	x		x
ICW23MAG	Winding 2 and Winding 3 combined current, C-phase, magnitude	A pri	x	x	x	x	x		x
ICW23ANG	Winding 2 and Winding 3 combined current, C-phase, angle	degrees	x	x	x	x	x		x
I1W23MAG	Winding 2 and Winding 3 combined current, positive-sequence, magnitude	A pri	x	x	x	x	x		x
I1W23ANG	Winding 2 and Winding 3 combined current, positive-sequence, angle	degrees	x	x	x	x	x		x
IGW23MAG	Winding 2 and Winding 3 combined current, calculated residual, magnitude	A pri	x	x	x	x	x		x
IGW23ANG	Winding 2 and Winding 3 combined current, calculated residual, angle	degrees	x	x	x	x	x		x
3I2W23MG	Winding 2 and Winding 3 combined current, negative-sequence, magnitude	A pri	x	x	x	x	x		x
3I2W23AG	Winding 2 and Winding 3 combined current, negative-sequence, angle	degrees	x	x	x	x	x		x

Table M.1 Analog Quantities (Sheet 6 of 18)

Name	Description	Units	Display Points	SELogic	Load Profile	DNP3/Fast Message Read/ IEC 60870-5-103/EtherNet/IP	Modbus[a]	Fast Meter	IEC 61850[b, c]
IN_MAG	Current, neutral, magnitude	A pri	x	x	x	x	x	x	x
IN_ANG	Current, neutral, angle	degrees	x	x	x	x	x		x
VA_MAG	Voltage, A-phase-to-neutral, magnitude	V pri	x	x	x	x	x		x
VA_ANG	Voltage, A-phase-to-neutral, angle	degrees	x	x	x	x	x		x
VB_MAG	Voltage, B-phase-to-neutral, magnitude	V pri	x	x	x	x	x		x
VB_ANG	Voltage, B-phase-to-neutral, angle	degrees	x	x	x	x	x		x
VC_MAG	Voltage, C-phase-to-neutral, magnitude	V pri	x	x	x	x	x		x
VC_ANG	Voltage, C-phase-to-neutral, angle	degrees	x	x	x	x	x		x
VAB_MAG	Voltage, A-to-B-phase, magnitude	V pri	x	x	x	x	x	x	x
VAB_ANG	Voltage, A-to-B-phase, angle	degrees	x	x	x	x	x		x
VBC_MAG	Voltage, B-to-C-phase, magnitude	V pri	x	x	x	x	x	x	x
VBC_ANG	Voltage, B-to-C-phase, angle	degrees	x	x	x	x	x		x
VCA_MAG	Voltage, C-to-A-phase, magnitude	V pri	x	x	x	x	x	x	x
VCA_ANG	Voltage, C-to-A-phase, angle	degrees	x	x	x	x	x		x
V1_MAG	Positive-sequence voltage, magnitude	V pri	x	x	x	x	x		x
V1_ANG	Positive-sequence voltage, angle	degrees	x	x	x	x	x		x
VG_MAG	Zero-sequence voltage, magnitude	V pri	x	x	x	x	x		x
VG_ANG	Zero-sequence voltage, angle	degrees	x	x	x	x	x		x
3V2_MAG	Voltage, negative-sequence, magnitude	V pri	x	x	x	x	x		x
3V2_ANG	Voltage, negative-sequence, angle	degrees	x	x	x	x	x		x
VS_MAG	Sync voltage, magnitude	V pri	x	x	x	x	x		x
VS_ANG	Sync voltage, angle	degrees	x	x	x	x	x		x
VDC	Station dc battery voltage	V	x	x	x	x	x	x	x
PA	A-phase real power	kW pri	x	x	x	x	x		x
PB	B-phase real power	kW pri	x	x	x	x	x		x
PC	C-phase real power	kW pri	x	x	x	x	x		x
P	Real power magnitude, three-phase	kW pri	x	x	x	x	x	x	x
QA	A-phase reactive power	kVAR pri	x	x	x	x	x		x
QB	B-phase reactive power	kVAR pri	x	x	x	x	x		x

Table M.1 Analog Quantities (Sheet 7 of 18)

Name	Description	Units	Display Points	SELOGIC	Load Profile	DNP3/Fast Message Read/ IEC 60870-5-103/EtherNet/IP	Modbus[a]	Fast Meter	IEC 61850[b, c]
QC	C-phase reactive power	kVAR pri	x	x	x	x	x		x
Q	Reactive power magnitude, three-phase	kVAR pri	x	x	x	x	x	x	x
SA	A-phase apparent power	kVA pri	x	x	x	x	x		x
SB	B-phase apparent power	kVA pri	x	x	x	x	x		x
SC	C-phase apparent power	kVA pri	x	x	x	x	x		x
S	Apparent power magnitude, three-phase	kVA pri	x	x	x	x	x	x	x
PFA	A-phase power factor	unitless	x	x	x	x	x		x
PFB	B-phase power factor	unitless	x	x	x	x	x		x
PFC	C-phase power factor	unitless	x	x	x	x	x		x
PF	Power factor, magnitude three-phase	unitless	x	x	x	x	x	x	x
FREQ	Frequency	Hz	x	x	x	x	x	x	x
FREQS	Sync frequency	Hz	x	x	x	x	x	x	x
VHZ	V/Hz	%	x	x	x	x	x	x	x
Thermal Metering[1] Note 1: Use caution when assigning RTD analog quantities to SELOGIC control equations or math variables because the conditions RTD open, short, comm fail, stat fail, fail, and NA will be reported as+32767, –32768, +32764, +32760, +32766, and +32752, respectively. Note 2: SEL Fast Message Label name for RTDAMB and RTDOTHMX are AMB and OTH, respectively. Note 3: RTD open is equivalent to +32767 and RTD short is equivalent to –32768 when RTDs are monitored via LDP.									
RTDAMB[2]	Ambient RTD temperature	°C	x	x	x	x	x		x
RTDOTHMX[2]	Other maximum RTD temperature	°C	x	x	x	x	x		x
RTD1 to RTD12[3]	RTD1 temperature to RTD12 temperature	°C	x	x	x	x	x		x
Analog Input Metering									
AI301 to AI304	Analog Input 301–Analog Input 304	EU	x	x	x	x	x		x
AI401 to AI404	Analog Input 401–Analog Input 404	EU	x	x	x	x	x		x
AI501 to AI504	Analog Input 501–Analog Input 504	EU	x	x	x	x	x		x
Energy Metering[4] Note 4: The time when Energy, Maximum/Minimum, Peak Demand, and Breaker Monitoring data was last reset is also reported in Modbus. Note 5: This analog quantity is not available for FMR.									
EM_LRDH	Energy last reset date/time high word					x[5]			
EM_LRDM	Energy last reset date/time middle word					x[5]			

Table M.1 Analog Quantities (Sheet 8 of 18)

Name	Description	Units	Display Points	SELogic	Load Profile	DNP3/Fast Message Read/ IEC 60870-5-103/EtherNet/IP	Modbus[a]	Fast Meter	IEC 61850[b, c]
EM_LRDL	Energy last reset date/time low word					x[5]			
MWHP	Real energy, three-phase positive	MWh pri	x	x		x	x		x
MWHN	Real energy, three-phase negative	MWh pri	x	x		x	x		x
MVARHP	Reactive energy, three-phase positive	MVARh pri	x	x		x	x		x
MVARHN	Reactive energy, three-phase negative	MVARh pri	x	x		x	x		x
Maximum/Minimum Metering[4,6] Note 6: Upon reset, the maximum and minimum quantities read +16777216 for MN and −16777216 for MX. Note 7: See the Engineering Unit settings (e.g., AI301EU) of the respective analog input quantity for the unit.									
MM_LRDH	Max/Min last reset date/time high word					x[5]			
MM_LRDM	Max/Min last reset date/time middle word					x[5]			
MM_LRDL	Max/Min last reset date/time low word					x[5]			
IAW1MX	Winding 1 current, A-phase, maximum magnitude	A pri	x	x		x	x		x
IBW1MX	Winding 1 current, B-phase, maximum magnitude	A pri	x	x		x	x		x
ICW1MX	Winding 1 current, C-phase, maximum magnitude	A pri	x	x		x	x		x
IGW1MX	Winding 1 current, residual, maximum magnitude	A pri	x	x		x	x		x
IAW2MX	Winding 2 current, A-phase, maximum magnitude	A pri	x	x		x	x		x
IBW2MX	Winding 2 current, B-phase, maximum magnitude	A pri	x	x		x	x		x
ICW2MX	Winding 2 current, C-phase, maximum magnitude	A pri	x	x		x	x		x
IGW2MX	Winding 2 current, residual, maximum magnitude	A pri	x	x		x	x		x
IAW3MX	Winding 3 current, A-phase, maximum magnitude	A pri	x	x		x	x		x
IBW3MX	Winding 3 current, B-phase, maximum magnitude	A pri	x	x		x	x		x
ICW3MX	Winding 3 current, C-phase, maximum magnitude	A pri	x	x		x	x		x
IGW3MX	Winding 3 current, residual, maximum magnitude	A pri	x	x		x	x		x

Table M.1 Analog Quantities (Sheet 9 of 18)

Name	Description	Units	Display Points	SELogic	Load Profile	DNP3/Fast Message Read/ IEC 60870-5-103/EtherNet/IP	Modbus[a]	Fast Meter	IEC 61850[b, c]
IAW4MX	Winding 4 current, A-phase, maximum magnitude	A pri	x	x		x	x		x
IBW4MX	Winding 4 current, B-phase, maximum magnitude	A pri	x	x		x	x		x
ICW4MX	Winding 4 current, C-phase, maximum magnitude	A pri	x	x		x	x		x
IGW4MX	Winding 4 current, residual, maximum magnitude	A pri	x	x		x	x		x
INMX	Current, neutral, maximum magnitude	A pri	x	x		x	x		x
IAW1MN	Winding 1 current, A-phase, minimum magnitude	A pri	x	x		x	x		x
IBW1MN	Winding 1 current, B-phase, minimum magnitude	A pri	x	x		x	x		x
ICW1MN	Winding 1 current, C-phase, minimum magnitude	A pri	x	x		x	x		x
IGW1MN	Winding 1 current, residual, minimum magnitude	A pri	x	x		x	x		x
IAW2MN	Winding 2 current, A-phase, minimum magnitude	A pri	x	x		x	x		x
IBW2MN	Winding 2 current, B-phase, minimum magnitude	A pri	x	x		x	x		x
ICW2MN	Winding 2 current, C-phase, minimum magnitude	A pri	x	x		x	x		x
IGW2MN	Winding 2 current, residual, minimum magnitude	A pri	x	x		x	x		x
IAW3MN	Winding 3 current, A-phase, minimum magnitude	A pri	x	x		x	x		x
IBW3MN	Winding 3 current, B-phase, minimum magnitude	A pri	x	x		x	x		x
ICW3MN	Winding 3 current, C-phase, minimum magnitude	A pri	x	x		x	x		x
IGW3MN	Winding 3 current, residual, minimum magnitude	A pri	x	x		x	x		x
IAW4MN	Winding 4 current, A-phase, minimum magnitude	A pri	x	x		x	x		x
IBW4MN	Winding 4 current, B-phase, minimum magnitude	A pri	x	x		x	x		x

Table M.1 Analog Quantities (Sheet 10 of 18)

Name	Description	Units	Display Points	SELogic	Load Profile	DNP3/Fast Message Read/ IEC 60870-5-103/EtherNet/IP	Modbus[a]	Fast Meter	IEC 61850[b, c]
ICW4MN	Winding 4 current, C-phase, minimum magnitude	A pri	x	x		x	x		x
IGW4MN	Winding 4 current, residual, minimum magnitude	A pri	x	x		x	x		x
INMN	Current, neutral, minimum magnitude	A pri	x	x		x	x		x
VABMX	Voltage, A-to-B-phase, maximum magnitude	V pri	x	x		x	x		x
VBCMX	Voltage, B-to-C-phase, maximum magnitude	V pri	x	x		x	x		x
VCAMX	Voltage, C-to-A-phase, maximum magnitude	V pri	x	x		x	x		x
VAMX	Voltage, A-phase-to-neutral, maximum magnitude	V pri	x	x		x	x		x
VBMX	Voltage, B-phase-to-neutral, maximum magnitude	V pri	x	x		x	x		x
VCMX	Voltage, C-phase-to-neutral, maximum magnitude	V pri	x	x		x	x		x
VABMN	Voltage, A-to-B-phase, minimum magnitude	V pri	x	x		x	x		x
VBCMN	Voltage, B-to-C-phase, minimum magnitude	V pri	x	x		x	x		x
VCAMN	Voltage, C-to-A-phase, minimum magnitude	V pri	x	x		x	x		x
VAMN	Voltage, A-phase-to-neutral, minimum magnitude	V pri	x	x		x	x		x
VBMN	Voltage, B-phase-to-neutral, minimum magnitude	V pri	x	x		x	x		x
VCMN	Voltage, C-phase-to-neutral, minimum magnitude	V pri	x	x		x	x		x
KVA3PMX	Apparent power magnitude, three-phase, maximum	kVA pri	x	x		x	x		x
KW3PMX	Real power magnitude, three-phase, maximum	kW pri	x	x		x	x		x
KVAR3PMX	Reactive power magnitude, three-phase, maximum	kVAR pri	x	x		x	x		x
KVA3PMN	Apparent power magnitude, three-phase, minimum	kVA pri	x	x		x	x		x

Table M.1 Analog Quantities (Sheet 11 of 18)

Name	Description	Units	Display Points	SELogic	Load Profile	DNP3/Fast Message Read/ IEC 60870-5-103/EtherNet/IP	Modbus[a]	Fast Meter	IEC 61850[b, c]
KW3PMN	Real power magnitude, three-phase, minimum	kW pri	x	x		x	x		x
KVAR3PMN	Reactive power magnitude, three-phase, minimum	kVAR pri	x	x		x	x		x
FREQMX	Maximum frequency	Hz	x	x		x	x		x
FREQMN	Minimum frequency	Hz	x	x		x	x		x
RTD1MX–RTD12MX	RTD1 maximum to RTD12 maximum	°C	x	x		x	x		x
RTD1MN–RTD12MN	RTD1 minimum to RTD12 minimum	°C	x	x		x	x		x
AI301MX–AI304MX	Analog Transducer Input 301–304 maximum[7]	EU	x	x		x	x		x
AI301MN–AI304MN	Analog Transducer Input 301–304 minimum[7]	EU	x	x		x	x		x
AI401MX–AI404MX	Analog Transducer Input 401–404 maximum[7]	EU	x	x		x	x		x
AI401MN–AI404MN	Analog Transducer Input 401–404 minimum[7]	EU	x	x		x	x		x
AI501MX–AI504MX	Analog Transducer Input 501–504 maximum[7]	EU	x	x		x	x		x
AI501MN–AI504MN	Analog Transducer Input 501–504 minimum[7]	EU	x	x		x	x		x
NOTE: EU is Engineering Units									
RMS Metering									
IAW1RMS	Winding 1 rms current, A-phase, magnitude	A pri	x	x	x	x	x		x
IBW1RMS	Winding 1 rms current, B-phase, magnitude	A pri	x	x	x	x	x		x
ICW1RMS	Winding 1 rms current, C-phase, magnitude	A pri	x	x	x	x	x		x
IAW2RMS	Winding 2 rms current, A-phase, magnitude	A pri	x	x	x	x	x		x
IBW2RMS	Winding 2 rms current, B-phase, magnitude	A pri	x	x	x	x	x		x
ICW2RMS	Winding 2 rms current, C-phase, magnitude	A pri	x	x	x	x	x		x
IAW3RMS	Winding 3 rms current, A-phase, magnitude	A pri	x	x	x	x	x		x

Table M.1 Analog Quantities (Sheet 12 of 18)

Name	Description	Units	Display Points	SELogic	Load Profile	DNP3/Fast Message Read/ IEC 60870-5-103/EtherNet/IP	Modbus[a]	Fast Meter	IEC 61850[b, c]
IBW3RMS	Winding 3 rms current, B-phase, magnitude	A pri	x	x	x	x	x		x
ICW3RMS	Winding 3 rms current, C-phase, magnitude	A pri	x	x	x	x	x		x
IAW4RMS	Winding 4 rms current, A-phase, magnitude	A pri	x	x	x	x	x		x
IBW4RMS	Winding 4 rms current, B-phase, magnitude	A pri	x	x	x	x	x		x
ICW4RMS	Winding 4 rms current, C-phase, magnitude	A pri	x	x	x	x	x		x
INRMS	Neutral rms current, magnitude	A pri	x	x	x	x	x		x
VARMS	RMS voltage, A-phase-to-neutral, magnitude	V pri	x	x	x	x	x		x
VBRMS	RMS voltage, B-phase-to-neutral, magnitude	V pri	x	x	x	x	x		x
VCRMS	RMS voltage, C-phase-to-neutral, magnitude	V pri	x	x	x	x	x		x
VABRMS	RMS voltage, A-to-B-phase, magnitude	V pri	x	x	x	x	x		x
VBCRMS	RMS voltage, B-to-C-phase, magnitude	V pri	x	x	x	x	x		x
VCARMS	RMS voltage, C-to-A-phase, magnitude	V pri	x	x	x	x	x		x
VSRMS	RMS sync voltage, magnitude	V pri	x	x	x	x	x		x
Demand Metering									
IAD	Phase A current demand	A pri	x	x		x	x	x	x
IBD	Phase B current demand	A pri	x	x		x	x	x	x
ICD	Phase C current demand	A pri	x	x		x	x	x	x
IGD	Residual current demand	A pri	x	x		x	x	x	x
3I2D	Negative-sequence current demand	A pri	x	x		x	x	x	x
Peak Demand Metering[4]									
PM_LRDH	Peak demand last reset date/time high word					x[5]			
PM_LRDM	Peak demand last reset date/time middle word					x[5]			
PM_LRDL	Peak demand last reset date/time low word					x[5]			
IAPD	Phase A current peak demand	A pri	x	x		x	x	x	x

Table M.1 Analog Quantities (Sheet 13 of 18)

Name	Description	Units	Display Points	SELOGIC	Load Profile	DNP3/Fast Message Read/ IEC 60870-5-103/EtherNet/IP	Modbus[a]	Fast Meter	IEC 61850[b, c]
IBPD	Phase B current peak demand	A pri	x	x		x	x	x	x
ICPD	Phase C current peak demand	A pri	x	x		x	x	x	x
IGPD	Residual current peak demand	A pri	x	x		x	x	x	x
3I2PD	Negative-sequence current peak demand	A pri	x	x		x	x	x	x
Harmonics Metering									
IAW1_THD	Winding 1 A-phase current THD	%	x	x		x	x		x
IBW1_THD	Winding 1 B-phase current THD	%	x	x		x	x		x
ICW1_THD	Winding 1 C-phase current THD	%	x	x		x	x		x
IAW2_THD	Winding 2 A-phase current THD	%	x	x		x	x		x
IBW2_THD	Winding 2 B-phase current THD	%	x	x		x	x		x
ICW2_THD	Winding 2 C-phase current THD	%	x	x		x	x		x
IAW3_THD	Winding 3 A-phase current THD	%	x	x		x	x		x
IBW3_THD	Winding 3 B-phase current THD	%	x	x		x	x		x
ICW3_THD	Winding 3 C-phase current THD	%	x	x		x	x		x
IAW4_THD	Winding 4 A-phase current THD	%	x	x		x	x		x
IBW4_THD	Winding 4 B-phase current THD	%	x	x		x	x		x
ICW4_THD	Winding 4 C-phase current THD	%	x	x		x	x		x
IN_THD	Neutral current THD	%	x	x		x	x		x
VA_THD	A-phase-to-neutral voltage THD	%	x	x		x	x		x
VB_THD	B-phase-to-neutral voltage THD	%	x	x		x	x		x
VC_THD	C-phase-to-neutral voltage THD	%	x	x		x	x		x
VAB_THD	A-to-B-phase voltage THD	%	x	x		x	x		x
VBC_THD	B-to-C-phase voltage THD	%	x	x		x	x		x
VCA_THD	C-to-A-phase voltage THD	%	x	x		x	x		x
Differential Element Metering									
IOP1	A-phase operate current	pu	x	x		x	x	x	x
IOP2	B-phase operate current	pu	x	x		x	x	x	x
IOP3	C-phase operate current	pu	x	x		x	x	x	x
IRT1	A-phase restraint current	pu	x	x		x	x	x	x

Table M.1 Analog Quantities (Sheet 14 of 18)

Name	Description	Units	Display Points	SELogic	Load Profile	DNP3/Fast Message Read/ IEC 60870-5-103/EtherNet/IP	Modbus[a]	Fast Meter	IEC 61850[b, c]
IRT2	B-phase restraint current	pu	x	x		x	x	x	x
IRT3	C-phase restraint current	pu	x	x		x	x	x	x
Negative-Sequence Differential Element Metering									
IOPQ	Negative-sequence differential operate current	pu	x	x		x		x	x
IRTQ	Negative-sequence differential restraint current	pu	x	x		x		x	x
Breaker Monitoring[4] (n = 1, 2, 3, 4)									
BM_LRD*n*H	Breaker Monitor *n* last reset date/time–high word					x[5]			
BM_LRD*n*M	Breaker Monitor *n* last reset date/time–middle word					x[5]			
BM_LRD*n*L	Breaker Monitor *n* last reset date/time–low word					x[5]			
INTTW*n*	Internal trips—counter		x	x	x	x	x		x
INTIAW*n*	Accumulated current—internal trips, A phase	kA pri	x	x	x	x	x		x
INTIBW*n*	Accumulated current—internal trips, B phase	kA pri	x	x	x	x	x		x
INTICW*n*	Accumulated current—internal trips, C phase	kA pri	x	x	x	x	x		x
EXTTW*n*	External trips—counter		x	x	x	x	x		x
EXTIAW*n*	Accumulated current—external trips, A phase	kA pri	x	x	x	x	x		x
EXTIBW*n*	Accumulated current—external trips, B phase	kA pri	x	x	x	x	x		x
EXTICW*n*	Accumulated current—external trips, C phase	kA pri	x	x	x	x	x		x
WEARAW*n*	Breaker wear, A-phase	%	x	x	x	x	x		x
WEARBW*n*	Breaker wear, B-phase	%	x	x	x	x	x		x
WEARCW*n*	Breaker wear, C-phase	%	x	x	x	x	x		x
Date/Time Note 8: DATE and TIME are also available as DNP Object 50. Note 9: DATE, TIME, RID, and TID are only available as display point settings (DP01–DP32).									
DATE[8,9]	Present date		x						
TIME[8,9]	Present time		x						

Table M.1 Analog Quantities (Sheet 15 of 18)

Name	Description	Units	Display Points	SELOGIC	Load Profile	DNP3/Fast Message Read/ IEC 60870-5-103/EtherNet/IP	Modbus[a]	Fast Meter	IEC 61850[b, c]
YEAR	Year number (0000-9999)			x					
DAYY	Day of year number (1–366)			x					
WEEK	Week number (1–52)			x					
DAYW	Day of week number (1–7)			x					
MINSM	Minutes since midnight			x					
RID/TID Note 10: STRING_RID and STRING_TID are only available as analog label quantities for the bay screen in the touchscreen display model.									
RID[9]	Relay identifier		x						
TID[9]	Terminal identifier		x						
STRING_RID	Relay identifier (Bay Screen)		x[10]						
STRING_TID	Terminal identifier (Bay Screen)		x[10]						
Serial Number Note 11: SER_NUM is available for use with display points in the two-line display model, but it is not available for use with analog labels in the touchscreen display model.									
SER_NUM	Serial number of the relay		x			x	x		x
Setting Group									
GROUP	Active Setting Group #		x	x		x			x
Math Variables									
MV01 to MV32	Math Variable 01 to Math Variable 32		x	x	x	x	x		x
SELOGIC Counters Note 12: SELOGIC counters are also available as a DNP counter object.									
SC01 to SC32	SELOGIC Counter 01 to SELOGIC Counter 32		x	x	x	x	x		x
Remote Analogs Note 13: FM refers to Fast Message support for remote analogs. Remote analogs can be written by using an unsolicited Fast Message Write command.									
RA001 to RA128	Remote Analog 001 to Remote Analog 128		x	x	x	x	x	x	x

Table M.1 Analog Quantities (Sheet 16 of 18)

Name	Description	Units	Display Points	SELogic	Load Profile	DNP3/Fast Message Read/ IEC 60870-5-103/EtherNet/IP	Modbus[a]	Fast Meter	IEC 61850[b, c]
Fault Information									
FFREQ	Description for 60870 fault analogs: Frequency of fault event Description for the rest: Frequency of the most recent fault	Hz	x	x		x			x
FIAW1	Description for 60870 fault analogs: Winding 1 A-phase current of fault event Description for the rest: Winding 1 A-phase current of the most recent fault	A pri	x	x		x			x
FIBW1	Description for 60870 fault analogs: Winding 1 B-phase current of fault event Description for the rest: Winding 1 B-phase current of the most recent fault	A pri	x	x		x			x
FICW1	Description for 60870 fault analogs: Winding 1 C-phase current of fault event Description for the rest: Winding 1 C-phase current of the most recent fault	A pri	x	x		x			x
FIGW1	Description for 60870 fault analogs: Winding 1 calculated-residual current of fault event Description for the rest: Winding 1 calculated-residual current of the most recent fault	A pri	x	x		x			x
FIAW2	Description for 60870 fault analogs: Winding 2 A-phase current of fault event Description for the rest: Winding 2 A-phase current of the most recent fault	A pri	x	x		x			x
FIBW2	Description for 60870 fault analogs: Winding 2 B-phase current of fault event Description for the rest: Winding 2 B-phase current of the most recent fault	A pri	x	x		x			x
FICW2	Description for 60870 fault analogs: Winding 2 C-phase current of fault event Description for the rest: Winding 2 C-phase current of the most recent fault	A pri	x	x		x			x
FIGW2	Description for 60870 fault analogs: Winding 2 calculated-residual current of fault event Description for the rest: Winding 2 calculated-residual current of the most recent fault	A pri	x	x		x			x

Table M.1 Analog Quantities (Sheet 17 of 18)

Name	Description	Units	Display Points	SELogic	Load Profile	DNP3/Fast Message Read/ IEC 60870-5-103/EtherNet/IP	Modbus[a]	Fast Meter	IEC 61850[b, c]
FIAW3	Description for 60870 fault analogs: Winding 3 A-phase current of fault event Description for the rest: Winding 3 A-phase current of the most recent fault	A pri	x	x		x			x
FIBW3	Description for 60870 fault analogs: Winding 3 B-phase current of fault event Description for the rest: Winding 3 B-phase current of the most recent fault	A pri	x	x		x			x
FICW3	Description for 60870 fault analogs: Winding 3 C-phase current of fault event Description for the rest: Winding 3 C-phase current of the most recent fault	A pri	x	x		x			x
FIGW3	Description for 60870 fault analogs: Winding 3 calculated-residual current of fault event Description for the rest: Winding 3 calculated-residual current of the most recent fault	A pri	x	x		x			x
FIAW4	Description for 60870 fault analogs: Winding 4 A-phase current of fault event Description for the rest: Winding 4 A-phase current of the most recent fault	A pri	x	x		x			x
FIBW4	Description for 60870 fault analogs: Winding 4 B-phase current of fault event Description for the rest: Winding 4 B-phase current of the most recent fault	A pri	x	x		x			x
FICW4	Description for 60870 fault analogs: Winding 4 C-phase current of fault event Description for the rest: Winding 4 C-phase current of the most recent fault	A pri	x	x		x			x
FIGW4	Description for 60870 fault analogs: Winding 4 calculated-residual current of fault event Description for the rest: Winding 4 calculated-residual current of the most recent fault	A pri	x	x		x			x
FIN	Description for 60870 fault analogs: Neutral current of fault event Description for the rest: Neutral current of the most recent fault	A pri	x	x		x			x

Table M.1 Analog Quantities (Sheet 18 of 18)

Name	Description	Units	Display Points	SELogic	Load Profile	DNP3/Fast Message Read/ IEC 60870-5-103/EtherNet/IP	Modbus[a]	Fast Meter	IEC 61850[b, c]
FVAB	Description for 60870 fault analogs: A-to-B-phase voltage of fault event Description for the rest: A-to-B-phase voltage of the most recent fault	V pri	x	x		x			x
FVBC	Description for 60870 fault analogs: B-to-C-phase voltage of fault event Description for the rest: B-to-C-phase voltage of the most recent fault	V pri	x	x		x			x
FVCA	Description for 60870 fault analogs: C-to-A-phase voltage of fault event Description for the rest: C-to-A-phase voltage of the most recent fault	V pri	x	x		x			x
FVAN	Description for 60870 fault analogs: A-phase-to-neutral voltage of fault event Description for the rest: A-phase-to-neutral voltage of the most recent fault	V pri	x	x		x			x
FVBN	Description for 60870 fault analogs: B-phase-to-neutral voltage of fault event Description for the rest: B-phase-to-neutral voltage of the most recent fault	V pri	x	x		x			x
FVCN	Description for 60870 fault analogs: C-phase-to-neutral voltage of fault event Description for the rest: C-phase-to-neutral voltage of the most recent fault	V pri	x	x		x			x
FVG	Description for 60870 fault analogs: Zero-sequence voltage of fault event Description for the rest: Zero-sequence voltage of the most recent fault	V pri	x	x		x			x
FLREP	Event report present (shall be 1, when an event report is present, and 0 otherwise)								x
FLRNUM	Unique identification number of the latest event								x
IEC 61850 Test Mode Note 14: The name of the analog quantity label for I850 protocol is I60MOD.									
I850MOD	IEC 61850 Test Mode status			x					x

[a] The Modbus register labels may be different from the corresponding analog quantity labels. See Appendix E: Modbus Communications for more information.

[b] IEC 61850 data object labels may be different from the corresponding analog quantity labels. See Appendix G: IEC 61850 Communications for more information.

[c] See Device Logical Nodes for a list of the analog quantities mapped in the default ICD file.

Appendix N
Cybersecurity Features

The SEL-787 provides a number of features to help meet cybersecurity design requirements.

Access Control

The SEL-787 has a number of mechanisms for managing electronic access. These include ways to limit access, provide user authentication, and monitor electronic and physical access.

Physical Port Controls

Each physical serial port and the Ethernet port can be individually disabled using the EPORT setting. By default, all of the ports are enabled. It is good security practice to disable unused ports.

IP Ports

When using Ethernet, there are a number of IP ports available within the SEL-787. Many of these IP port numbers are configurable. All IP ports can be disabled. *Table N.1* describes each of these.

Table N.1 IP Port Numbers

IP Port Default	Port Selection Setting	Network Protocol	Default Port State	Port Enable Setting	Purpose
21	--	TCP	Enabled	EFTPSERV	FTP protocol access for file transfer of settings and reports
23	TPORT	TCP	Enabled	ETELNET	Telnet access for general engineering terminal access
80	HTTPPORT	TCP	Enabled	EHTTP	Web server access to various relay information
102	--	TCP	Disabled	E61850	IEC 61850 MMS for SCADA functionality
123	SNTPPORT	UDP	Disabled	ESNTP	SNTP time synchronization
319/320	--	UDP	Disabled	EPTP[a]	PTP time synchronization
502	MODNUM1/ MODNUM2	TCP	Disabled	EMOD	MODBUS for SCADA functionality
2222/ 44818	--	TCP/UDP	Disabled	EEIP	EtherNet/IP for SCADA functionality
4712/ 4713	PMOTCP1/ PMOUDP1	TCP/UDP	Disabled	PMOTS1	Synchrophasor data output, Session 1
4722/ 4713	PMOTCP2/ PMOUDP2	TCP/UDP	Disabled	PMOTS2	Synchrophasor data output, Session 2
20000	DNPNUM	TCP/UDP	Disabled	EDNP	DNP for SCADA functionality

[a] When PTPPRO = DEFAULT and PTPTR = UDP.

See *PORT 1 on page 4.137* and *Ethernet Port on page 7.3* for more information on these settings.

Authentication and Authorization

The SEL-787 supports four levels of access, as described in *Access Levels on page 7.27*. Refer to this section to learn how each level is accessed and how to change passwords. It is good security practice to change the default passwords of each access level and to use a unique password for each level.

The MAXACC setting limits the level of access for each port. This permits you to operate under the principle of “least privilege”, restricting ports to the levels necessary for the functions performed on those ports.

The SEL-787 supports strong passwords with as many as 12 characters, using any printable character, allowing users to select complex passwords if they so choose. SEL recommends that passwords have a minimum of 8 characters and include at least one of each of the following: lowercase letter, uppercase letter, number, and special character.

Ethernet protocols Telnet and FTP require the proper passwords to gain access to level-protected functions. Ethernet protocol MMS requires a password to gain access if MMS Authentication is enabled via the CID file. See *Section 7: Communications* for more information on access restrictions for the Ethernet protocols.

Monitoring and Logging

NOTE: Refer to Access Commands (ACCESS, 2ACCESS, and CAL) for more information on when SALARM is pulsed for access level changes and unsuccessful password entry attempts.

The SEL-787 provides Relay Word bits that are useful for monitoring relay access:

- SALARM—Pulses for approximately one second whenever a user gains access to Level 2 or higher, when an incorrect password is entered or when a setting is changed.
- PASEL, PBSEL—Asserted while the Ethernet port(s) is active.
- LINK1, LINKA, LINKB—Asserted while the link is active on the Ethernet port(s). Loss of a link can be an indication that an Ethernet cable has been disconnected.
- LINKFAIL—Asserted if link is lost on the active IP port (ports 1A or 1B).

These bits can be mapped for SCADA monitoring via DNP3, IEC 61850, Modbus, EtherNet/IP, or SEL Fast Message. They also may be added to the SER for later analysis or assigned to output contacts for alarm purposes.

The SEL-787 SER is a useful tool for capturing a variety of relay events. In addition to capturing state changes of user selected Relay Word bits, it captures all power-ups, settings changes, and group switches. See *Sequential Events Recorder (SER) Report on page 10.41* for more information about SER.

Configuration Management

Many users are concerned about managing the configuration of their relays. The SEL-787 provides mechanisms to help users manage relay configuration.

All settings changes are logged to the SER log. Analysis of this log indicates if any unauthorized settings changes occurred. The SALARM Relay Word bit also indicates changes in the relay configuration by pulsing for approximately one second when any of the following occur:

- Settings are changed or saved
- A password changes
- The relay switches settings groups

See *Self-Test on page 11.17* for more information regarding the Relay Word bit SALARM.

Malware Protection

The SEL-787 has inherent and continuous monitoring for malware. For a full description of this, see selinc.com/mitigating_malware/.

Firmware Hash Algorithm

This device supports digitally signed firmware upgrades. SEL uses the SHA-256 secure hash algorithm to compress and digitally sign firmware upgrade files. The signature ensures that the file has been provided by SEL and that its contents have not been altered. When the file is uploaded to the relay, the signature is verified using a public key stored on the relay. If the relay cannot verify the signature, it rejects the file. See *Appendix B: Firmware Upgrade Instructions* for more information on firmware upgrades.

Operating System/ Firmware

SEL-787 relays are embedded devices that do not allow additional software to be installed. SEL-787 relays include a self-test that continually checks running code against the known good baseline version of code in nonvolatile memory. This process is outlined in more detail in the document titled *The SEL Process for Mitigating Malware Risk to Embedded Devices* located at selinc.com/mitigating_malware/. SEL-787 relays run in an embedded environment for which there is no commercial anti-virus software available.

Software/Firmware Verification

SEL-787 relays have the ability to install firmware updates in the field. Authenticity and integrity of firmware updates can be verified by using the *Firmware Hash* page at selinc.com/products/firmware.

Physical Access Security

Physical security of cybersecurity assets is a common concern. Typically, relays are installed within a control enclosure that provides physical security. Other times, they are installed in boxes within the switchyard. The relay provides some tools that may be useful to manage physical security, especially when the unit is installed in the switchyard.

You can monitor physical ingress by wiring a door sensor to one of the relay contact inputs. This input can then be mapped for SCADA monitoring or added to the SER log so that you can detect when physical access to the relay occurs.

It is also possible to wire an electronic latch to a relay contact output. You could then map this input for SCADA control.

Vulnerability Notification Process

Security Vulnerability Process

SEL provides security disclosure alerts to customers, and SEL instruction manuals document all releases. SEL security vulnerability disclosures are described in *The SEL Process for Disclosing Security Vulnerabilities* at selinc.com.

Emailed Security Notification

You can sign up to receive email notifications when SEL releases security vulnerability notices and service bulletin at selinc.com/support/security-notifications/.

Settings Erasure

NOTE: Do not erase the settings when sending the relay to the factory for service. SEL needs to be able to see how the relay was configured to properly diagnose many problems.

NOTE: In firmware versions R302-V0 and later, the relay firmware retains the IP address, subnet mask, and default router settings after an **R_S** command is issued.

It is often desirable to erase the settings from the relay when it is removed from service. You can completely erase all the configuration settings from the SEL-787 using this procedure:

Step 1. Go to Access Level C. See *Access Levels on page 7.27*.

Step 2. Execute the **R_S** command.

Step 3. Allow the relay to restart.

Once this procedure is complete, all internal instances of user settings and passwords will be erased. Do not do this when sending in the relay for service at the factory. SEL needs to see how the relay was configured in order to properly diagnose many problems.

Appendix O
Protection Application Examples

Overview

This section provides instructions for setting the SEL-787 Relay protection functions. Use these application examples to help familiarize yourself with the relay and assist you with your own protection settings calculations. This section is not intended to provide a complete settings guide for the relay.

Transformer Winding and CT Connection Compensation Settings Examples

In electromechanical and solid-state transformer differential relays, the standard current transformer (CT) configuration was wye connected on the delta winding of the transformer and delta connected on the wye winding of the transformer. The CT delta connection was constructed based on the power transformer delta to compensate for the phase shift that occurred on the system primary currents because of the power transformer connection. The CT configuration allowed the currents entering the relay for through-load or external faults to be 180 degrees out-of-phase so that the phasor sum of the currents added to zero (no differential current) in an electromechanical differential relay. Taps on the relay current inputs compensated for magnitude differences. Modern digital relays perform both the connection (or phase) and magnitude compensation mathematically so all CTs can be connected in wye.

NOTE: In this settings guideline, the term "phase rotation" is synonymous with "phase sequence." This settings guideline uses "phase rotation" to be consistent with the relay Global setting, PHROT.

This section provides a procedure for SEL-787 Relays to determine and set the Terminal *n* CT connection compensation settings, W*n*CTC (where *n* = 1, 2, 3, or 4), to compensate for the phase shift across the transformer. Each of the connection compensation settings offer thirteen 3x3 matrices, CTC(0)–CTC(12), permitting CT connection compensation from 0 degrees to 360 degrees, in increments of 30 degrees, respectively. Refer to *Section 4: Protection and Logic Functions* (*Table 4.5*) for each of the compensation matrices. When applied on a system with an ABC phase rotation, these matrices perform phase angle correction in a counterclockwise (CCW) direction in multiples of 30 degrees, as shown in *Table O.1*. For a system with an ACB phase rotation, the direction of correction is clockwise (CW). See *Special Cases* for a compensation settings example on a system with an ACB phase rotation.

Table O.1 WnCTC Setting: Corresponding Phase and Direction of Correction

WnCTC Setting[a]	Matrix	Amount and Direction of Correction	
		ABC Phase Rotation	ACB Phase Rotation
0	CTC(0)	0°	0°
1	CTC(1)	30° CCW	30° CW
2	CTC(2)	60° CCW	60° CW
3	CTC(3)	90° CCW	90° CW
4	CTC(4)	120° CCW	120° CW
5	CTC(5)	150° CCW	150° CW
6	CTC(6)	180° CCW	180° CW
7	CTC(7)	210° CCW	210° CW
8	CTC(8)	240° CCW	240° CW
9	CTC(9)	270° CCW	270° CW
10	CTC(10)	300° CCW	300° CW
11	CTC(11)	330° CCW	330° CW
12	CTC(12)	0° (360°) CCW	0° (360°) CW

[a] n = 1, 2, 3, 4.

As shown in *Section 4: Protection and Logic Functions* (*Table 4.5*), compensation matrix CTC(0) multiplies the currents by the identity matrix and creates no change in the currents. Compensation matrix CTC(12) is similar to CTC(0) in that it produces no phase shift (or, more correctly, 360 degrees of shift) in a balanced set of phasors separated by 120 degrees. However, CTC(12) removes zero-sequence components from the measured current, as do all of the matrices with non-zero values.

Transformer Nameplates and System Connections

To determine the phase shift seen by the relay, the following information is required:

- ➤ Transformer phasor (vector) diagram (transformer nameplate)
- ➤ Three-line connection diagram showing:
  - ➢ System phase-to-transformer bushing connections
  - ➢ CT connections
  - ➢ CT-to-relay connections

Figure O.1 shows the key information from a typical nameplate for a two-winding transformer. The winding connection diagram and the phasor (vector) diagram are needed to determine the winding compensation settings in the relay.

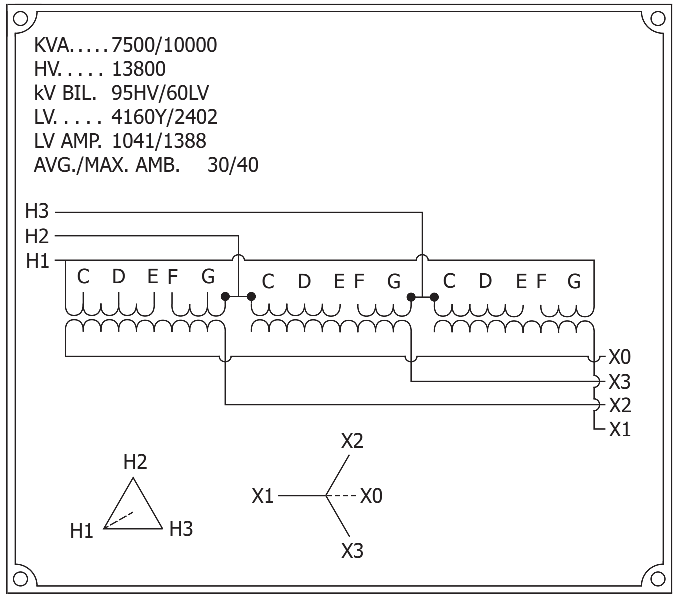

Figure O.1 Transformer Nameplate

Note that there is no phase designation nor any phase rotation designation on the nameplate. However, the phasor diagram is representative of an H1-H2-H3 sequence. The phase shift on the power system depends on the transformer winding connections, the system phase-to-transformer bushing connections, and the system phase rotation.

Figure O.2 shows a three-line connection diagram with the transformer shown in *Figure O.1* with what this guideline refers to as standard connections. Standard phase-to-bushing connections are A-phase to H1, B-phase to H2, C-phase to H3, a-phase to X1, b-phase to X2, and c-phase to X3. Standard CT connections include wye-connected CTs with polarity marks of both CTs away from or towards the transformer. *Figure O.2* shows both H-side and X-side CTs connected in wye and the polarity marks away from the transformer. A CT-to-relay connection is considered to be standard when the polarity of the CT is connected to the polarity of the relay analog current input and the primary system phase current is connected to the same phase input on the relay (e.g., IA system to IAW1). Unless otherwise noted, an ABC phase rotation is assumed for the following discussion.

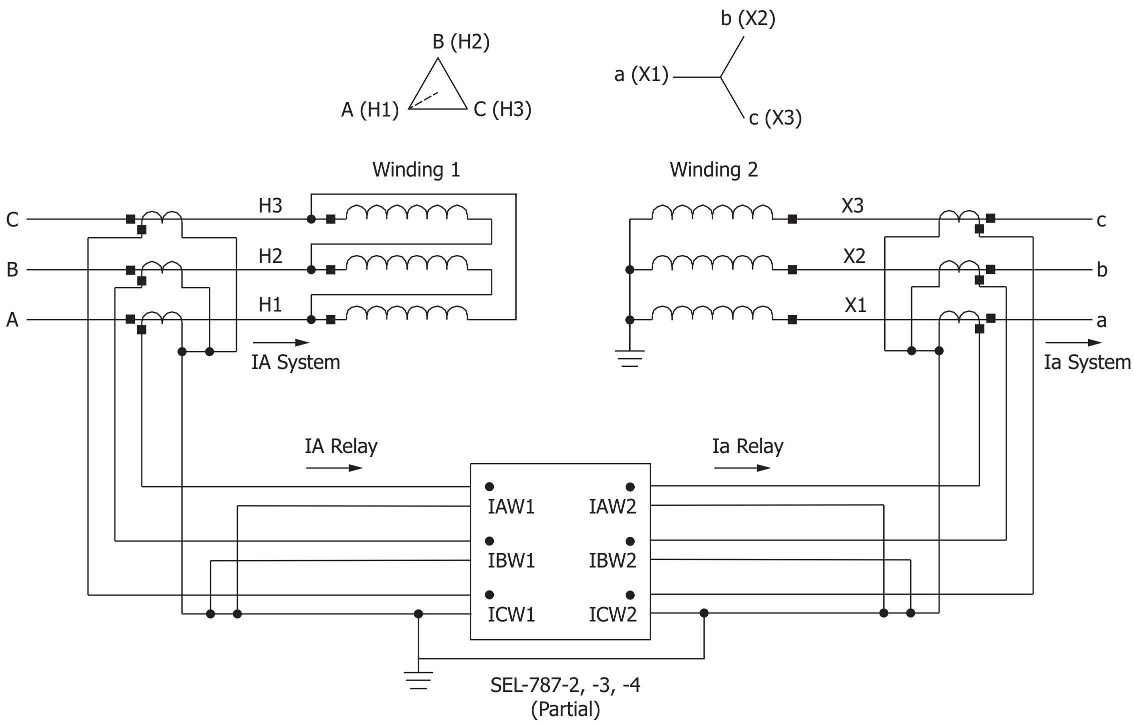

Figure O.2 Three-Line Diagram Showing System Phase-to-Transformer Bushing, CT, and CT-to-Relay Connections

If all the connections are standard as shown in *Figure O.2*, under a through-load condition the phase relationship between the system primary currents (Ia system and IA system) and corresponding secondary currents as seen by the relay (IAW2 and IAW1) will look like as shown in *Figure O.3* (Ia lags IA by 30 degrees) and *Figure O.4* (IAW2 lags IAW1 by 210 degrees), respectively. The goal of the compensation settings is to compensate IAW2 so as to bring IAW2_compensated 180 degrees out-of-phase with IAW1 for proper application of the differential function.

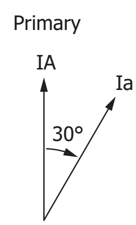

Figure O.3 Primary Current Phasors

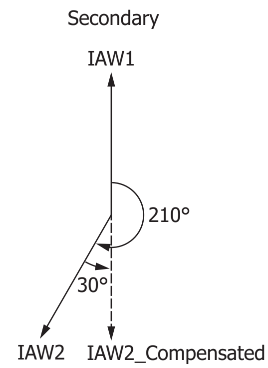

Figure O.4 Current at the Relay Terminals

Many applications do not conform to the standard connections, but compensation settings are adaptable to fit any application. The subsequent sections outline the procedure to determine the phase shift and current transformer compensation settings, and also discuss what to do with non-standard phase-to-bushing, CT, and CT-to-relay connections.

Steps to Determine the Compensation Settings (WnCTC)

Use the following guidelines to determine compensation settings for your application(s).

Step 1. Determine the phase shift as seen by the relay.

a. Determine the phase shift in the primary load current.

b. Determine if there are non-standard CT connections.

Step 2. Select the reference winding and associated relay terminal.

a. If a delta winding exists and is wired into the relay, choose it as the reference winding. Select matrix CTC(0) for the compensation of the delta winding. If a zig zag grounding transformer exists on the delta side of the transformer and is within the zone of protection, then select matrix CTC(12).

b. If a delta winding does not exist, select one of the wye windings as the reference and choose matrix CTC(11) for the compensation.

Step 3. Determine the required compensation setting for all other windings. Select matrix CTC(0) for delta windings. Use odd matrices for compensating wye-windings. Avoid the use of even matrices when possible.

There may be applications that require the guidelines to be violated, but they should be followed when possible.

The rest of this section discusses each of the guidelines in detail. Examples and special cases are provided to illustrate the application of the guidelines in determining the compensation settings.

Step 1. Determine the Phase Shift as Seen by the Relay

Determine the Phase Shift in the Primary Load Current

The first step in selecting the compensation setting in the relay is to determine the phase shift in the primary load current.

Standard System Phase-to-Transformer Bushing Connections.

NOTE: Unless otherwise stated, this discussion assumes an ABC system phase rotation.

Consider the transformer in *Figure O.1* and the phase-to-bushing connections in *Figure O.2*. Assume balanced X-side (wye-winding) three-phase currents Ia, Ib, and Ic, as shown in *Figure O.5*. The currents on the H-side (delta-winding) of the transformer are Ia/N, Ib/N, and Ic/N where N is the turns ratio of the transformer. Because the discussion focuses on the phase shift and not the magnitude, you can assume N = 1 for this discussion.

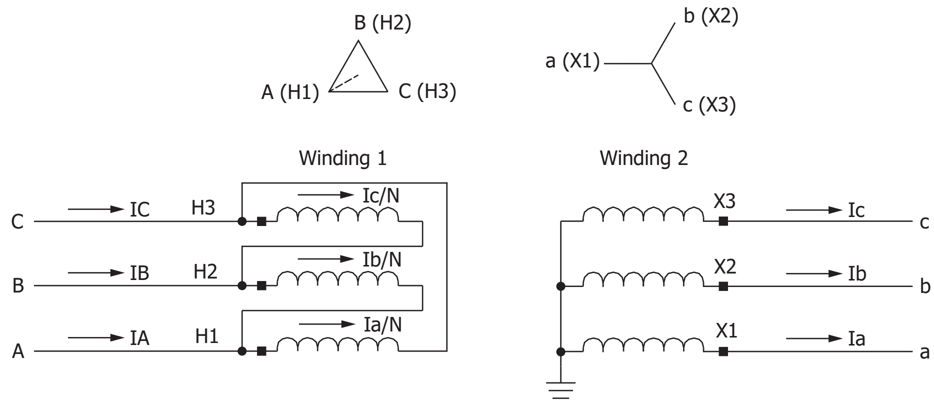

Figure O.5 Standard System Phase-to-Transformer Bushing Connections

Kirchhoff's Current Law is used at each H-node to determine the primary phase currents on the H-side of the system:

IA = Ia – Ib

IB = Ib – Ic

IC = Ic – Ia

The following examples start with the currents on the wye-side of the transformer to graphically derive the currents on the delta side of the transformer. *Figure O.6* shows that system primary current Ia (X-side) lags the system primary current IA (H-side) by 30 degrees.

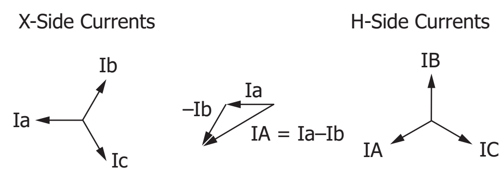

Figure O.6 X- and H-Side Current Phasors for Figure O.5

The primary load phase shift determined in *Figure O.6* applies for the phase-to-bushing connections shown in *Table O.2*. In each of these phase-to-bushing connections, the order of the phases (A, B, C) matches the order of the bushings (H1, H2, H3).

Table O.2 (A, B, C) to (H1, H2, H3) Phase-to-Bushing Connections

	Bushing					
	H1	**H2**	**H3**	**X1**	**X2**	**X3**
System Phase	A	B	C	a	b	c
	B	C	A	b	c	a
	C	A	B	c	a	b

Non-Standard Phase-to-Bushing Connections. Consider the transformer connections in *Figure O.7*. This is the same transformer discussed in *Figure O.5*, but with different phase-to-bushing connections: A-phase to H3, B-phase to H2, C-phase to H1, a-phase to X3, b-phase to X2, and c-phase to X1.

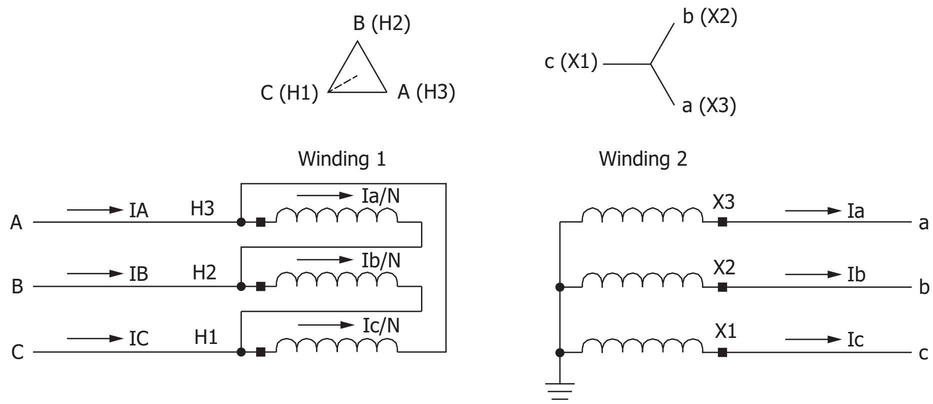

Figure O.7 Non-Standard System Phase-to-Transformer Bushing Connections

Assume balanced X-side (wye-winding) three-phase currents Ia, Ib, and Ic. Kirchhoff's Current Law is used at each H-node to determine the primary phase currents on the H-side of the system:

IA = Ia – Ic

IB = Ib – Ia

IC = Ic – Ib

Figure O.8 shows that system primary current Ia (X-side) leads the system primary current IA (H-side) by 30 degrees.

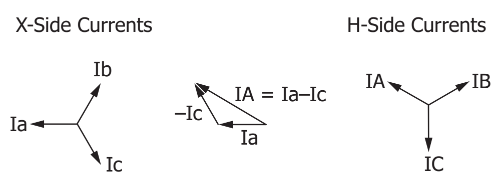

Figure O.8 X- and H-Side Current Phasors for Figure O.7

The primary load phase shift determined in *Figure O.8* applies for the phase-to-bushing connections shown in *Table O.3*. In each of these phase-to-bushing connections, the order of the phase connections (A, C, B) is opposite the order of the bushings (H1, H2, H3).

Table O.3 (A, C, B) to (H1, H2, H3) Phase-to-Bushing Connections

	Bushing					
	H1	**H2**	**H3**	**X1**	**X2**	**X3**
System Phase	C	B	A	c	b	a
	B	A	C	b	a	c
	A	C	B	a	c	b

The system phase-to-transformer bushing connection diagrams in *Figure O.5* and *Figure O.7* are on the same transformer, but with a different order of the phases connected to the transformer bushings. As a result, the X-side primary current shifts 30 degrees in opposite directions in the two systems.

Combination of Standard and Non-Standard Phase-to-Bushing Connections. Consider the transformer connections shown in *Figure O.9*. The transformer is the same as in previous examples. However, in this example, the H-side phase-to-bushing connections are standard: A-phase to H1, B-phase to H2, and C-phase to H3. The X-side connections are non-standard: a-phase to X2, b-phase to X3, and c-phase to X1.

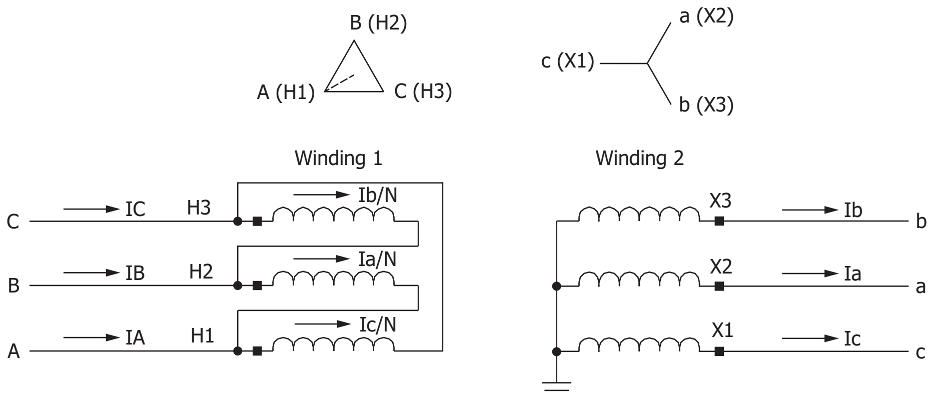

Figure O.9 Combination of Standard and Non-Standard Phase-to-Bushing Connection Diagram

Assume balanced X-side (wye-winding) three-phase currents Ia, Ib, and Ic. Kirchhoff's Current Law is used at each H-node to determine the primary phase currents on the H-side of the system:

IA = Ic – Ia

IB = Ia – Ib

IC = Ib – Ic

Figure O.10 shows that system primary current Ia (X-side) lags the system primary current IA (H-side) by 150 degrees.

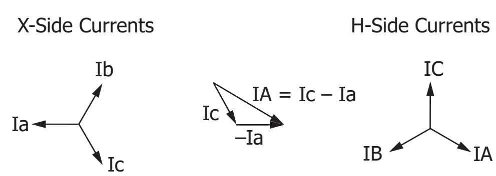

Figure O.10 X- and H-Side Current Phasors for Figure O.9

These three examples show that the same transformer winding connections can produce different phase shifts in the system primary load current based on the phase-to-bushing connections.

Determine if There Are Non-Standard CT Connections

Figure O.11 shows the transformer of *Figure O.2* with a standard current transformer configuration; that is, both the H-side and X-side CTs are connected in wye and the polarity marks are away from the power transformer.

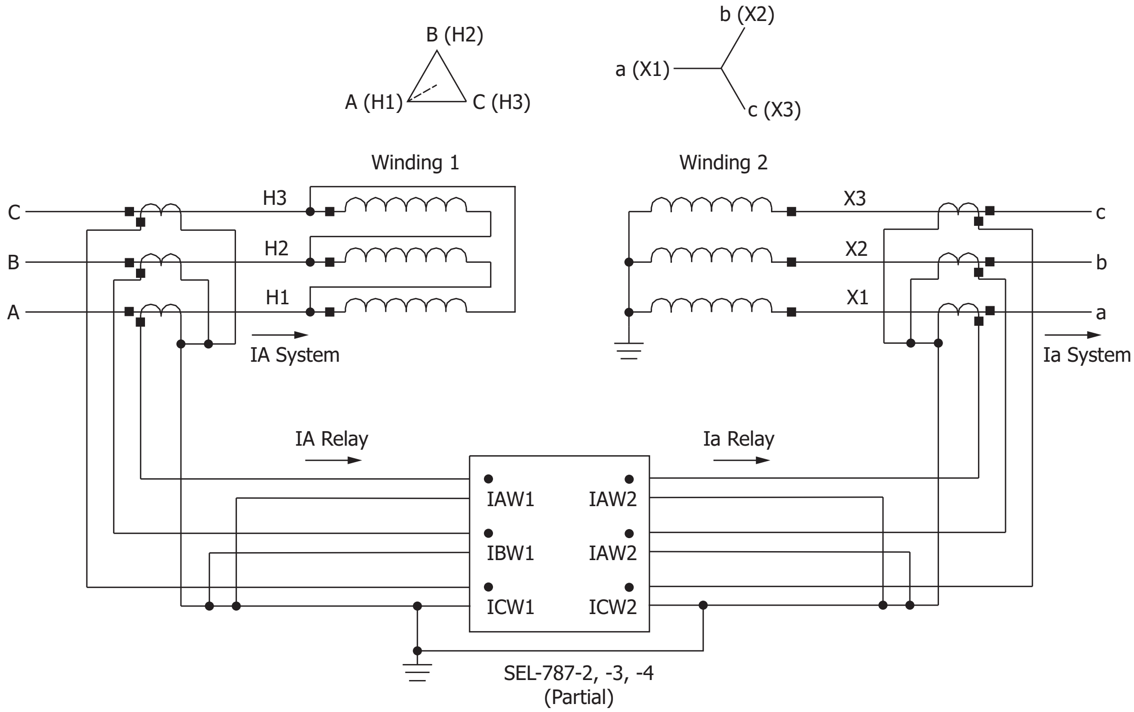

Figure O.11 Standard CT Connections

Standard CT Connections. In *Figure O.11*, the polarity of the CT connects to the polarity of the relay current input, and the primary system phase current connects to the same phase input on the relay (e.g., IA system to IAW1 relay input). While the H-side currents connect to the W1-terminal and the X-side currents connect to W2-terminal, they could be connected to any two sets of current inputs on the relay. *Figure O.11* represents the standard connections for the transformer, CTs, and relay.

Figure O.11 also shows the primary system currents (IA system, Ia system) and the CT secondary currents seen by the relay (IA relay, Ia relay) based on the currents of *Figure O.6*. For these connections, with power flow from the H-side to the X-side of the transformer, currents enter the relay at the polarity mark on the H-side, and leave the relay at the polarity mark on the X-side. Thus, on the primary system, Ia lags IA by 30 degrees, but at the relay, IAW2 leads IAW1 by 150 degrees, as shown in *Figure O.12*. B- and C-phases follow this relationship. Only A-phase is discussed for simplicity, but the concept is the same.

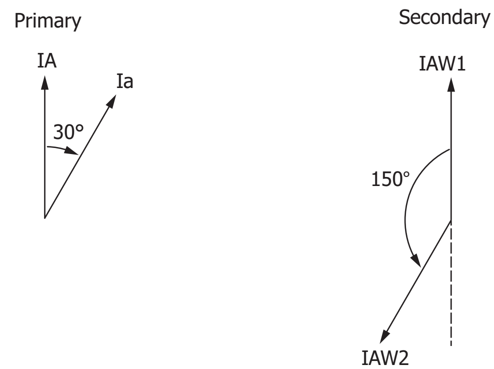

Figure O.12 Primary System Currents and Currents as seen by the Relay

Non-Standard CT Connections: Reversed CT Polarity. *Figure O.13* shows the X-side CT polarity marks toward the transformer. However, because the connections to the relay remain the same, the relay currents flow the same, as in *Figure O.12*. No additional adjustments need to be made because of this type of non-standard CT connection.

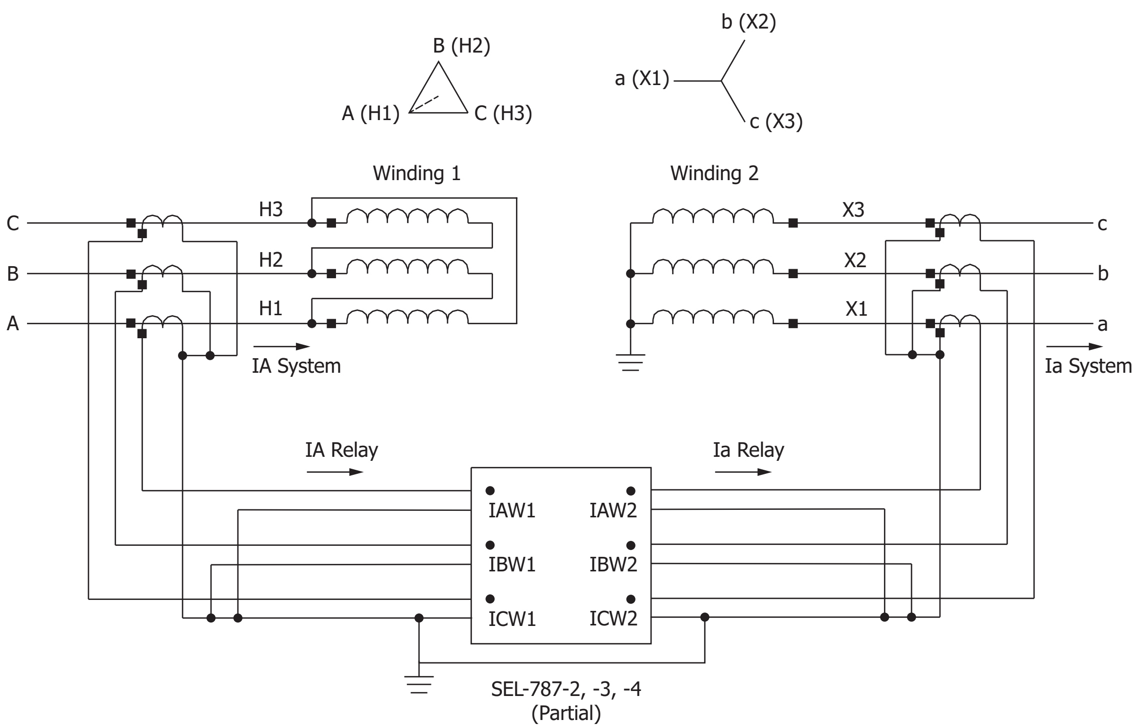

Figure O.13 Current Flow With Reversed X-Side CT Polarity

Non-Standard CT Connections: Reversed CT Polarity and Reversed Connections. In *Figure O.14*, the polarity marks of the X-side CTs are toward the transformer, as in *Figure O.13*, but the neutral sides of the CTs are away from the transformer. With these connections, the H-side and X-side currents are both entering the relay at the relay polarity mark.

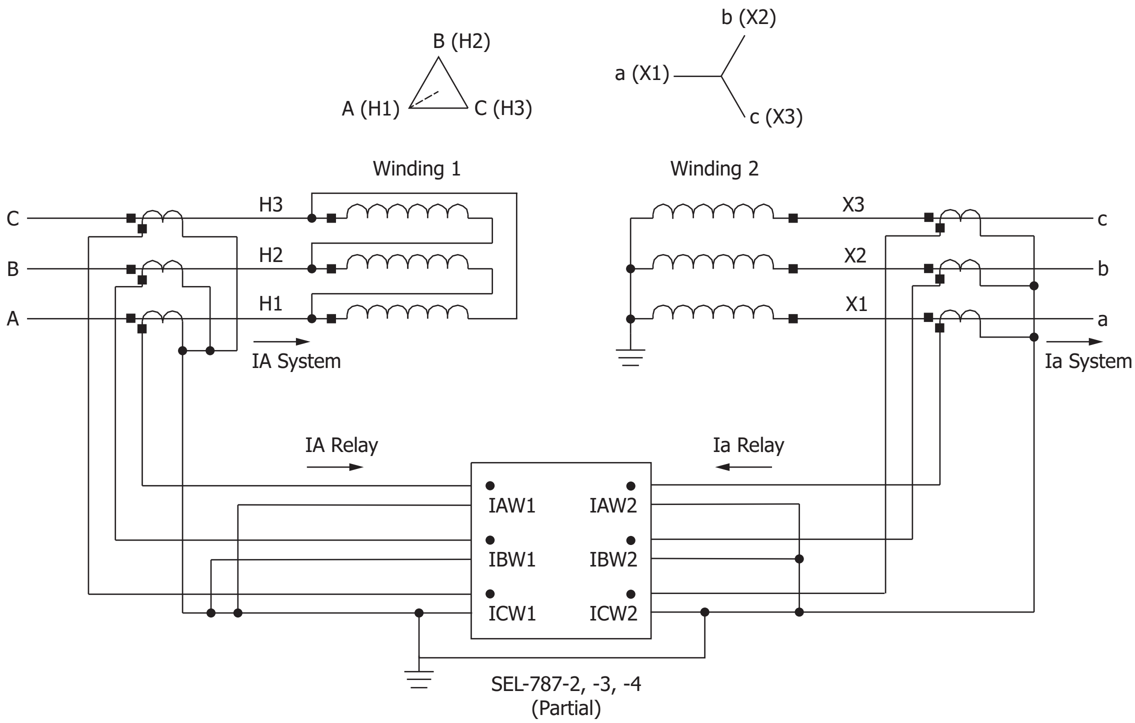

Figure O.14 Current Flow With Reversed X-Side CT Polarity and Reversed Connections

As shown in *Figure O.15*, the resulting IAW2 current measured by the relay is now shifted 180 degrees, as compared to *Figure O.12*.

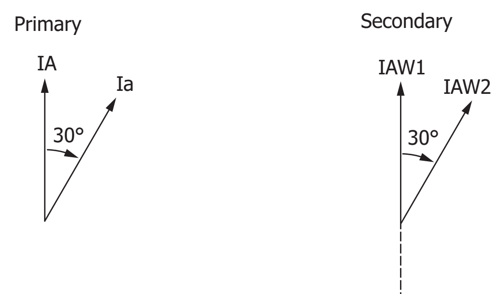

Figure O.15 Results of Reversed X-Side CT Polarity and Reversed Connections

One method to correct this is to reverse the current connections at the relay. Connect the non-polarity terminal of the CT to the polarity terminal of the relay current input and the polarity terminal of the CT to the non-polarity terminal of the relay current input. These changes result in the connections shown in *Figure O.13*.

An alternate method to correct the phase shift is to use the CT compensation setting, W*n*CTC. As shown in *Table O.1*, each CTC setting results in a counter-clockwise phase shift that is a multiple of 30 degrees for an ABC system phase rotation. Selecting a compensation setting of 6 effectively shifts the current by 180 degrees (6 • 30° = 180°). Further explanation for selecting the final settings for non-standard CT connections is provided in *Example O.3*.

Step 2. Select the Reference Winding and Associated Relay Terminal

If there is a delta winding on the power transformer, the delta winding should be selected as the reference winding regardless of whether it is the high- or low-voltage winding. The reference winding can be associated with any analog current measurement terminal on the relay. For example, if the delta winding current is measured by the W1-terminal inputs on the relay, W1CTC is the setting that corresponds to the reference winding.

The compensation for the delta winding should be set to matrix CTC(0) (W*n*CTC = 0) unless there is a grounding bank on the delta winding within the differential zone. Grounding banks are a source of zero-sequence current and this current needs to be filtered to avoid operation of the differential element for external ground faults. If there is a grounding bank within the differential zone, use W*n*CTC = 12. Both W*n*CTC = 0 and W*n*CTC = 12 result in no phase shift, but W*n*CTC = 12 additionally removes zero-sequence current from the differential calculation.

If there is no delta winding, select one of the wye windings as the reference and set the compensation setting to 11 (W*n*CTC = 11) for the reference winding.

Step 3. Determine the Required Compensation Settings for All Other Windings

Use the following guidelines for choosing the remaining CT compensation settings.

1. Compensate delta windings with matrix CTC(0)
2. Compensate wye windings with odd matrices
3. Avoid the use of even matrices

There may be applications that require one or more of the guidelines to be violated, but they should be followed when possible. The following examples illustrate the steps required to determine the compensation setting(s) for the remaining winding(s).

Application Examples

EXAMPLE O.1 Delta-Wye Transformer With Standard Phase-to-Bushing Connections, Standard CT Connections, and an ABC System Phase Rotation

Consider the system shown in Figure O.16. The primary current phase shift for these connections was determined in Figure O.6. Figure O.17 shows the phase relationship of both the primary system phase currents and the secondary phase currents as seen by the relay. The system primary current Ia (X-side) lags the system primary current IA (H-side) by 30 degrees. The CT connections are standard, which results in IAW2 leading IAW1 by 150 degrees.

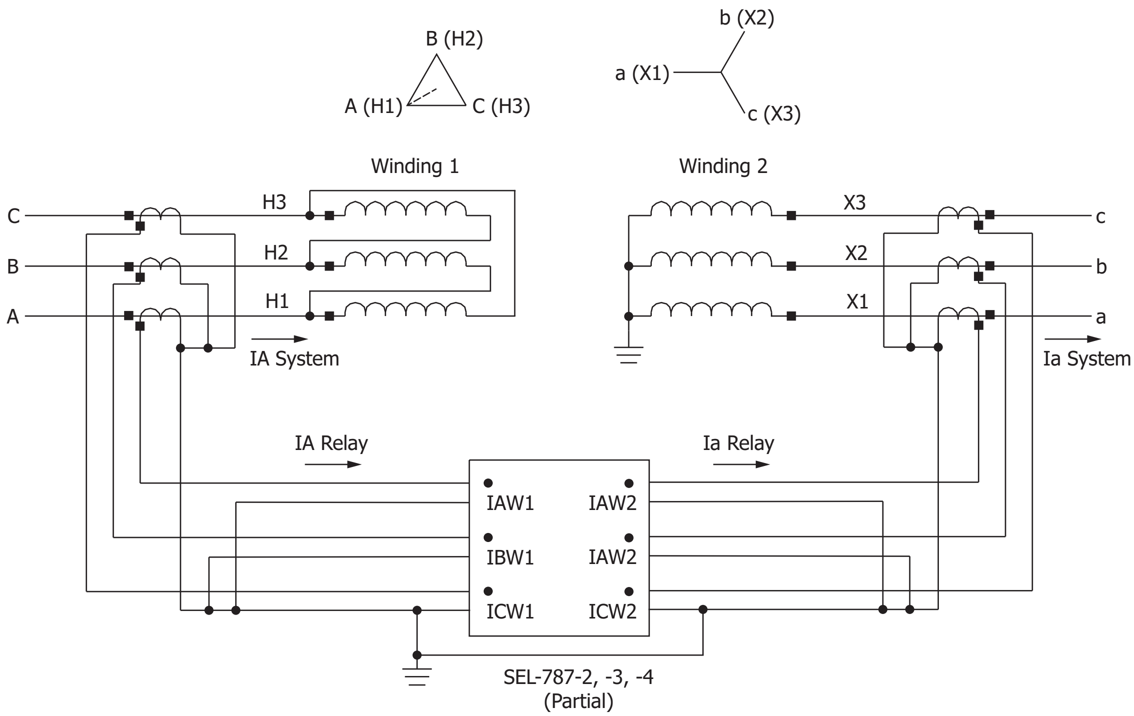

Figure O.16 Delta-Wye Transformer With Standard Phase-to-Bushing Connections

Select the delta winding as the reference winding. The H-side delta current is connected to Terminal W1 of the SEL-787 Relay. Therefore, set W1CTC = 0. The X-side currents are connected to Terminal W2 of the SEL-787 Relay, so W2CTC must be determined.

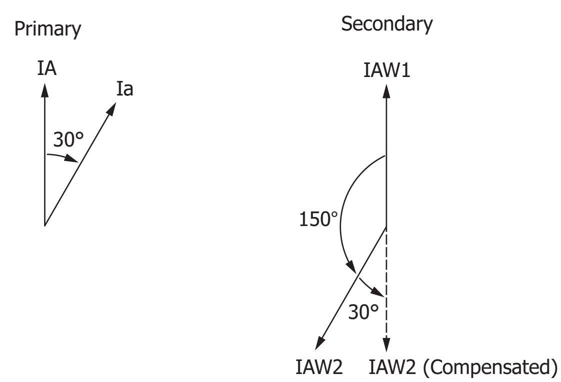

Figure O.17 Primary Currents and Secondary Currents as Measured by the Relay

IAW2 must be rotated 30 degrees (1 multiple of 30 degrees) in the counterclockwise direction for a system with an ABC phase rotation to be 180 degrees out-of-phase with IAW1. Therefore, set W2CTC = 1. The resulting compensation settings for this system are W1CTC = 0 and W2CTC = 1.

EXAMPLE O.2 Delta-Wye Transformer With Non-Standard Phase-to-Bushing Connections, Standard CT Connections, and an ABC System Phase Rotation

This example uses the transformer and relay connections of Figure O.18. This is the same transformer as in Example O.1, but with non-standard phase-to-bushing connections. Figure O.19 shows that for this connection, the system current Ia (X-side) leads the system current IA (H-side) by 30 degrees, or lags by 330 degrees. The CT connections are standard, which results in IAW2 lagging IAW1 by 150 degrees. Figure O.19 shows the phase relationship of both the primary system phase currents and the secondary phase currents as seen by the relay.

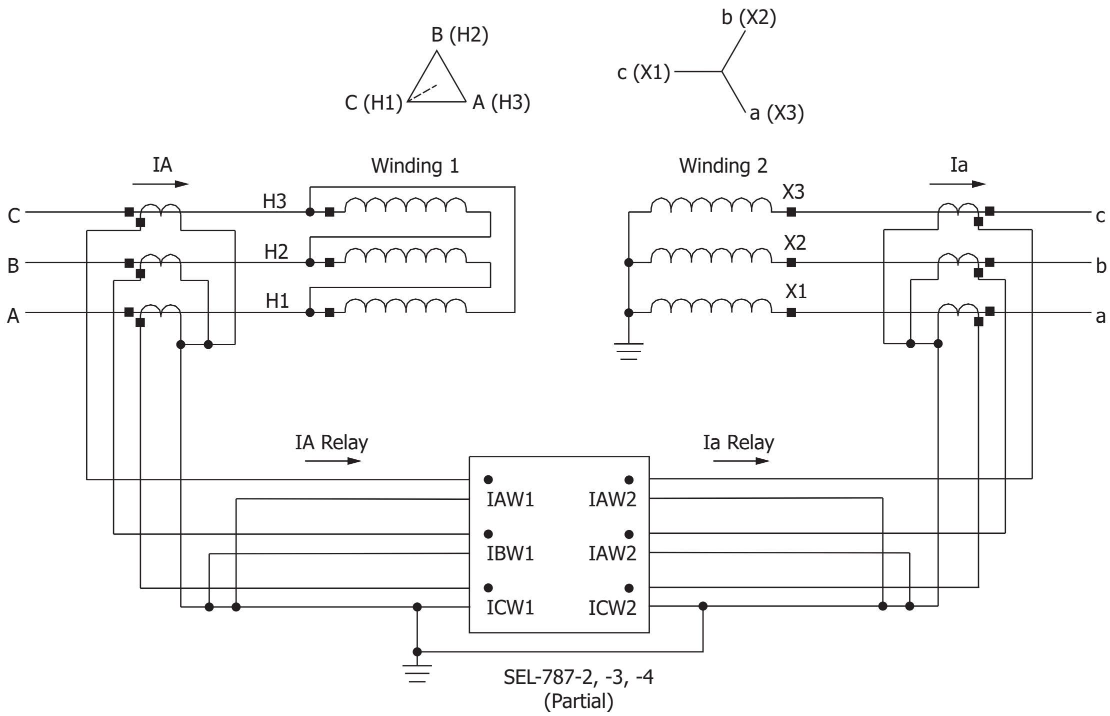

Figure O.18 Delta-Wye Transformer With Non-Standard Phase-to-Bushing Connections

Select the delta winding as the reference winding. The H-side delta current is connected to Terminal W1 of the SEL-787 Relay. Therefore, set W1CTC = 0. The X-side currents are connected to Terminal W2, so W2CTC must be determined.

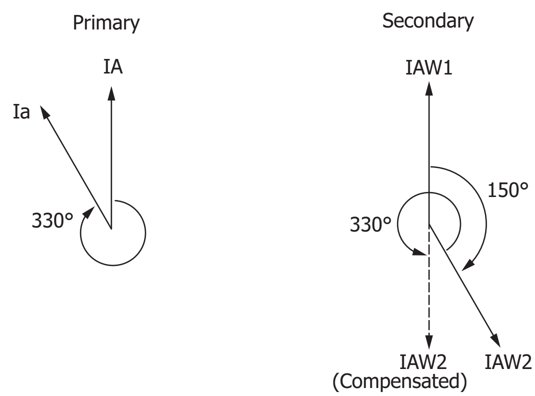

Figure O.19 Primary Currents and Secondary Currents as Measured by the Relay

IAW2 must be rotated 330 degrees (11 multiples of 30 degrees) in the counter-clockwise direction for a system with an ABC phase rotation to be 180 degrees out-of-phase with IAW1. Therefore, set W2CTC = 11. The resulting compensation settings are W1CTC = 0 and W2CTC = 11. Although the same transformer is used in Example O.1 and Example O.2, notice that the non-standard phase-to-bushing connections affect the compensation settings in both examples.

EXAMPLE O.3 Delta-Wye Transformer With Standard Phase-to-Bushing Connections, X-Side Non-Standard CT Connections, and an ABC System Phase Rotation

This example uses standard phase-to-bushing connections as shown in Figure O.20. Notice the X-side CT connections are non-standard. This example differs from the previous examples because the wye winding is now on the high side. The method to solve for the compensation settings is the same.

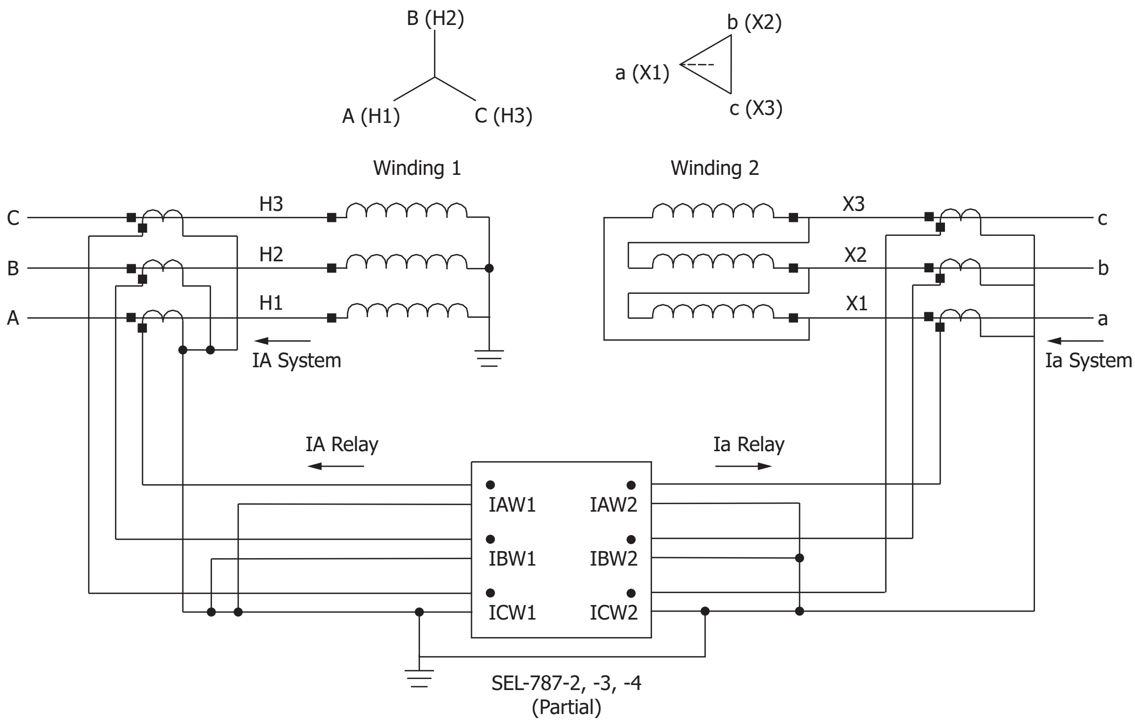

Figure O.20 Wye-Delta Transformer With Non-Standard CT Connections on the X-Side

Assume balanced three-phase currents on the wye side of the transformer. In this example, the wye side is associated with the H-side of the transformer. The phase currents on the X-side are:

Ia = IA – IC
Ib = IB – IA
Ic = IC – IB

In Figure O.21, IA on the wye side of the transformer is chosen as the reference to derive the phasor diagram of the delta-side currents. The system primary current Ia (X-side) lags IA (H-side) by 30 degrees or leads IA by 330 degrees.

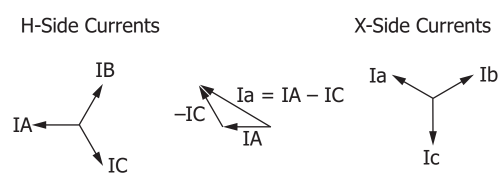

Figure O.21 X- and H-Side Current Phasors for Figure O.20

With the reversed CT polarity on the X-side, the current is leaving Terminal W2 at the polarity mark instead of entering the polarity mark, which makes the current seen by the relay 180 degrees out-of-phase compared to a standard CT connection. In Non-Standard CT Connections: Reversed CT Polarity and Reversed Connections, two methods are proposed to correct the phase shift for reverse polarity CTs. The first method is to rewire the current inputs on the relay so that they match the standard connections. The second method is to use the compensation settings; by adding or subtracting 6 from the setting. This example explores the latter method.

Following the settings guidelines, select the delta side as the reference. The delta side of the transformer is connected to relay Terminal W2, therefore, W2CTC = 0 and is used as the reference. Figure O.22 compares the current phasors if the X-side CT connections use standard connections rather than non-standard connections. On the left side of Figure O.22, standard CT connections and an ABC phase rotation require IAW1 to be rotated by 330 degrees (11 multiples of 30 degrees) counterclockwise in order to be 180 degrees out-of-phase with IAW2. Therefore, if the X-side CTs have standard connections, set W1CTC = 11. The resulting compensation settings with standard CT connections are W2CTC = 0 and W1CTC = 11.

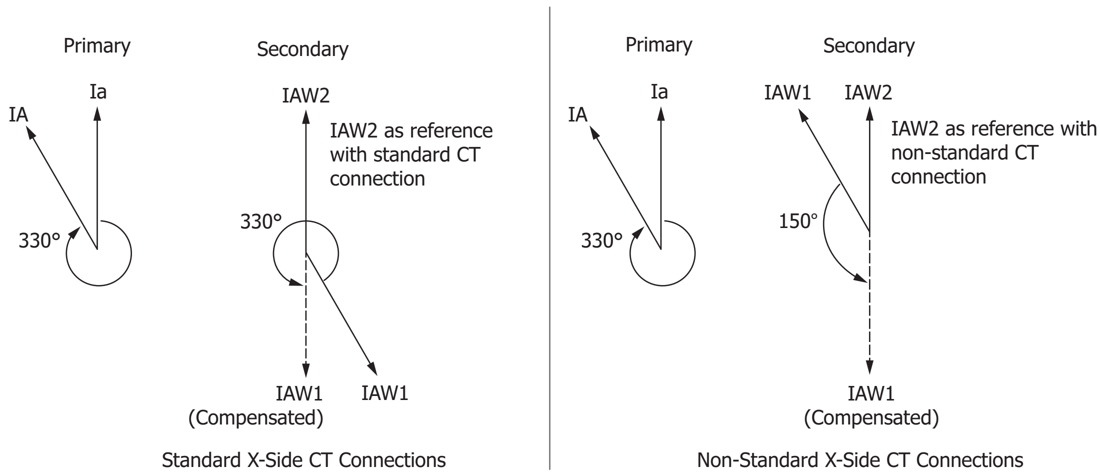

Figure O.22 Comparison of Standard and Non-Standard CT Connections on the X-Side of the Transformer

However, in this example, non-standard CT connections are used on the delta winding, which results in IAW1 leading IAW2 by 30 degrees. IAW1 needs to rotate 150 degrees (5 multiples of 30 degrees) counterclockwise for a system with an ABC phase rotation in order to be 180 degrees out-of-phase with IAW2. Therefore, set W1CTC = 5. The resulting compensation settings with non-standard CT connections on the X-side are W2CTC = 0 and W1CTC = 5.

EXAMPLE O.4 Autotransformer, Standard Phase-to-Bushing Connections, Standard CT Connections, and an ABC System Phase Rotation

Consider the autotransformer shown in Figure O.23. The delta tertiary exists, but is buried and not brought out to the relay. The primary current phase shift for these connections is shown in Figure O.24. The system primary current Ia (X-side) is in phase with the system primary current IA (H-side). The CT connections are standard, which results in IAW2 180 degrees out-of-phase with IAW1.

Per the guidelines, since there is no delta winding connected to the relay, choose any one of the wye windings, say H-side, as the reference winding and choose matrix CTC(11) for the compensation. The H-side currents are connected to Terminal W1 of the SEL-787 Relay. Therefore, set W1CTC = 11. The X-side currents are connected to Terminal W2, so W2CTC must be determined. Figure O.24 shows the phase relationship of both the primary system phase currents and the secondary phase currents as seen by the relay. Since Matrix 11 is applied to Winding 1, this will shift IAW1 11 multiples of 30 degrees in the counterclockwise direction. In order to keep Winding 2 current, IAW2 180 degrees out-of-phase with IAW1, you must also shift IAW2 by 11 multiples of 30 degrees in the counterclockwise direction. The resulting compensation settings are W1CTC = 11 and W2CTC = 11.

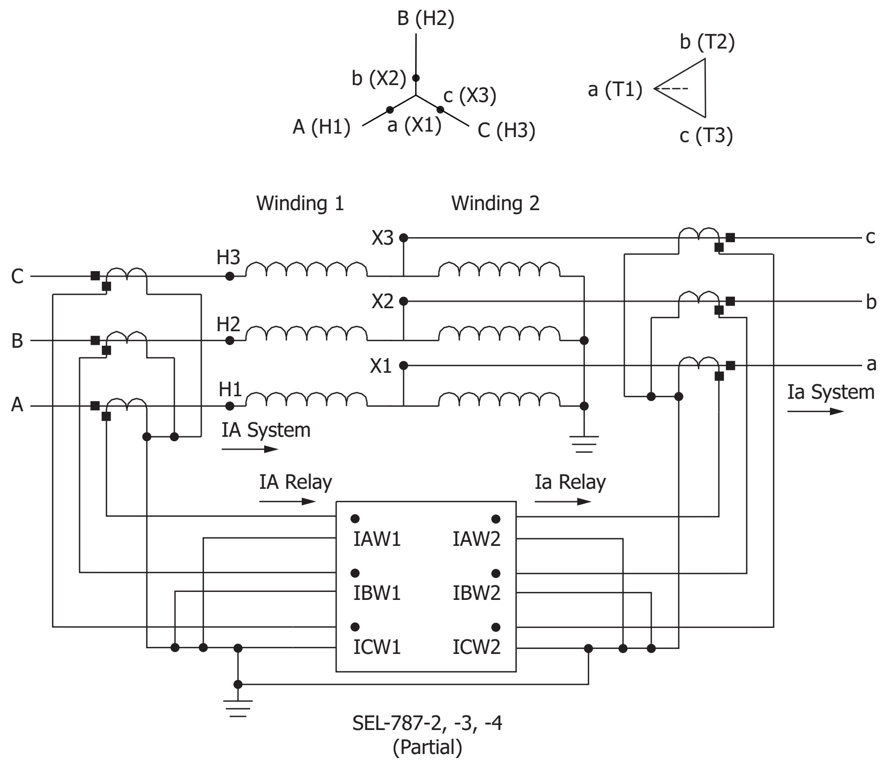

Figure O.23 Autotransformer With Standard Phase-to-Bushing Connections

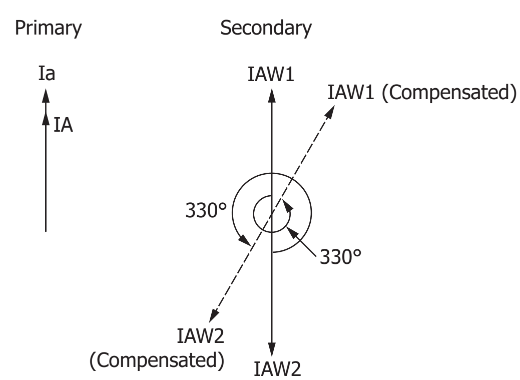

Figure O.24 Primary Currents and Secondary Currents as Measured by the Relay

Special Cases

EXAMPLE O.5 Delta-Wye Transformer With Standard Phase-to-Bushing Connections, Standard CT Connections, and an ACB System Phase Rotation

Consider the application in Figure O.25 with standard phase-to-bushing connections, standard CT connections, and an ACB system phase rotation.

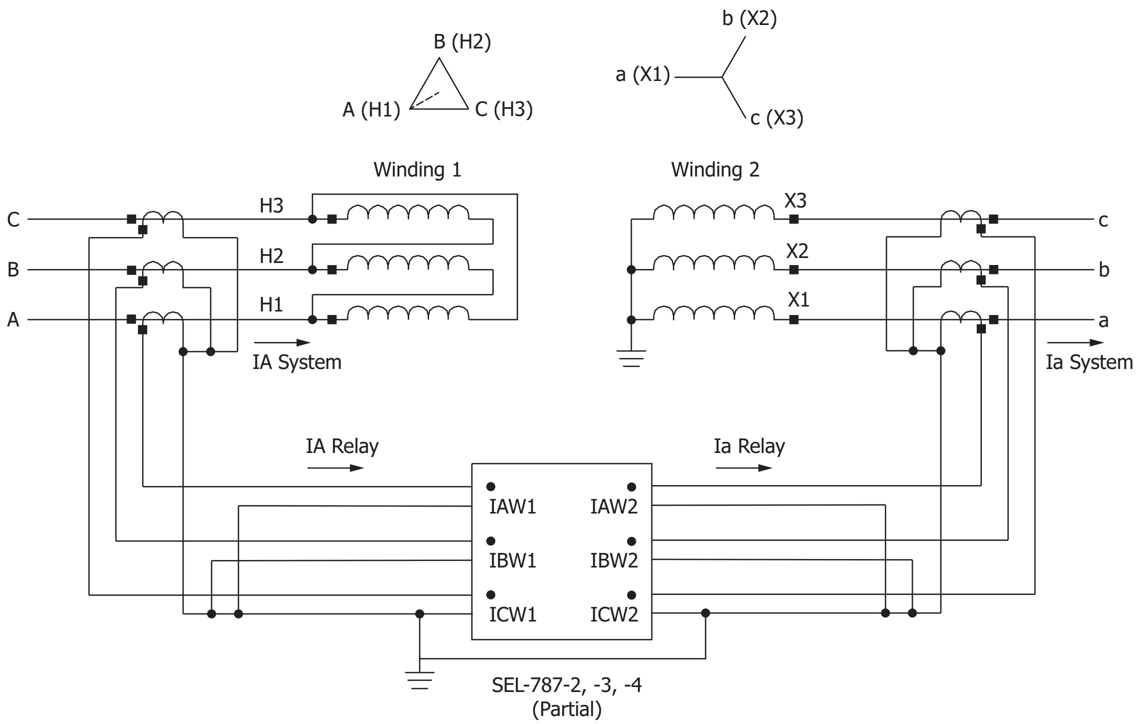

Figure O.25 Delta-Wye Transformer With Standard Phase-to-Bushing Connections With an ACB Phase Rotation

The H-side currents are:

IA = Ia – Ib
IB = Ib – Ic
IC = Ic – Ia

Figure O.26 uses a balanced set of three-phase currents with an ACB phase sequence on the wye winding as a reference to derive the delta winding (H-side) currents. When compared to Example O.1, even with the same transformer and the same connections, Figure O.26 shows that Ia (X-side) now leads IA (H-side) by 30 degrees because of the system phase rotation. Note that in Example O.1, Ia (X-side) lags IA (H-side) by 30 degrees. The CT connections are standard, which results in IAW2 lagging IAW1 by 150 degrees. Figure O.28 shows the phase relationship of both the primary system phase currents and the secondary phase currents as seen by the relay.

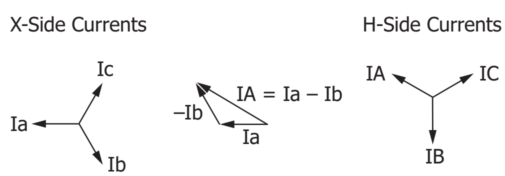

Figure O.26 X- and H-Side Current Phasors for Figure O.25

A common misconception is that a different compensation setting pair is required depending on the system phase rotation. However, closer inspection of the compensation matrices and the direction of correction in Table O.1 (also shown in Figure O.27) indicate that the matrix causes the compensated currents to rotate in the opposite direction depending on the system phase rotation.

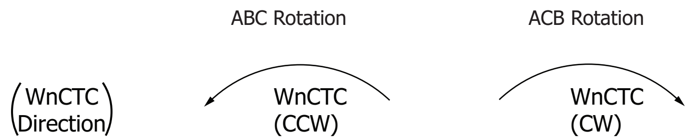

Figure O.27 Direction of Compensation Based on System Phase Rotation

Thus, the compensation settings required for Example O.1 and Example O.5 are the same. Following the settings guideline, the delta side of the transformer is selected as the reference, so W1CTC = 0. Figure O.28 shows IAW2 needs to be rotated 30 degrees (1 multiple of 30 degrees) clockwise for a system with an ACB phase rotation in order to be 180 degrees out-of-phase with IAW1. Therefore, set W2CTC = 1. The resulting compensation settings are W1CTC = 0 and W2CTC = 1.

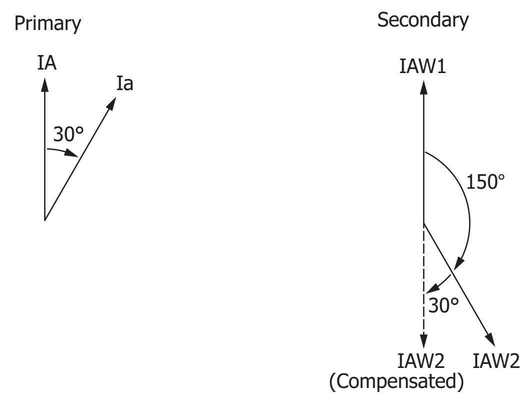

Figure O.28 Primary Currents and Secondary Currents as Measured by the Relay

If the relay is set assuming an ABC phase rotation, but the actual system phase sequence is ACB, the relay compensation settings do not need to be changed. However, the calculated positive- and negative-sequence currents will be incorrect unless the Global setting for phase rotation, PHROT, matches the system phase sequence. PHROT does not affect the compensation settings or the differential protection.

EXAMPLE O.6 Delta-Wye Transformer With Standard Phase-to-Bushing Connections, Standard CT Connections, and an ABC System Phase Rotation With a Zig-Zag Grounding Transformer Within the Differential Zone on the Delta Side

This example uses the same transformer and CT connections as in Example O.1, except that it includes a zig-zag grounding transformer within the differential zone on the delta side of the transformer. Zig-zag transformers are typically used for grounding purposes and act as a source of zero-sequence current. If the zig-zag transformer is located outside of the differential zone on the delta side, it can be ignored, and the compensation settings will remain the same as in Example O.1. The same is true if the zig-zag transformer is present on the wye side, be it inside or outside the differential zone. If the zig-zag grounding transformer is within the differential zone on the delta side, then it has to be accounted for when determining the compensation settings.

The compensation settings in Example O.1 are W1CTC = 0 for the delta winding (reference winding) and W2CTC = 1 for the wye winding. When a ground current source is within the differential zone on the delta side, the recommended compensation setting of W1CTC = 0 cannot be used. The zero-sequence current needs to be filtered to avoid an operation of the differential element for external ground faults. Therefore, set W1CTC = 12. Matrix CTC(12) has no phase shift, but CTC(12) removes zero-sequence current from the differential calculation.

Quick Settings Guide for Standard Connections

Figure O.29 shows examples of common transformer connections. *Table O.4* is a quick reference guide to be used when all standard phase-to-bushing, CT, and relay connections are present. *Table O.4* is applicable to both ABC and ACB system phase rotations.

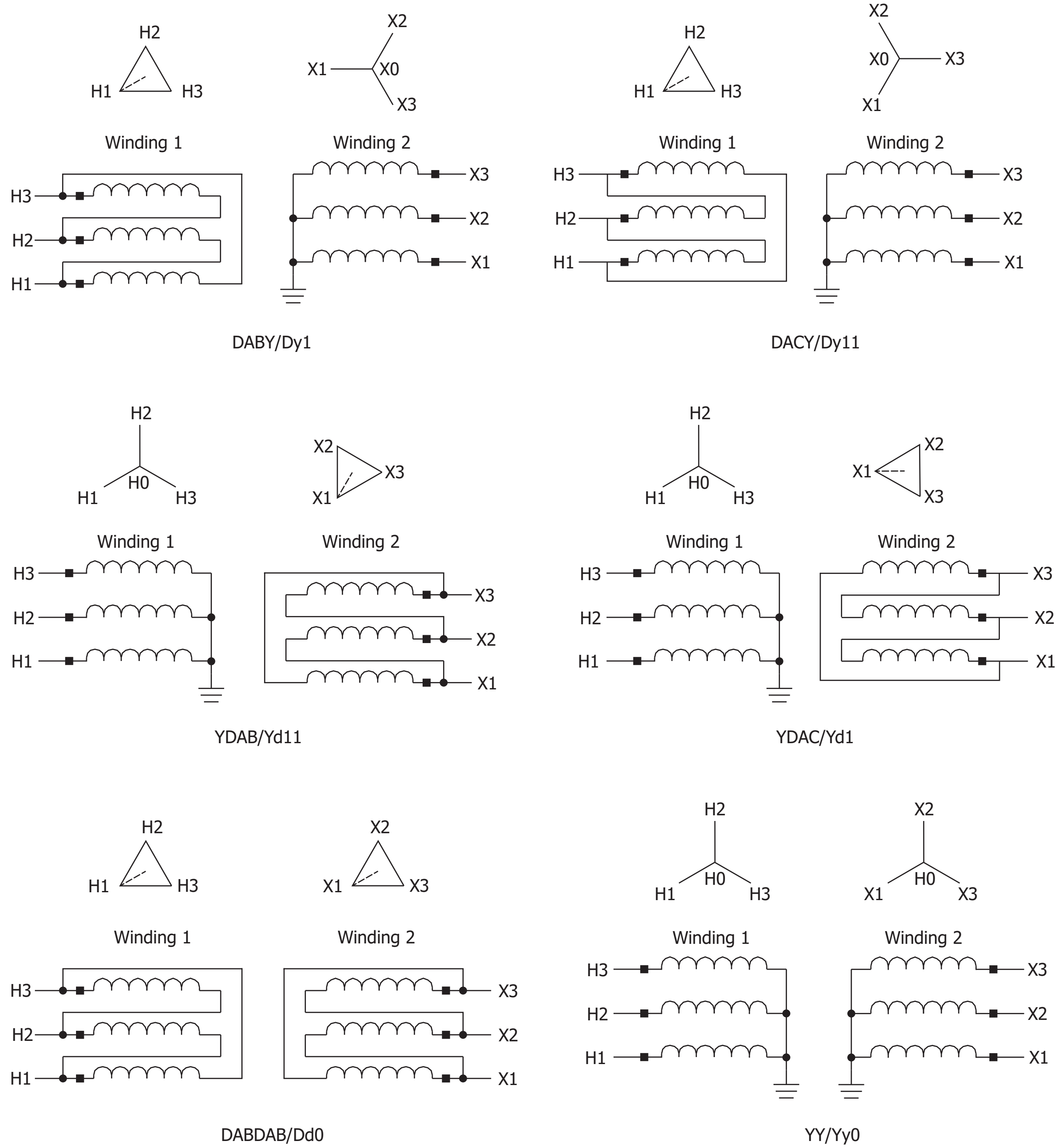

Figure O.29 Common Transformer Connections

Table O.4 Quick Settings Guide for Common Transformer Configurations and Standard Connections

XFMR Connection	W1CTC (Winding 1)	W2CTC (Winding 2)
DABY/Dy1	0	1
DACY/Dy11	0	11
YDAC/Yd1	11	0
YDAB/Yd11	1	0
DABDAB/Dd0 DACDAC/Dd0	0	0
YY/Yy0	11	11

The compensation settings of *Table O.4* assume that the Winding 1 side of the transformer is connected to relay Terminal W1 and the Winding 2 side of the transformer is connected to relay Terminal W2. These settings apply for all standard phase-to-bushing connections shown in *Table O.2*. In each of these phase-to-bushing connections, the order of the phase connections (A, B, C) matches the order of the bushings (H1, H2, H3).

References

Further discussion on selecting transformer compensations settings can be found in the technical paper, *Beyond the Nameplate – Selecting Transformer Compensation Settings for Secure Differential Protection* by Barker Edwards, David G. Williams, Ariana Hargrave, Matthew Watkins, and Vinod K. Yedidi, available at selinc.com.

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Glossary

A — Abbreviation for amps or amperes; units of electrical current magnitude.

acSELerator Architect SEL-5032 Software — Design and commissioning tool for IEC 61850 communications.

acSELerator Bay Screen Builder SEL-5036 Software — An intuitive and powerful interface to design bay screens to meet application needs.

acSELerator QuickSet SEL-5030 Software — A Windows-based program that simplifies settings and provides analysis support.

Ambient Temperature — Temperature of the ambient air adjacent to the transformer. Measured by an RTD whose location setting is AMB.

Analog — In this instruction manual, Analog is synonymous with Transducer.

ANSI Standard Device Numbers — A list of standard numbers used to represent electrical protection and control relays. The standard device numbers used in this instruction manual include:

24	Volts/Hz Element (Overexcitation)
25	Synchronism-Check Element
27	Undervoltage Element
27I	Inverse-Time Undervoltage Element
32	Directional Power Element
50	Instantaneous Overcurrent Element
51	Inverse Time-Overcurrent Element
52	AC Circuit Breaker
55	Power Factor Element
59	Overvoltage Element
59I	Inverse-Time Overvoltage Element
60	Loss-of-Potential Element
81	Frequency Element
87	Differential Element

These numbers are frequently used within a suffix letter to further designate application. The suffix letters used in this instruction manual include:

P	Phase Element
G	Residual/Ground Element
N	Neutral/Ground Element
Q	Negative-Sequence (3I2) Element

Apparent Power, S — Complex power expressed in units of volt-amps (VA), kilovolt-amps (kVA), or megavolt-amps (MVA). Accounts for both real (P) and reactive (Q) power dissipated in a circuit: S = P + jQ.

ASCII Abbreviation for American Standard Code for Information Interchange. Defines a standard way to communicate text characters between two electronic devices. The SEL-787 Transformer Protection Relay uses ASCII text characters to communicate using the relay front- and rear-panel EIA-232 serial ports.

Assert To activate; to fulfill the logic or electrical requirements needed to operate a device. To apply a short-circuit or closed contact to an SEL-787 input. To set a logic condition to the true state (logical 1). To close a normally open output contact. To open a normally closed output contact.

Breaker Auxiliary Contact A spare electrical contact associated with a circuit breaker that opens or closes to indicate the breaker position. A Form A breaker auxiliary contact (ANSI Standard Device Number 52A) closes when the breaker is closed, opens when the breaker is open. A Form B breaker auxiliary contact (ANSI Standard Device Number 52B) opens when the breaker is closed and closes when the breaker is open.

C37.118 IEEE C37.118 Standard for Synchrophasors for Power Systems.

C37.238 IEEE C37.238 Standard Profile for Use of IEEE 1588 Precision Time Protocol in Power System Applications.

Checksum A numeric identifier of the firmware in the relay. Calculated by the result of a mathematic sum of the relay code.

CID Abbreviation for Checksum Identifier. The checksum of the specific firmware installed in the relay.

CID File IEC 61850 Configured IED Description file. XML file that contains the configuration for a specific IED.

COMTRADE Abbreviation for Common Format for Transient Data Exchange. The SEL-787 supports the IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems, IEEE C37.111-1999.

Contiguous Items in sequence; the second immediately following the first.

CR_RAM Abbreviation for Critical RAM. Refers to the area of relay Random Access Memory (RAM) where the relay stores mission-critical data.

CRC-16 Abbreviation for Cyclical Redundancy Check-16. A mathematical algorithm applied to a block of digital information to produce a unique, identifying number. Used to ensure that the information was received without data corruption.

CT Abbreviation for current transformer.

Current Differential Element A protection element that measures the difference current between the two windings to detect internal faults.

Deassert To deactivate; to remove the logic or electrical requirements needed to operate a device. To remove a short-circuit or closed contact from an SEL-787 input. To clear a logic condition to the false state (logical 0). To open a normally open output contact. To close a normally closed output contact.

Delta A phase-to-phase connection of voltage transformers for electrical measuring purposes. Typically, two voltage transformers are used with one primary lead of the first transformer connected to A-phase and the other lead connected to B-phase. The second voltage transformer is connected to measure the voltage from B-phase to C-phase. When two transformers are used, this connection is frequently called “Open-Delta.”

DNP3 (Distributed Network Protocol) Manufacturer-developed, hardware-independent communications protocol.

Dropout Time The time measured from the removal of an input signal until the output signal deasserts. The time can be settable, as in the case of a logic variable timer, or can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element dropout time.

Ethernet A network physical and data link layer defined by IEEE 802.2 and IEEE 802.3.

EtherNet/IP An Ethernet-based protocol that provides ease of integration for industrial automation applications and access to metering data, protection elements, targets, and contact I/O.

Event History A quick look at recent relay activity that includes a standard report header; event number, date, time, and type; maximum fault phase current; and targets.

Event Report A text-based collection of data stored by the relay in response to a triggering condition, such as a fault or command. The data show relay measurements before and after the trigger, in addition to the states of protection elements, relay inputs, and relay outputs each processing interval. After an electrical system fault, use event reports to analyze relay and system performance.

Event Summary A shortened version of stored event reports. An event summary includes items such as event date and time, event type, fault voltages, currents, etc. The relay sends an event report summary (if auto messaging is enabled) to the relay serial port a few seconds after an event.

Fail-Safe Refers to an output contact that is energized during normal relay operation and de-energized when relay power is removed or if the relay fails.

Fast Meter, Fast Operate Binary serial port commands that the relay recognizes at the relay front-and rear-panel EIA-232 serial ports. These commands and the responses from the relay make relay data collection by a communications processor faster and more efficient than transfer of the same data through use of formatted ASCII text commands and responses.

FID Relay firmware identification string. Lists the relay model, firmware version and date code, and other information that uniquely identifies the firmware installed in a particular relay.

Firmware The nonvolatile program stored in the relay that defines relay operation.

Flash A type of nonvolatile relay memory used for storing large blocks of nonvolatile data, such as load profile records.

Fundamental Frequency The component of the measured electrical signal for which frequency is equal to the normal electrical system frequency, usually 50 or 60 Hz. Generally used to differentiate between the normal system frequency and any harmonic frequencies present.

Fundamental Meter Type of meter data presented by the SEL-787 that includes the present values measured at the relay ac inputs. The word “Fundamental” is used to indicate that the values are Fundamental Frequency values and do not include harmonics.

GOOSE IEC 61850 Generic Object Oriented Substation Event. GOOSE objects can quickly and conveniently transfer status, controls, and measured values among peers on an IEC 61850 network.

IA, IB, IC Measured A-, B-, and C-phase currents.

ICD File IEC 61850 IED Capability Description file. An XML file that describes IED capabilities, including information on logical node and GOOSE support.

IEC 60870-5-103 Standard protocol developed by the IEC Technical Committee of teleprotection, telecontrol, and telecommunications for electrical engineering and power system automation. It defines systems used for supervisory control and data acquisition (SCADA), including details related to communications between devices.

IEC 61850 Standard protocol for real-time exchange of data between databases in multi-vendor devices.

IG Residual current, calculated from the sum of the phase currents. In normal, balanced operation, this current is very small or zero. When a ground fault occurs, this current can be large.

IN Neutral current measured by the relay IN input. The IN input is typically connected to the secondary winding of a window-CT for ground fault detection on resistance-grounded systems.

IP Address An identifier for a computer or device on a TCP/IP network. Networks using the TCP/IP protocol route messages based on the IP address of the destination. The format of an IP address is a 32-bit numeric address written as four numbers separated by periods. Each number can be zero to 255. For example, 1.160.10.240 could be an IP address.

IRIG-B A time code input that the relay can use to set the internal relay clock.

LCD Abbreviation for liquid crystal display. Used as the relay front-panel alphanumeric display.

LED Abbreviation for light-emitting diode. Used as indicator lamps on the relay front panel.

Logical Node In IEC 61850, the smallest part of a function that exchanges data. A logical node (LN) is an object defined by its data and methods. Each logical node represents a group of data (status, controls, measurements, etc.) associated with a particular function.

Loss-of-Potential Loss of one or more phase voltage inputs to the relay.

MAC Address The Media Access Control (hardware) address of a device connected to a shared network medium, most often used with Ethernet networks.

MIRRORED BITS Protocol for direct relay-to-relay communications.

MMS Manufacturing Message Specification, a data exchange protocol used by IEC 61850.

NEMA Abbreviation for National Electrical Manufacturers Association.

Neutral Overcurrent Element A protection element that causes the relay to trip when the neutral current magnitude (measured by the IN input) exceeds a user settable value. Used to detect and trip in response to ground faults.

Nominal Frequency Normal electrical system frequency, usually 50 or 60 Hz.

Nonfail-Safe Refers to an output contact that is not energized during normal relay operation. When referred to a trip output contact, the protected equipment remains in operation unprotected when relay power is removed or if the relay fails.

Nonvolatile Memory Relay memory that is able to correctly maintain data it is storing even when the relay is de-energized.

Overfrequency Element A protection element that causes the relay to trip when the measured electrical system frequency exceeds a settable frequency.

Phase Rotation The sequence of voltage or current phasors in a multi-phase electrical system. In an ABC phase rotation system, the B-phase voltage lags the A-phase voltage by 120 degrees, and the C-phase voltage lags B-phase voltage by 120 degrees. In an ACB phase rotation system, the C-phase voltage lags the A-phase voltage by 120°, and the B-phase voltage lags the C-phase voltage by 120 degrees.

Pickup Time The time measured from the application of an input signal until the output signal asserts. The time can be settable, as in the case of a logic variable timer, or can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element pickup time.

Pinout The definition or assignment of each electrical connection at an interface. Typically refers to a cable, connector, or jumper.

Power, P Real part of the complex power (S) expressed in units of watts (W), kilowatts (kW), or megawatts (MW).

Power Factor The cosine of the angle by which phase current lags phase voltage in an ac electrical circuit. Power factor equals 1.0 for power flowing to a resistive load.

Power, Q Reactive part of the complex power (S) expressed in units of Vars (Var), kilovars (kVar), or megavars (MVar).

Protection and Control Processing Processing interval is four times per power system cycle (except for math variables and analog quantities, which are processed every 25 ms).

PT Abbreviation for potential transformer. Also referred to as a voltage transformer or VT.

PRP Parallel Redundancy Protocol provides seamless recovery from any single Ethernet network failure in a dual redundant Ethernet network, in accordance with IEC 62439-3.

PTP Precision Time Protocol, as defined in IEEE 1588 for high-accuracy clock synchronization.

RAM Abbreviation for Random Access Memory. Volatile memory where the relay stores intermediate calculation results, Relay Word bits, and other data that are updated every processing interval.

Relay Word The collection of relay element and logic results. Each element or result is represented by a unique identifier, known as a Relay Word bit.

Relay Word Bit A single relay element or logic result that the relay updates once each processing interval. A Relay Word bit can be equal to either logical 1 or logical 0. Logical 1 represents a true logic condition, picked up element, or asserted contact input or contact output. Logical 0 represents a false logic condition, dropped out element, or deasserted contact input or contact output. You can use Relay Word bits in SELOGIC control equations to control relay tripping, event triggering, and output contacts, as well as other functions.

Remote Bit A Relay Word bit for which state is controlled by serial port commands, including the **CONTROL** command, binary Fast Operate command, or Modbus command.

Residual Current The sum of the measured phase currents. In normal, balanced operation, this current is very small or zero. When a ground fault occurs, this current can be large.

Restricted Earth Fault Element (REF) Provides sensitive protection against ground faults in wye-connected transformer windings. The element is “restricted” to ground faults within a zone defined by neutral and line CT placement.

RMS Abbreviation for Root-Mean-Square. Refers to the effective value of the sinusoidal current and voltage measured by the relay, accounting for the fundamental frequency and higher order harmonics in the signal.

Rogowski Coil An air-core coil around a current-carrying conductor that generates a voltage proportional to the rate of change of current. An integrator is used to derive current from the output of the Rogowski coil.

ROM Abbreviation for Read-Only Memory. Nonvolatile memory where the relay firmware is stored.

RSTP Abbreviation for Rapid Spanning Tree Protocol. RSTP provides improved an improved failover response in response in Ethernet networks in accordance with IEEE 802.1Q-2014.

RTD Abbreviation for Resistance Temperature Detector. An RTD is made of a metal having a precisely known resistance and temperature coefficient of resistance. The SEL-787 (and the SEL-2600 RTD Module RTD modules) can measure the resistance of the RTD, and thus, determine the temperature at the RTD location, typically embedded in the transformer and oil tank.

Self-Test A function that verifies the correct operation of a critical device subsystem and indicates if an out-of-tolerance condition is detected. The SEL-787 is equipped with self-tests that validate the relay power supply, microprocessor, memory, and other critical systems.

SELOGIC Control Equation A relay setting that allows you to control a relay function (such as an output contact) by using a logical combination of relay element outputs and fixed logic outputs. Logical AND, OR, INVERT, rising edge [/], and falling edge [\] operators, plus a single level of parentheses are available to use in each control equation setting.

Sequential Events Recorder
A relay function that stores a record of the date and time of each assertion and deassertion of every Relay Word bit in a settable list. Provides a useful way to determine the order and timing of events following a relay operation.

SER
Abbreviation for Sequential Events Recorder or the relay serial port command to request a report of the latest 1024 sequential events.

Synchrophasors
The word synchrophasor is derived from two words: synchronized phasor. Synchrophasor measurement refers to the concept of providing measurements taken on a synchronized schedule in multiple locations. A high-accuracy clock, commonly a Global Positioning System (GPS) receiver such as the SEL-2407 Satellite-Synchronized Clock, makes synchrophasor measurement possible.

Terminal Emulation Software
Personal computer (PC) software that can be used to send and receive ASCII text messages via the PC serial port.

TFE
A through-fault event (TFE) monitor is designed to capture cumulative mechanical stresses caused by faults that occur outside the transformer unit protection zone.

Transducer
Device that converts the input to the device to an analog output quantity of either current (±1, 2.5, 5, 10 and 20 mA, or 4–20 mA), or voltage (±1, 2.5, 5, or 10 V).

Underfrequency Element
A protection element that causes the relay to trip when the measured electrical system frequency is less than a settable frequency.

VA, VB, VC
Measured A-, B-, and C-phase-to-neutral voltages.

VAB, VBC, VCA
Measured or calculated phase-to-phase voltages.

VBAT
Measured station DC battery voltage.

VG
Residual voltage calculated from the sum of the three phase-to-neutral voltages, if connected.

VS
Measured phase-to-neutral or phase-to-phase synchronism-check voltage.

VT
Abbreviation for voltage transformer. Also referred to as a potential transformer or PT.

Volts/Hz
The ratio of voltage to frequency is a measure of transformer excitation and the Volts/Hz element protects against overexcitation.

Wye
As used in this instruction manual, a phase-to-neutral connection of voltage transformers for electrical measuring purposes. Three voltage transformers are used with one primary lead of the first transformer connected to A-phase and the other lead connected to ground. The second and third voltage transformers are connected to measure the voltage from B-phase and C-phase-to-ground, respectively. This connection is frequently called “four-wire wye,” alluding to the three phase leads plus the neutral lead.

Z-Number
That portion of the relay RID string that identifies the proper QuickSet relay driver version when creating or editing relay settings files.

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>, Trigger Row 10.11

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SEL-787-2, -3, -4 Relay Command Summary

The following table lists the front serial port ASCII commands associated with particular activities. The commands are shown in uppercase letters, but you can also enter these with lowercase letters. Commands can be initiated with the three initial letters of the command. Refer to *SEL ASCII Protocol and Commands* for additional details and capabilities of each command.

La siguiente tabla muestra los comandos ASCII del puerto serie frontal asociados con diferentes actividades. Los comandos se pueden usar en mayúsculas o minúsculas. Los comandos se pueden ejecutar usando las primeras tres letras del nombre. Por más detalles consulte la guía *SEL ASCII Protocol and Commands*.

Serial Port Command	Command Description
Access Level 0 Commands	
ACC	Go to 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.
ID	Relay identification code.
QUI	Go to Access Level 0.
Access Level 1 Commands	
2AC	Go to 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.
BRE *n*	Display breaker *n* monitor data (trips, interrupted current, wear) where *n* = 1, 2, 3, or 4 for the SEL-787-4X model. For the SEL-787-3E/3S, *n* = 1, 2, or 3. For SEL-787-2X/2E/21, *n* = 1 or 2.
CEV *n*	Shows compressed event report number *n*, at 1/4-cycle resolution. If *n* is omitted, the most recent compressed event report is displayed.
CEV *n* R	Shows compressed raw event report number *n*, at 1/32-cycle resolution. If *n* is omitted, the most recent compressed event report is displayed.
CEV *n* DIFF	Shows compressed differential element report *n*, at 1/4-cycle resolution. If *n* is omitted, the most recent compressed differential element report is displayed.
COM A	Returns a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.
COM B	Returns a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel B.

Comando del Puerto Serial	Descripción del Comando
Comandos del Nivel de Acceso 0	
ACC	Ir a Nivel de Acceso 1. Si el jumper de acceso en la tarjeta principal no está en su lugar, el relé pedirá la contraseña de Acceso del Nivel 1.
ID	Código de identificación del relé.
SAL	Ir al Nivel de Acceso 0.
Comandos del Nivel de Acceso 1	
2AC	Ir a Nivel de Acceso 2. Si el jumper de acceso en la tarjeta principal no está en su lugar, el relé pedirá la contraseña de Acceso del Nivel 2.
INT *n*	Mostrar información sobre el interruptor *n* (disparos, corriente interrumpida, desgaste). Para relés SEL-787-4X *n* = 1, 2, 3 o 4. Para relés SEL-787-3E/3S *n* = 1, 2 o 3. Para relés SEL-787-2X/2E/21 *n* = 1 o 2.
CEV *n*	Mostrar el reporte comprimido de evento número *n*, resolución de 1/4 de ciclo.
CEV *n* R	Agregue R para mostrar el reporte de evento comprimido sin filtro, resolución 1/32 de ciclo. Si no se especifica n se muestra el evento comprimido mas reciente.
CEV *n* DIFF	Mostrar el reporte diferencial de evento *n*, (4 muestras por ciclo). Si se omite *n* se muestra el reporte más reciente.
COM A	Presentar un informe de síntesis de los últimos 255 registros en el buffer de comunicaciones MIRRORED BITS Canal A.
COM B	Presentar un informe de síntesis de los últimos 255 registros en el buffer de comunicaciones MIRRORED BITS Canal B.

Serial Port Command	Command Description
COM C	Clears all of the communications records. If both MIRRORED BITS channels are enabled, omitting the channel specifier (A or B) clears both channels.
COM C A	Clears all communications records for Channel A.
COM C B	Clears all communications records for Channel B.
COM L	Appends a long report to the summary report of the last 255 records in the MIRRORED BITS communications buffer.
COM L A	Appends a long report to the summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.
COM L B	Appends a long report to the summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel B.
COM S	Returns a summary report of the last 255 records in the MIRRORED BITS communications buffer.
COU *n*	Shows current state of device counters. *n* = repeat the report *n* times, with a 1/2 second delay between each report.
DATE	Shows the date.
DATE *dd/mm/yyyy*	Sets the date in DMY format if DATE_F setting is DMY.
DATE *mm/dd/yyyy*	Sets the date in MDY format if DATE_F setting is MDY.
DATE *yyyy/mm/dd*	Sets the date in YMD format if DATE_F setting is YMD.
ETH	Shows the Ethernet port status.
EVE *n*	Shows standard analog event report *n* for Slot Z with 4 samples per cycle. If *n* is omitted, the most recent report is displayed.
EVE E *n*	Shows standard analog event report *n* for Slot E with 4 samples per cycle. If *n* is omitted, the most recent report is delayed.
EVE *n* R	Shows standard analog event report *n* for Slot Z with raw (unfiltered) 32 samples per cycle data.
EVE E *n* R	Shows standard analog event report *n* for Slot E with raw (unfiltered) 32 samples per cycle data.
EVE D *n*	Shows digital data event report number *n* for Slot Z, with 1/4-cycle resolution.

Comando del Puerto Serial	Descripción del Comando
COM C	Borra todos los registros de comunicaciones. Si los dos canales MIRRORED BITS están habilitados, suprimiendo el especificador de canales (A o B) se borran los dos canales.
COM C A	Borra todos los registros de comunicaciones del Canal A.
COM C B	Borra todos los registros de comunicaciones del Canal B.
COM L	Anexa un informe detallado al informe de síntesis de los últimos 255 registros en el buffer de comunicaciones MIRRORED BITS.
COM L A	Anexa un informe detallado al informe de síntesis de los últimos 255 registros en el buffer de comunicaciones MIRRORED BITS del Canal A.
COM L B	Anexa un informe detallado al informe de síntesis de los últimos 255 registros en el buffer de comunicaciones MIRRORED BITS del Canal B.
COM S	Muestra un resumen de los últimos 255 registros en el buffer de comunicaciones MIRRORED BITS.
COU *n*	Muestra el estado actualizado de los contadores del dispositivo. *n* = repite el informe *n* veces, con 1/2 segundos entre cada informe.
FECHA	Ver fecha.
FECHA *dd/mm/yyyy*	Si DATE_F es igual a DMA, ingrese fecha en formato Día Mes Año
FECHA *mm/dd/yyyy*	Si DATE_F es MDA, ingrese fecha en formato Mes Día Año.
FECHA *yyyy/mm/dd*	Si DATE_F es AMD, ingrese fecha en formato Año Mes Día.
ETH	Mostrar el estado del puerto de Ethernet.
EVE *n*	Mostrar el reporte de evento estándar número *n* con mediciones en el Slot Z, con 4 muestras por ciclo. Omitiendo *n*, se muestra el informe más reciente.
EVE E *n*	Mostrar el reporte de evento estándar numero *n* con mediciones en el Slot E, con 4 muestras por ciclo. Omitiendo *n*, se muestra el informe más reciente.
EVE *n* R	Mostrar el reporte de evento *n* sin filtrar con 32 muestras por ciclo con mediciones en el Slot Z.
EVE E *n* R	Mostrar el reporte de evento *n* sin filtrar con 32 muestras por ciclo con mediciones en el Slot E.
EVE D *n*	Mostrar el reporte digital de eventos *n*, con 4 muestras por ciclo con mediciones en el Slot Z.

Serial Port Command	Command Description
EVE D E *n*	Shows digital event report number *n* for Slot E, with 1/4-cycle resolution.
EVE D *n* R	Shows digital data event report number *n* for Slot Z, with 1/32-cycle resolution.
EVE D E *n* R	Shows digital data event report number *n* for Slot E, with 1/32-cycle resolution.
EVE DIF1 *n*	Shows Differential Element 1 event report number *n*, with 1/4-cycle resolution.
EVE DIF2 *n*	Shows Differential Element 2 event report number *n*, with 1/4-cycle resolution.
EVE DIF3 *n*	Shows Differential Element 3 event report number *n*, with 1/4-cycle resolution.
EVE R *n*	Shows raw analog data event report number *n* for Slot Z, with 1/32-cycle resolution, same as **EVE *n* R**.
EVE E R *n*	Shows raw analog data event report number *n* for Slot E, with 1/32-cycle resolution, same as **EVE E *n* R**.
FIL DIR	Returns a list of files.
FIL READ *filename*	Transfers settings file *filename* from the relay to the PC.
FIL SHOW *filename*	*Filename* displays the contents of the corresponding file.
GOOSE *k*	Displays transmit and receive GOOSE messaging information. Enter number *k* to scroll the GOOSE data *k* times on the screen.
GROUP	Displays active group setting.
HELP	Displays a short description of selected commands.
HIS *n*	Shows summary of *n* latest event reports, where *n* = 1 is the most recent entry. If *n* is omitted, all of the event report summaries are displayed.
HIS C or **R**	Clears or resets the history buffer.
IRIG	Forces synchronization of internal control clock to IRIG-B time-code input.
LDP	Displays signal profile data.
LDP *row1 row2*	Displays load profile report rows from *row1* to *row2*, starting with *row1*. If *row2* is omitted, displays the first *row1* rows.
LDP *date1 date2*	Displays load profile report rows from *date1* to *date2*, starting with *date1*.
LDP C	Clears load profile data.
MAC	Displays the MAC address of the Ethernet port (PORT 1).

Comando del Puerto Serial	Descripción del Comando
EVE D E *n*	Mostrar el reporte digital de eventos *n*, con 4 muestras por ciclo con mediciones en el Slot E.
EVE D *n* R	Mostrar el reporte digital de eventos *n*, con 32 muestras por ciclo con mediciones en el Slot Z.
EVE D E *n* R	Mostrar el reporte digital de eventos *n*, con 32 muestras por ciclo con mediciones en el Slot E.
EVE DIF1 *n*	Mostrar el reporte de evento *n* del elemento diferencial 1, con 4 muestras por ciclo.
EVE DIF2 *n*	Mostrar el reporte de evento *n* del elemento diferencial 2, con 4 muestras por ciclo.
EVE DIF3 *n*	Mostrar el reporte de evento *n* del elemento diferencial 3, con 4 muestras por ciclo.
EVE R *n*	Mostrar el reporte de evento *n* sin filtrar con 32 muestras por ciclo con mediciones en el Slot Z, igual que **EVE *n* R**.
EVE E R *n*	Mostrar el reporte de evento *n* sin filtrar con 32 muestras por ciclo con mediciones en el Slot E, igual que **EVE *n* R**.
FIL DIR	Mostrar lista de archivos.
FIL READ *filename*	Transferir el archivo de configuración *filename* del relé a la computadora.
FIL SHOW *filename*	Muestra el contenido del archivo *filename*.
GOOSE *k*	Mostrar información de transmisión y recepción de mensajes GOOSE. Ingresar el numero *k* para mostrar los datos GOOSE *k* veces en la pantalla.
GRUPO	Mostrar el grupo de ajustes activo.
AYUDA	Mostrar una descripción corta de los comandos elegidos.
HIS *n*	Mostrar el resumen de los últimos *n* informes de eventos, donde *n* = 1 es la entrada más reciente. Si *n* es no está especificado, muestra todos los resúmenes de reportes de eventos.
HIS D o **R**	Borrar la historia de eventos.
IRIG	Forzar la sincronización del reloj interno a IRIG-B.
LDP	Mostrar los datos de perfil carga.
LDP *row1 row2*	Mostrar los datos de perfil carga entra las filas *row1* y *row2*. Si se omite *row2*, muestra las primeras *row1* columnas.
LDP *date1 date2*	Mostrar los datos de perfil carga entra las filas *date1* y *date2*.
LDP D	Borra datos de perfil de carga.
MAC	Mostrar la dirección MAC del puerto de Ethernet (PUERTO 1).

Serial Port Command	Command Description
MET or **MET F**	Displays fundamental metering data.
MET *k*	Displays fundamental metering data *k* times, where *k* is between 1 and 32767.
MET AI	Displays analog input (transducer) data.
MET DE	Displays demand metering data in primary amperes.
MET DIF	Displays differential metering data.
MET E	Displays energy metering data.
MET H	Generates harmonic report for all input currents and voltages, showing first- to fifth-harmonic levels and %THD (total harmonic distortion).
MET M	Displays minimum and maximum metering data.
MET MV	Displays SELOGIC math variable data.
MET PE	Displays peak demand metering data in primary amperes.
MET PM	Displays synchrophasor metering data.
MET RA	Displays remote analog metering data.
MET RD	Resets demand metering values.
MET RE	Resets energy metering data.
MET RM	Resets minimum and maximum metering data.
MET RMS	Displays rms metering data.
MET RP	Resets demand and peak demand metering values.
MET T	Displays RTD metering data.
PING *x.x.x.x t*	Determines if Ethernet port is functioning and configured properly. *x.x.x.x* is the IP address and *t* is the PING interval settable from 2 to 255 seconds. Default *t* is 1 second. Press Q to stop.
RSTP	Displays the RSTP statistics and the current RSTP configuration of Port 1.
SER	Displays the entire Sequential Events Recorder (SER) report.
SER *date1*	Displays all the rows in the SER report recorded on the specified date (see **DATE** command for date format).
SER *date1 date2*	Displays all the rows in the SER report recorded between dates *date1* and *date2*, inclusive.

Comando del Puerto Serial	Descripción del Comando
MED or **MED F**	Mostrar los datos de medición fundamentales.
MED *k*	Mostrar los datos de medición fundamentales *k* veces, donde *k* entre 1 y 32767.
MED EA	Mostrar los datos de entrada analógica.
MED DE	Mostrar los datos de demanda de medición en amperes primarios.
MED DIF	Mostrar los datos de medición diferencial.
MED E	Mostrar los datos de medición de energía.
MED A	Generar un informe de armónicos para todas las entradas de corriente y voltaje, mostrando del primero al quinto armónico y el porcentaje de distorión armónica total (THD).
MED M	Mostrar datos de medición mínimos y máximos.
MED V	Mostrar datos de variables matemáticas SELOGIC.
MED PIC	Mostrar los datos de demanda de medicion pico en amperes primarios.
MED PM	Mostrar fasores sincronizados.
MED RA	Mostrar datos analogicos de medición remota.
MED RD	Reiniciar mediciones de demanda.
MED RE	Reiniciar los datos de medición de energía.
MED RM	Reiniciar los datos de medición mínima y máxima.
MED RMS	Mostrar los datos de medición rms.
MED RP	Reiniciar los valores de medición de demanda pico.
MED T	Mostrar los datos de medición RTD.
PING *x.x.x.x t*	Determinar si el puerto Ethernet esta funcionando y configurado adecuadamente. *x.x.x.x* es la dirección IP. *t* es el intervalo entre PINGs, *t* es ajustable entre 2 y 255 segundos. Por omisión, *t* = 1 segundo. Oprima Q para detener.
RSTP	Muestra estadisticas y configuracion RSTP actual.
SER	Mostrar el reporte completo del Registrador de Eventos Secuenciales (SER).
SER *date1*	Mostrar todas las filas en el reporte SER del día *date1* (vea el comando **FECHA** por el formato de fecha).
SER *date1 date2*	Mostrar todas las filas en el reporte SER entre el día *date1* y el día *date2* (vea el comando **FECHA** por el formato de fecha).

Serial Port Command	Command Description
SER ***row1***	Displays the latest *row1* rows in the SER report (*row1* = 1024, where 1 is the most recent entry).
SER ***row1 row2***	Displays rows *row1–row2* in the SER report.
SER C or **R**	Clears SER data.
SER D	Displays SER delete report, which shows deleted items (use when SER Auto Deletion is selected to remove chatter).
SHO ***n***	Displays the relay settings for Group *n*, where *n* = 1, 2, 3, or 4. If *n* is not specified, the default is the active settings group.
SHO DNP ***m***	Displays the DNP data map settings for Map *m* (*m* = 1, 2, or 3).
SHO E ***m***	Displays EtherNet/IP assembly map settings for Map *m* (*m* = 1, 2, or 3).
SHO F	Displays the front-panel settings.
SHO G	Displays the global settings.
SHO I	Displays the IEC 60870-5-103 map settings.
SHO L ***n***	Displays the general logic settings for Group n, where *n* = 1, 2, 3, or 4. If *n* is not specified, default is the active settings group.
SHO M	Displays the Modbus user map settings.
SHO P ***n***	Displays the port settings, where *n* specifies Port 1, 2, 3, 4, or F; *n* defaults to the active port if not listed.
SHO R	Displays the report settings.
STA	Displays the relay self-test status.
STA S	Displays the SELOGIC usage status report.
SUM ***n***	Displays Event Summary *n*. If *n* is omitted, displays the most recent event summary.
SUM R or **C**	Resets the event summary buffer.
TAR	Displays the default target row or the most recently viewed target row.
TAR ***n***	Displays Target Row *n*.
TAR ***n k***	Displays Target Row *n*. Repeats display of Target Row *n* for repeat count *k*.
TAR ***name***	Displays the target row with target *name* in the row.
TAR ***name k***	Displays the target row with target *name* in the row. Repeat display of this row for repeat count *k*.
TAR R	Resets any latched targets and the most recently viewed target row.

Comando del Puerto Serial	Descripción del Comando
SER ***row1***	Mostrar las ultimas *row1* filas en el reporte SER (*row1* = 1–1024, 1 es la fila más reciente).
SER ***row1 row2***	Mostrar las filas entre *row1–row2*.
SER D o **R**	Borrar los datos SER.
SER B	Muestra ítems removidos del SER. Útil cuando la supresión automática de SER esta activada.
MOS ***n***	Mostrar configuraciones de puerto, donde *n* especifica el puerto (1, 2, 3, 4 o F); por defecto muestra ajustes del puerto activo.
MOS DNP ***m***	Mostrar ajustes de mapa de datos DNP para el Mapa *m* (*m* = 1, 2 o 3).
MOS E ***m***	Mostrar ajustes EtherNet/IP del mapa número *m* (*m* = 1, 2, 3).
MOS F	Mostrar ajustes del panel frontal.
MOS G	Mostrar ajustes globales.
MOS I	Mostrar mapa de ajustes IEC 60870-5-103.
MOS L ***n***	Mostrar la lógica de configuración general del Grupo *n* del relé (*n* = 1, 2, 3 o 4). Por omisión, muestra grupo de ajustes 1.
MOS M	Mostrar ajustes del mapa del usuario Modbus.
MOS P ***n***	Mostrar configuraciones de puerto, donde *n* especifica el puerto (1, 2, 3, 4 o F); por defecto muestra ajustes del puerto activo.
MOS R	Mostrar configuración de reportes.
EST	Muestra estado de diagnostico automático del relé.
EST S	Mostrar reporte de utilización SELOGIC.
SUM ***n***	Muestra un resumen del evento *n*.
SUM C o **R**	Borrar el buffer de resúmenes de evento.
BAN	Mostrar la fila de banderas por defecto o la última fila de banderas mostrada.
BAN ***n***	Mostrar la fila de banderas *n*.
BAN ***n k***	Mostrar la fila de banderas *n k* veces.
BAN ***name***	Mostrar la fila de banderas que contiene la bandera *name*.
BAN ***name k***	Mostrar la fila de banderas que contiene la bandera *name k* veces.
BAN R	Resetea o reinicia todas las banderas y la fila de banderas más reciente.

Serial Port Command	Command Description
TFE	Displays the cumulative and individual through-fault event data. The twenty (20) most recent individual events are displayed.
TFE *n*	Displays the cumulative and individual through-fault event data. The *n* most recent individual events are displayed, where *n* = 1 to 500.
TFE A	Displays the cumulative and individual through-fault event data. The most recent individual events are displayed, to as many as 500.
TIME	Displays the time.
TIME *hh*	Sets the time by entering **TIME** followed by hours, as shown (24-hour clock).
TIME *hh:mm*	Sets the time by entering **TIME** followed by hours and minutes, as shown (24-hour clock).
TIME *hh:mm:ss*	Sets the time by entering **TIME** followed by hours, minutes, and seconds, as shown (24-hour clock).
TRI	Triggers an event report data capture.
Access Level 2 Commands	
89C *m*	Closes Two-Position Disconnect *m*, where *m* = 1–16.
89O *m*	Opens Two-Position Disconnect *m*, where *m* = 1–16.
89C *n m*	Closes Three-Position Disconnect *m*, where *m* = 1 or 2 and *n* = L or E (in-line or earthing disconnect).
89O *n m*	Opens Three-Position Disconnect *m*, where *m* = 1 or 2 and *n* = L or E (in-line or earthing disconnect).
ANA *c p t*	Tests analog output channel where *c* is the channel name or number, *p* is a percentage of full scale or either letter “R” or “r” indicates ramp mode, and *t* is the duration of the test in decimal minutes.
BRE *n* R	Resets breaker data for Breaker *n*, where *n* = 1, 2, 3, or 4 for the SEL-787-4X model, *n* = 1, 2, or 3 for the SEL-787-3E/3S models, and *n* = 1 or 2 for the SEL-787-2X/2E/21 models.
BRE *n* W	Preloads breaker data for Breaker *n*, where *n* = 1, 2, 3, or 4 for the SEL-787-4X model, *n* = 1, 2, or 3 for the SEL-787-3E/3S models, and *n* = 1 or 2 for the SEL-787-2X/2E/21 models.

Comando del Puerto Serial	Descripción del Comando
TFE	Muestra datos individuales y acumulados de fallas externas. Se muestran los últimos 20 eventos individuales.
TFE *n*	Muestra datos individuales y acumulados de fallas externas. Se muestran los *n* eventos individuales más recientes donde *n* = 1 a 500.
TFE A	Muestra datos individuales y acumulados de fallas externas. Se muestran los más eventos recientes (hasta 500 eventos).
HORA	Ver hora.
HORA *hh*	Configurar la hora ingresando **HORA** seguido por horas como se muestra (relog 24 horas).
HORA *hh:mm*	Configurar la hora ingresando **HORA** seguido por horas y minutos como se muestra (relog 24 horas).
HORA *hh:mm:ss*	Configurar la hora ingresando **HORA** seguido por horas, minutos y segundos como se muestra (relog 24 horas).
TRI	Disparar la captura de un reporte de evento.
Comandos del Nivel de Acceso 2	
89C *m*	Cierra el seccionador de 2-posiciones *m*, donde *m* = 1–16.
89A *m*	Abre el seccionador de 2-posiciones *m*, donde *m* = 1–16.
89C *n m*	Cierra el seccionador de 3-posiciones *m*, donde *m* = 1 o 2 y n = L o E (línea o tierra).
89A *n m*	Abre el seccionador de 3-posiciones *m*, donde *m* = 1 o 2 y n = L o E (línea o tierra).
ANA *c p t*	Probar el canal de salida analógica donde *c* es el nombre o el número del canal, *p* es el porcentaje de escala completa, o las letras “R” o “r” para indicar el modo de rampa y *t* para indicar la duración de la prueba en minutos decimales.
INT *n* R	Borrar datos del interruptor *n.* Para reles SEL-787-4X *n* = 1, 2, 3 o 4. Para reles SEL-787-3E/3S *n* = 1, 2, o 3. Para reles SEL-787-2X/2E/21 *n* = 1 o 2.
INT *n* W	Cargar datos del interruptor para el interruptor *n.* Para reles SEL-787-4X *n* = 1, 2, 3 o 4. Para reles SEL-787-3E/3S *n* = 1, 2, o 3. Para reles SEL-787-2X/2E/21 *n* = 1 o 2.

Serial Port Command	Command Description
CAL	Enters 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.
CLO *n*	Closes Circuit Breaker *n*, where *n* = 1, 2, 3, or 4 for the SEL-787-4X model, *n* = 1, 2, or 3 for the SEL-787-3E/3S models, and *n* = 1 or 2 for the SEL-787-2X/2E/21 models.
CON RB*nn k*	Selects a remote bit to set, clear, or pulse where *nn* is a number from 01 to 32, representing RB01 through RB32. *k* is S, C, or P for Set, Clear, or Pulse.
COPY *m n*	Copies relay and logic settings from Group *m* to Group *n*.
DTO	Downloads volts/Hz user curve from the SEL-5806 Curve Designer Software.
FIL WRITE *filename*	Transfers settings file *filename* from the PC to the relay.
GROUP *n*	Changes the active group to Group *n*, where *n* = 1, 2, 3, or 4.
L_D	Loads new firmware.
LOO	Enables loopback testing of MIRRORED BITS channels.
LOO A	Enables loopback on MIRRORED BITS Channel A for the next 5 minutes.
LOO B	Enables loopback on MIRRORED BITS Channel B for the next 5 minutes.
LOO R	Disables the loopback on both channels and returns the device to normal operation.
LOO *xx* DATA	Enables loopback mode for *xx* minutes and allows the loopback data to modify the RMB values.
OPE *n*	Opens Circuit Breaker *n*, where *n* = 1, 2, 3, or 4 for the SEL-787-4X model, *n* = 1, 2, or 3 for the SEL-787-3E/3S models, and *n* = 1 or 2 for the SEL-787-2X/2E/21 models.
PARTNO	Allows for updates to the part number after the relay hardware configuration has been changed.
PAS 1	Changes the Access Level 1 password.
PAS 2	Changes the Access Level 2 password.
PUL OUT*nnn*	Pulse Output Contact *nnn*.
PUL OUT*nnn s*	Pulses Output Contact *nnn,* where *nnn* = OUT101…, for *s* (1 to 30, default is 1) seconds.

Comando del Puerto Serial	Descripción del Comando
CAL	Ingresar al Nivel de Acceso C. Si el jumper de acceso en la tarjeta principal no está en su lugar, el relé pedirá la contraseña de Acceso del Nivel C. El Nivel de Acceso C está reservado para uso exclusivo de SEL.
CER *n*	Cerrar el interruptor *n.* Para reles SEL-787-4X *n* = 1, 2, 3 o 4. Para reles SEL-787-3E/3S *n* = 1, 2, o 3. Para reles SEL-787-2X/2E/21 *n* = 1 o 2.
CON RB*nn k*	Seleccionar un bit remoto para activar, desactivar o pulsar donde *nn* es un número del 01 al 32, representando desde RB01 hasta RB32. *k* es A, D o P para Activar, Deactivar o Pulsar.
COPY *m n*	Copiar configuración de relé y la configuración lógica del Grupo *m* al Grupo *n*.
DTO	Descargar curva volts/Hz del SEL-5806 Curve Designer Software.
FIL WRITE *filename*	Transferir el archivo de configuración *filename* de la computadora al relé.
GRUPO *n*	Usar Grupo de configuraciones *n*, donde *n* = 1, 2, 3 o 4.
L_D	Cargar un firmware nuevo.
LOO	Habilitar loopback de los canales MIRRORED BITS.
LOO A	Habilitar loopback en Canal MIRRORED BITS A por los siguientes 5 minutos.
LOO B	Habilitar loopback en Canal MIRRORED BITS B por los siguientes 5 minutos.
LOO R	Deshabilita loopback en canales MB A y B.
LOO *xx* DATA	Habilita loopback for *xx* minutos y permite modificar valores RMB.
ABR *n*	Abrir el interruptor *n.* Para reles SEL-787-4X *n* = 1, 2, 3 o 4. Para reles SEL-787-3E/3S *n* = 1, 2 o 3. Para reles SEL-787-2X/2E/21 *n* = 1 o 2.
PARTNO	Cambia el número de parte del relé use despues de cambiar una tarjeta del relé.
PAS 1	Cambiar la contraseña del Nivel de Acceso 1.
PAS 2	Cambiar la contraseña del Nivel de Acceso 2.
PUL OUT*nnn*	Pulsar el contacto de salida *nnn*.
PUL OUT*nnn s*	Pulsar el contacto de salida *nnn* (*nnn* = OUT101…) por *s* (de 1 a 30, el numero predeterminado es 1) segundos.

Serial Port Command	Command Description
R_S	Restores the factory-default settings and passwords and reboots the relay; available only after a firmware upgrade.
SET *n*	Modifies the relay settings for Group *n*, where *n* = 1, 2, 3, or 4. If *n* is not specified, default is the active settings group.
SET *name*	For all **SET** commands, jump ahead to a specific setting by entering the setting name, e.g., 50P11P.
SET DNP *n*	Modifies DNP data map settings for Map *n*, where *n* = 1, 2, or 3.
SET E *m*	Modifies EtherNet/IP assembly map settings for Map *m* (*m* = 1, 2, or 3).
SET F	Modifies front-panel settings.
SET G	Modifies global settings.
SET I	Modifies IEC 60870-5-103 settings.
SET L *n*	Modifies the SELOGIC variable and timer settings for Group *n*, where *n* = 1, 2, 3, or 4. If *n* is not specified, the default is the active settings group.
SET M	Modifies Modbus user map settings.
SET P *n*	Modifies Port *n* settings, where *n* = 1, 2, 3, 4, or F. If not specified, the default is the active port.
SET R	Modifies report settings.
SET … TERSE	For all **SET** commands, **TERSE** disables the automatic **SHO** command after the settings entry.
STA C or **R**	Clears the self-test status and restarts the relay.
TEST DB	Displays the present status of digital and analog overrides.
TFE C or **R**	Clears/resets cumulative and individual through-fault event data.
TFE P	Preloads cumulative through-fault event data.
VEC D	Displays the diagnostic vector report.
VEC E	Displays the exception vector report.
Access Level C Commands	
PAS C	Changes the Access Level C password.

Comando del Puerto Serial	Descripción del Comando
R_S	Resetea el relé usando ajustes y passwords por defacto y después reinicia el relé. Disponible solamente después de una actualización de firmware.
AJU *n*	Modificar el Grupo *n* de ajustes del relé, donden *n* =1, 2, 3 o 4. Si no se especifica *n*, se modifica el grupo activo.
AJU *nombre*	Para todos los comandos **SET**, adelántese a un ajuste ingresando el nombre del ajuste, por ejemplo, 50P11P.
AJU DNP *n*	Modificar la configuración del mapa de datos DNP para el Mapa *n*, donde *n* = 1, 2 o 3.
AJU E *m*	Modificar ajustes EtherNet/IP del mapa número *m* (*m* = 1, 2, or 3)
AJU F	Modificar la configuración del panel frontal.
AJU G	Modificar las ajustes globales.
AJU I	Modificar ajustes IEC 60870-5-103.
AJU L *n*	Modifica ajustes SELOGIC, laches, variables lógicas (SV) y matemáticas (MV) en el grupo de ajustes *n*. Si no se especifica *n*, se modifica el grupo activo.
AJU M	Modificar las configuración del Mapa del Usuario Modbus.
AJU P *n*	Modificar la configuración del Puerto *n*, donde *n* = 1, 2, 3, 4 o F. Si n no está especificado, el puerto predeterminado es el puerto activo.
AJU R	Modificar la configuración de reportes.
AJU ... TERSO	Para todos los comandos **AJU**, **TERSO** desactiva los comandos automáticos **MOS** después de modificar las configuraciones.
EST C o **R**	Salir del modo de diagnostico automático y reiniciar el relé.
TEST DB	Mostrar el estado actual de variable digitales y analógicas con valores forzados.
TFE C o **R**	Borra/reinicia eventos individuales y acumulados de fallas externas.
TFE P	Carga eventos acumulados de fallas externas.
VEC D	Mostar reporte de reinicio del rele.
VEC E	Mostar reporte de reinicio del relé.
Comandos del Nivel del Acceso C	
PAS C	Cambiar la contraseña del Nivel de Acceso C.

SEL-787-2, -3, -4 Relay Command Summary

The following table lists the front serial port ASCII commands associated with particular activities. The commands are shown in uppercase letters, but you can also enter these with lowercase letters. Commands can be initiated with the three initial letters of the command. Refer to *SEL ASCII Protocol and Commands* for additional details and capabilities of each command.

La siguiente tabla muestra los comandos ASCII del puerto serie frontal asociados con diferentes actividades. Los comandos se pueden usar en mayúsculas o minúsculas. Los comandos se pueden ejecutar usando las primeras tres letras del nombre. Por más detalles consulte la guía *SEL ASCII Protocol and Commands*.

Serial Port Command	Command Description
Access Level 0 Commands	
ACC	Go to 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.
ID	Relay identification code.
QUI	Go to Access Level 0.
Access Level 1 Commands	
2AC	Go to 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.
BRE *n*	Display breaker *n* monitor data (trips, interrupted current, wear) where *n* = 1, 2, 3, or 4 for the SEL-787-4X model. For the SEL-787-3E/3S, *n* = 1, 2, or 3. For SEL-787-2X/2E/21, *n* = 1 or 2.
CEV *n*	Shows compressed event report number *n*, at 1/4-cycle resolution. If *n* is omitted, the most recent compressed event report is displayed.
CEV *n* R	Shows compressed raw event report number *n*, at 1/32-cycle resolution. If *n* is omitted, the most recent compressed event report is displayed.
CEV *n* DIFF	Shows compressed differential element report *n*, at 1/4-cycle resolution. If *n* is omitted, the most recent compressed differential element report is displayed.
COM A	Returns a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.
COM B	Returns a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel B.

Comando del Puerto Serial	Descripción del Comando
Comandos del Nivel de Acceso 0	
ACC	Ir a Nivel de Acceso 1. Si el jumper de acceso en la tarjeta principal no está en su lugar, el relé pedirá la contraseña de Acceso del Nivel 1.
ID	Código de identificación del relé.
SAL	Ir al Nivel de Acceso 0.
Comandos del Nivel de Acceso 1	
2AC	Ir a Nivel de Acceso 2. Si el jumper de acceso en la tarjeta principal no está en su lugar, el relé pedirá la contraseña de Acceso del Nivel 2.
INT *n*	Mostrar información sobre el interruptor *n* (disparos, corriente interrumpida, desgaste). Para relés SEL-787-4X *n* = 1, 2, 3 o 4. Para relés SEL-787-3E/3S *n* = 1, 2 o 3. Para relés SEL-787-2X/2E/21 *n* = 1 o 2.
CEV *n*	Mostrar el reporte comprimido de evento número *n*, resolución de 1/4 de ciclo.
CEV *n* R	Agregue R para mostrar el reporte de evento comprimido sin filtro, resolución 1/32 de ciclo. Si no se especifica n se muestra el evento comprimido mas reciente.
CEV *n* DIFF	Mostrar el reporte diferencial de evento *n*, (4 muestras por ciclo). Si se omite *n* se muestra el reporte más reciente.
COM A	Presentar un informe de síntesis de los últimos 255 registros en el buffer de comunicaciones MIRRORED BITS Canal A.
COM B	Presentar un informe de síntesis de los últimos 255 registros en el buffer de comunicaciones MIRRORED BITS Canal B.

Serial Port Command	Command Description
COM C	Clears all of the communications records. If both MIRRORED BITS channels are enabled, omitting the channel specifier (A or B) clears both channels.
COM C A	Clears all communications records for Channel A.
COM C B	Clears all communications records for Channel B.
COM L	Appends a long report to the summary report of the last 255 records in the MIRRORED BITS communications buffer.
COM L A	Appends a long report to the summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.
COM L B	Appends a long report to the summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel B.
COM S	Returns a summary report of the last 255 records in the MIRRORED BITS communications buffer.
COU *n*	Shows current state of device counters. *n* = repeat the report *n* times, with a 1/2 second delay between each report.
DATE	Shows the date.
DATE *dd/mm/yyyy*	Sets the date in DMY format if DATE_F setting is DMY.
DATE *mm/dd/yyyy*	Sets the date in MDY format if DATE_F setting is MDY.
DATE *yyyy/mm/dd*	Sets the date in YMD format if DATE_F setting is YMD.
ETH	Shows the Ethernet port status.
EVE *n*	Shows standard analog event report *n* for Slot Z with 4 samples per cycle. If *n* is omitted, the most recent report is displayed.
EVE E *n*	Shows standard analog event report *n* for Slot E with 4 samples per cycle. If *n* is omitted, the most recent report is delayed.
EVE *n* R	Shows standard analog event report *n* for Slot Z with raw (unfiltered) 32 samples per cycle data.
EVE E *n* R	Shows standard analog event report *n* for Slot E with raw (unfiltered) 32 samples per cycle data.
EVE D *n*	Shows digital data event report number *n* for Slot Z, with 1/4-cycle resolution.

Comando del Puerto Serial	Descripción del Comando
COM C	Borra todos los registros de comunicaciones. Si los dos canales MIRRORED BITS están habilitados, suprimiendo el especificador de canales (A o B) se borran los dos canales.
COM C A	Borra todos los registros de comunicaciones del Canal A.
COM C B	Borra todos los registros de comunicaciones del Canal B.
COM L	Anexa un informe detallado al informe de síntesis de los últimos 255 registros en el buffer de comunicaciones MIRRORED BITS.
COM L A	Anexa un informe detallado al informe de síntesis de los últimos 255 registros en el buffer de comunicaciones MIRRORED BITS del Canal A.
COM L B	Anexa un informe detallado al informe de síntesis de los últimos 255 registros en el buffer de comunicaciones MIRRORED BITS del Canal B.
COM S	Muestra un resumen de los últimos 255 registros en el buffer de comunicaciones MIRRORED BITS.
COU *n*	Muestra el estado actualizado de los contadores del dispositivo. *n* = repite el informe *n* veces, con 1/2 segundos entre cada informe.
FECHA	Ver fecha.
FECHA *dd/mm/yyyy*	Si DATE_F es igual a DMA, ingrese fecha en formato Día Mes Año
FECHA *mm/dd/yyyy*	Si DATE_F es MDA, ingrese fecha en formato Mes Día Año.
FECHA *yyyy/mm/dd*	Si DATE_F es AMD, ingrese fecha en formato Año Mes Día.
ETH	Mostrar el estado del puerto de Ethernet.
EVE *n*	Mostrar el reporte de evento estándar número *n* con mediciones en el Slot Z, con 4 muestras por ciclo. Omitiendo *n*, se muestra el informe más reciente.
EVE E *n*	Mostrar el reporte de evento estándar numero *n* con mediciones en el Slot E, con 4 muestras por ciclo. Omitiendo *n*, se muestra el informe más reciente.
EVE *n* R	Mostrar el reporte de evento *n* sin filtrar con 32 muestras por ciclo con mediciones en el Slot Z.
EVE E *n* R	Mostrar el reporte de evento *n* sin filtrar con 32 muestras por ciclo con mediciones en el Slot E.
EVE D *n*	Mostrar el reporte digital de eventos *n*, con 4 muestras por ciclo con mediciones en el Slot Z.

Serial Port Command	Command Description
EVE D E *n*	Shows digital event report number *n* for Slot E, with 1/4-cycle resolution.
EVE D *n* R	Shows digital data event report number *n* for Slot Z, with 1/32-cycle resolution.
EVE D E *n* R	Shows digital data event report number *n* for Slot E, with 1/32-cycle resolution.
EVE DIF1 *n*	Shows Differential Element 1 event report number *n*, with 1/4-cycle resolution.
EVE DIF2 *n*	Shows Differential Element 2 event report number *n*, with 1/4-cycle resolution.
EVE DIF3 *n*	Shows Differential Element 3 event report number *n*, with 1/4-cycle resolution.
EVE R *n*	Shows raw analog data event report number *n* for Slot Z, with 1/32-cycle resolution, same as **EVE *n* R**.
EVE E R *n*	Shows raw analog data event report number *n* for Slot E, with 1/32-cycle resolution, same as **EVE E *n* R**.
FIL DIR	Returns a list of files.
FIL READ *filename*	Transfers settings file *filename* from the relay to the PC.
FIL SHOW *filename*	*Filename* displays the contents of the corresponding file.
GOOSE *k*	Displays transmit and receive GOOSE messaging information. Enter number *k* to scroll the GOOSE data *k* times on the screen.
GROUP	Displays active group setting.
HELP	Displays a short description of selected commands.
HIS *n*	Shows summary of *n* latest event reports, where *n* = 1 is the most recent entry. If *n* is omitted, all of the event report summaries are displayed.
HIS C or **R**	Clears or resets the history buffer.
IRIG	Forces synchronization of internal control clock to IRIG-B time-code input.
LDP	Displays signal profile data.
LDP *row1 row2*	Displays load profile report rows from *row1* to *row2*, starting with *row1*. If *row2* is omitted, displays the first *row1* rows.
LDP *date1 date2*	Displays load profile report rows from *date1* to *date2*, starting with *date1*.
LDP C	Clears load profile data.
MAC	Displays the MAC address of the Ethernet port (PORT 1).

Comando del Puerto Serial	Descripción del Comando
EVE D E *n*	Mostrar el reporte digital de eventos *n*, con 4 muestras por ciclo con mediciones en el Slot E.
EVE D *n* R	Mostrar el reporte digital de eventos *n*, con 32 muestras por ciclo con mediciones en el Slot Z.
EVE D E *n* R	Mostrar el reporte digital de eventos *n*, con 32 muestras por ciclo con mediciones en el Slot E.
EVE DIF1 *n*	Mostrar el reporte de evento *n* del elemento diferencial 1, con 4 muestras por ciclo.
EVE DIF2 *n*	Mostrar el reporte de evento *n* del elemento diferencial 2, con 4 muestras por ciclo.
EVE DIF3 *n*	Mostrar el reporte de evento *n* del elemento diferencial 3, con 4 muestras por ciclo.
EVE R *n*	Mostrar el reporte de evento *n* sin filtrar con 32 muestras por ciclo con mediciones en el Slot Z, igual que **EVE *n* R**.
EVE E R *n*	Mostrar el reporte de evento *n* sin filtrar con 32 muestras por ciclo con mediciones en el Slot E, igual que **EVE *n* R**.
FIL DIR	Mostrar lista de archivos.
FIL READ *filename*	Transferir el archivo de configuración *filename* del relé a la computadora.
FIL SHOW *filename*	Muestra el contenido del archivo *filename*.
GOOSE *k*	Mostrar información de transmisión y recepción de mensajes GOOSE. Ingresar el numero *k* para mostrar los datos GOOSE *k* veces en la pantalla.
GRUPO	Mostrar el grupo de ajustes activo.
AYUDA	Mostrar una descripción corta de los comandos elegidos.
HIS *n*	Mostrar el resumen de los últimos *n* informes de eventos, donde *n* = 1 es la entrada más reciente. Si *n* es no está especificado, muestra todos los resúmenes de reportes de eventos.
HIS D o **R**	Borrar la historia de eventos.
IRIG	Forzar la sincronización del reloj interno a IRIG-B.
LDP	Mostrar los datos de perfil carga.
LDP *row1 row2*	Mostrar los datos de perfil carga entra las filas *row1* y *row2*. Si se omite *row2*, muestra las primeras *row1* columnas.
LDP *date1 date2*	Mostrar los datos de perfil carga entra las filas *date1* y *date2*.
LDP D	Borra datos de perfil de carga.
MAC	Mostrar la dirección MAC del puerto de Ethernet (PUERTO 1).

Serial Port Command	Command Description
MET or **MET F**	Displays fundamental metering data.
MET *k*	Displays fundamental metering data *k* times, where *k* is between 1 and 32767.
MET AI	Displays analog input (transducer) data.
MET DE	Displays demand metering data in primary amperes.
MET DIF	Displays differential metering data.
MET E	Displays energy metering data.
MET H	Generates harmonic report for all input currents and voltages, showing first- to fifth-harmonic levels and %THD (total harmonic distortion).
MET M	Displays minimum and maximum metering data.
MET MV	Displays SELOGIC math variable data.
MET PE	Displays peak demand metering data in primary amperes.
MET PM	Displays synchrophasor metering data.
MET RA	Displays remote analog metering data.
MET RD	Resets demand metering values.
MET RE	Resets energy metering data.
MET RM	Resets minimum and maximum metering data.
MET RMS	Displays rms metering data.
MET RP	Resets demand and peak demand metering values.
MET T	Displays RTD metering data.
PING *x.x.x.x t*	Determines if Ethernet port is functioning and configured properly. *x.x.x.x* is the IP address and *t* is the PING interval settable from 2 to 255 seconds. Default *t* is 1 second. Press Q to stop.
RSTP	Displays the RSTP statistics and the current RSTP configuration of Port 1.
SER	Displays the entire Sequential Events Recorder (SER) report.
SER *date1*	Displays all the rows in the SER report recorded on the specified date (see **DATE** command for date format).
SER ***date1 date2***	Displays all the rows in the SER report recorded between dates *date1* and *date2*, inclusive.

Comando del Puerto Serial	Descripción del Comando
MED or **MED F**	Mostrar los datos de medición fundamentales.
MED *k*	Mostrar los datos de medición fundamentales *k* veces, donde *k* entre 1 y 32767.
MED EA	Mostrar los datos de entrada analógica.
MED DE	Mostrar los datos de demanda de medición en amperes primarios.
MED DIF	Mostrar los datos de medición diferencial.
MED E	Mostrar los datos de medición de energía.
MED A	Generar un informe de armónicos para todas las entradas de corriente y voltaje, mostrando del primero al quinto armónico y el porcentaje de distorión armónica total (THD).
MED M	Mostrar datos de medición mínimos y máximos.
MED V	Mostrar datos de variables matemáticas SELOGIC.
MED PIC	Mostrar los datos de demanda de medicion pico en amperes primarios.
MED PM	Mostrar fasores sincronizados.
MED RA	Mostrar datos analogicos de medición remota.
MED RD	Reiniciar mediciones de demanda.
MED RE	Reiniciar los datos de medición de energía.
MED RM	Reiniciar los datos de medición mínima y máxima.
MED RMS	Mostrar los datos de medición rms.
MED RP	Reiniciar los valores de medición de demanda pico.
MED T	Mostrar los datos de medición RTD.
PING *x.x.x.x t*	Determinar si el puerto Ethernet esta funcionando y configurado adecuadamente. *x.x.x.x* es la dirección IP. *t* es el intervalo entre PINGs, *t* es ajustable entre 2 y 255 segundos. Por omisión, *t* = 1 segundo. Oprima Q para detener.
RSTP	Muestra estadisticas y configuracion RSTP actual.
SER	Mostrar el reporte completo del Registrador de Eventos Secuenciales (SER).
SER *date1*	Mostrar todas las filas en el reporte SER del día *date1* (vea el comando **FECHA** por el formato de fecha).
SER ***date1 date2***	Mostrar todas las filas en el reporte SER entre el día *date1* y el día *date2* (vea el comando **FECHA** por el formato de fecha).

Serial Port Command	Command Description
SER *row1*	Displays the latest *row1* rows in the SER report (*row1* = 1024, where 1 is the most recent entry).
SER *row1 row2*	Displays rows *row1–row2* in the SER report.
SER C or **R**	Clears SER data.
SER D	Displays SER delete report, which shows deleted items (use when SER Auto Deletion is selected to remove chatter).
SHO *n*	Displays the relay settings for Group *n*, where *n* = 1, 2, 3, or 4. If *n* is not specified, the default is the active settings group.
SHO DNP *m*	Displays the DNP data map settings for Map *m* (*m* = 1, 2, or 3).
SHO E *m*	Displays EtherNet/IP assembly map settings for Map *m* (*m* = 1, 2, or 3).
SHO F	Displays the front-panel settings.
SHO G	Displays the global settings.
SHO I	Displays the IEC 60870-5-103 map settings.
SHO L *n*	Displays the general logic settings for Group n, where *n* = 1, 2, 3, or 4. If *n* is not specified, default is the active settings group.
SHO M	Displays the Modbus user map settings.
SHO P *n*	Displays the port settings, where *n* specifies Port 1, 2, 3, 4, or F; *n* defaults to the active port if not listed.
SHO R	Displays the report settings.
STA	Displays the relay self-test status.
STA S	Displays the SELOGIC usage status report.
SUM *n*	Displays Event Summary *n*. If *n* is omitted, displays the most recent event summary.
SUM R or **C**	Resets the event summary buffer.
TAR	Displays the default target row or the most recently viewed target row.
TAR *n*	Displays Target Row *n*.
TAR *n k*	Displays Target Row *n*. Repeats display of Target Row *n* for repeat count *k*.
TAR *name*	Displays the target row with target *name* in the row.
TAR *name k*	Displays the target row with target *name* in the row. Repeat display of this row for repeat count *k*.
TAR R	Resets any latched targets and the most recently viewed target row.

Comando del Puerto Serial	Descripción del Comando
SER *row1*	Mostrar las ultimas *row1* filas en el reporte SER (*row1* = 1–1024, 1 es la fila más reciente).
SER *row1 row2*	Mostrar las filas entre *row1–row2*.
SER D o **R**	Borrar los datos SER.
SER B	Muestra ítems removidos del SER. Útil cuando la supresión automática de SER esta activada.
MOS *n*	Mostrar configuraciones de puerto, donde *n* especifica el puerto (1, 2, 3, 4 o F); por defecto muestra ajustes del puerto activo.
MOS DNP *m*	Mostrar ajustes de mapa de datos DNP para el Mapa *m* (*m* = 1, 2 o 3).
MOS E *m*	Mostrar ajustes EtherNet/IP del mapa número *m* (*m* = 1, 2, 3).
MOS F	Mostrar ajustes del panel frontal.
MOS G	Mostrar ajustes globales.
MOS I	Mostrar mapa de ajustes IEC 60870-5-103.
MOS L *n*	Mostrar la lógica de configuración general del Grupo *n* del relé (*n* = 1, 2, 3 o 4). Por omisión, muestra grupo de ajustes 1.
MOS M	Mostrar ajustes del mapa del usuario Modbus.
MOS P *n*	Mostrar configuraciones de puerto, donde *n* especifica el puerto (1, 2, 3, 4 o F); por defecto muestra ajustes del puerto activo.
MOS R	Mostrar configuración de reportes.
EST	Muestra estado de diagnostico automático del relé.
EST S	Mostrar reporte de utilización SELOGIC.
SUM *n*	Muestra un resumen del evento *n*.
SUM C o **R**	Borrar el buffer de resúmenes de evento.
BAN	Mostrar la fila de banderas por defecto o la última fila de banderas mostrada.
BAN *n*	Mostrar la fila de banderas *n*.
BAN *n k*	Mostrar la fila de banderas *n k* veces.
BAN *name*	Mostrar la fila de banderas que contiene la bandera *name*.
BAN *name k*	Mostrar la fila de banderas que contiene la bandera *name k* veces.
BAN R	Resetea o reinicia todas las banderas y la fila de banderas más reciente.

Serial Port Command	Command Description
TFE	Displays the cumulative and individual through-fault event data. The twenty (20) most recent individual events are displayed.
TFE *n*	Displays the cumulative and individual through-fault event data. The *n* most recent individual events are displayed, where *n* = 1 to 500.
TFE A	Displays the cumulative and individual through-fault event data. The most recent individual events are displayed, to as many as 500.
TIME	Displays the time.
TIME *hh*	Sets the time by entering **TIME** followed by hours, as shown (24-hour clock).
TIME *hh:mm*	Sets the time by entering **TIME** followed by hours and minutes, as shown (24-hour clock).
TIME *hh:mm:ss*	Sets the time by entering **TIME** followed by hours, minutes, and seconds, as shown (24-hour clock).
TRI	Triggers an event report data capture.
Access Level 2 Commands	
89C *m*	Closes Two-Position Disconnect *m*, where *m* = 1–16.
89O *m*	Opens Two-Position Disconnect *m*, where *m* = 1–16.
89C *n m*	Closes Three-Position Disconnect *m*, where *m* = 1 or 2 and *n* = L or E (in-line or earthing disconnect).
89O *n m*	Opens Three-Position Disconnect *m*, where *m* = 1 or 2 and *n* = L or E (in-line or earthing disconnect).
ANA *c p t*	Tests analog output channel where *c* is the channel name or number, *p* is a percentage of full scale or either letter “R” or “r” indicates ramp mode, and *t* is the duration of the test in decimal minutes.
BRE *n* R	Resets breaker data for Breaker *n*, where *n* = 1, 2, 3, or 4 for the SEL-787-4X model, *n* = 1, 2, or 3 for the SEL-787-3E/3S models, and *n* = 1 or 2 for the SEL-787-2X/2E/21 models.
BRE *n* W	Preloads breaker data for Breaker *n*, where *n* = 1, 2, 3, or 4 for the SEL-787-4X model, *n* = 1, 2, or 3 for the SEL-787-3E/3S models, and *n* = 1 or 2 for the SEL-787-2X/2E/21 models.

Comando del Puerto Serial	Descripción del Comando
TFE	Muestra datos individuales y acumulados de fallas externas. Se muestran los últimos 20 eventos individuales.
TFE *n*	Muestra datos individuales y acumulados de fallas externas. Se muestran los *n* eventos individuales más recientes donde *n* = 1 a 500.
TFE A	Muestra datos individuales y acumulados de fallas externas. Se muestran los más eventos recientes (hasta 500 eventos).
HORA	Ver hora.
HORA *hh*	Configurar la hora ingresando **HORA** seguido por horas como se muestra (relog 24 horas).
HORA *hh:mm*	Configurar la hora ingresando **HORA** seguido por horas y minutos como se muestra (relog 24 horas).
HORA *hh:mm:ss*	Configurar la hora ingresando **HORA** seguido por horas, minutos y segundos como se muestra (relog 24 horas).
TRI	Disparar la captura de un reporte de evento.
Comandos del Nivel de Acceso 2	
89C *m*	Cierra el seccionador de 2-posiciones *m*, donde *m* = 1–16.
89A *m*	Abre el seccionador de 2-posiciones *m*, donde *m* = 1–16.
89C *n m*	Cierra el seccionador de 3-posiciones *m*, donde *m* = 1 o 2 y n = L o E (línea o tierra).
89A *n m*	Abre el seccionador de 3-posiciones *m*, donde *m* = 1 o 2 y n = L o E (línea o tierra).
ANA *c p t*	Probar el canal de salida analógica donde *c* es el nombre o el número del canal, *p* es el porcentaje de escala completa, o las letras “R” o “r” para indicar el modo de rampa y *t* para indicar la duración de la prueba en minutos decimales.
INT *n* R	Borrar datos del interruptor *n.* Para reles SEL-787-4X *n* = 1, 2, 3 o 4. Para reles SEL-787-3E/3S *n* = 1, 2, o 3. Para reles SEL-787-2X/2E/21 *n* = 1 o 2.
INT *n* W	Cargar datos del interruptor para el interruptor *n.* Para reles SEL-787-4X *n* = 1, 2, 3 o 4. Para reles SEL-787-3E/3S *n* = 1, 2, o 3. Para reles SEL-787-2X/2E/21 *n* = 1 o 2.

Serial Port Command	Command Description
CAL	Enters 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.
CLO *n*	Closes Circuit Breaker *n*, where *n* = 1, 2, 3, or 4 for the SEL-787-4X model, *n* = 1, 2, or 3 for the SEL-787-3E/3S models, and *n* = 1 or 2 for the SEL-787-2X/2E/21 models.
CON RB*nn k*	Selects a remote bit to set, clear, or pulse where *nn* is a number from 01 to 32, representing RB01 through RB32. *k* is S, C, or P for Set, Clear, or Pulse.
COPY *m n*	Copies relay and logic settings from Group *m* to Group *n*.
DTO	Downloads volts/Hz user curve from the SEL-5806 Curve Designer Software.
FIL WRITE *filename*	Transfers settings file *filename* from the PC to the relay.
GROUP *n*	Changes the active group to Group *n*, where *n* = 1, 2, 3, or 4.
L_D	Loads new firmware.
LOO	Enables loopback testing of MIRRORED BITS channels.
LOO A	Enables loopback on MIRRORED BITS Channel A for the next 5 minutes.
LOO B	Enables loopback on MIRRORED BITS Channel B for the next 5 minutes.
LOO R	Disables the loopback on both channels and returns the device to normal operation.
LOO *xx* DATA	Enables loopback mode for *xx* minutes and allows the loopback data to modify the RMB values.
OPE *n*	Opens Circuit Breaker *n*, where *n* = 1, 2, 3, or 4 for the SEL-787-4X model, *n* = 1, 2, or 3 for the SEL-787-3E/3S models, and *n* = 1 or 2 for the SEL-787-2X/2E/21 models.
PARTNO	Allows for updates to the part number after the relay hardware configuration has been changed.
PAS 1	Changes the Access Level 1 password.
PAS 2	Changes the Access Level 2 password.
PUL OUT*nnn*	Pulse Output Contact *nnn*.
PUL OUT*nnn s*	Pulses Output Contact *nnn,* where *nnn* = OUT101…, for *s* (1 to 30, default is 1) seconds.

Comando del Puerto Serial	Descripción del Comando
CAL	Ingresar al Nivel de Acceso C. Si el jumper de acceso en la tarjeta principal no está en su lugar, el relé pedirá la contraseña de Acceso del Nivel C. El Nivel de Acceso C está reservado para uso exclusivo de SEL.
CER *n*	Cerrar el interruptor *n.* Para reles SEL-787-4X *n* = 1, 2, 3 o 4. Para reles SEL-787-3E/3S *n* = 1, 2, o 3. Para reles SEL-787-2X/2E/21 *n* = 1 o 2.
CON RB*nn k*	Seleccionar un bit remoto para activar, desactivar o pulsar donde *nn* es un número del 01 al 32, representando desde RB01 hasta RB32. *k* es A, D o P para Activar, Deactivar o Pulsar.
COPY *m n*	Copiar configuración de relé y la configuración lógica del Grupo *m* al Grupo *n*.
DTO	Descargar curva volts/Hz del SEL-5806 Curve Designer Software.
FIL WRITE *filename*	Transferir el archivo de configuración *filename* de la computadora al relé.
GRUPO *n*	Usar Grupo de configuraciones *n*, donde *n* = 1, 2, 3 o 4.
L_D	Cargar un firmware nuevo.
LOO	Habilitar loopback de los canales MIRRORED BITS.
LOO A	Habilitar loopback en Canal MIRRORED BITS A por los siguientes 5 minutos.
LOO B	Habilitar loopback en Canal MIRRORED BITS B por los siguientes 5 minutos.
LOO R	Deshabilita loopback en canales MB A y B.
LOO *xx* DATA	Habilita loopback for *xx* minutos y permite modificar valores RMB.
ABR *n*	Abrir el interruptor *n.* Para reles SEL-787-4X *n* = 1, 2, 3 o 4. Para reles SEL-787-3E/3S *n* = 1, 2 o 3. Para reles SEL-787-2X/2E/21 *n* = 1 o 2.
PARTNO	Cambia el número de parte del relé use despues de cambiar una tarjeta del relé.
PAS 1	Cambiar la contraseña del Nivel de Acceso 1.
PAS 2	Cambiar la contraseña del Nivel de Acceso 2.
PUL OUT*nnn*	Pulsar el contacto de salida *nnn*.
PUL OUT*nnn s*	Pulsar el contacto de salida *nnn* (*nnn* = OUT101…) por *s* (de 1 a 30, el numero predeterminado es 1) segundos.

Serial Port Command	Command Description
R_S	Restores the factory-default settings and passwords and reboots the relay; available only after a firmware upgrade.
SET *n*	Modifies the relay settings for Group *n*, where *n* = 1, 2, 3, or 4. If *n* is not specified, default is the active settings group.
SET *name*	For all **SET** commands, jump ahead to a specific setting by entering the setting name, e.g., 50P11P.
SET DNP *n*	Modifies DNP data map settings for Map *n*, where *n* = 1, 2, or 3.
SET E *m*	Modifies EtherNet/IP assembly map settings for Map *m* (*m* = 1, 2, or 3).
SET F	Modifies front-panel settings.
SET G	Modifies global settings.
SET I	Modifies IEC 60870-5-103 settings.
SET L *n*	Modifies the SELOGIC variable and timer settings for Group *n*, where *n* = 1, 2, 3, or 4. If *n* is not specified, the default is the active settings group.
SET M	Modifies Modbus user map settings.
SET P *n*	Modifies Port *n* settings, where *n* = 1, 2, 3, 4, or F. If not specified, the default is the active port.
SET R	Modifies report settings.
SET … TERSE	For all **SET** commands, **TERSE** disables the automatic **SHO** command after the settings entry.
STA C or **R**	Clears the self-test status and restarts the relay.
TEST DB	Displays the present status of digital and analog overrides.
TFE C or **R**	Clears/resets cumulative and individual through-fault event data.
TFE P	Preloads cumulative through-fault event data.
VEC D	Displays the diagnostic vector report.
VEC E	Displays the exception vector report.
Access Level C Commands	
PAS C	Changes the Access Level C password.

Comando del Puerto Serial	Descripción del Comando
R_S	Resetea el relé usando ajustes y passwords por defacto y después reinicia el relé. Disponible solamente después de una actualización de firmware.
AJU *n*	Modificar el Grupo *n* de ajustes del relé, donden *n* =1, 2, 3 o 4. Si no se especifica *n*, se modifica el grupo activo.
AJU *nombre*	Para todos los comandos **SET**, adelántese a un ajuste ingresando el nombre del ajuste, por ejemplo, 50P11P.
AJU DNP *n*	Modificar la configuración del mapa de datos DNP para el Mapa *n*, donde *n* = 1, 2 o 3.
AJU E *m*	Modificar ajustes EtherNet/IP del mapa número *m* (*m* = 1, 2, or 3)
AJU F	Modificar la configuración del panel frontal.
AJU G	Modificar las ajustes globales.
AJU I	Modificar ajustes IEC 60870-5-103.
AJU L *n*	Modifica ajustes SELOGIC, laches, variables lógicas (SV) y matemáticas (MV) en el grupo de ajustes *n*. Si no se especifica *n*, se modifica el grupo activo.
AJU M	Modificar las configuración del Mapa del Usuario Modbus.
AJU P *n*	Modificar la configuración del Puerto *n*, donde *n* = 1, 2, 3, 4 o F. Si n no está especificado, el puerto predeterminado es el puerto activo.
AJU R	Modificar la configuración de reportes.
AJU ... TERSO	Para todos los comandos **AJU**, **TERSO** desactiva los comandos automáticos **MOS** después de modificar las configuraciones.
EST C o **R**	Salir del modo de diagnostico automático y reiniciar el relé.
TEST DB	Mostrar el estado actual de variable digitales y analógicas con valores forzados.
TFE C o **R**	Borra/reinicia eventos individuales y acumulados de fallas externas.
TFE P	Carga eventos acumulados de fallas externas.
VEC D	Mostar reporte de reinicio del rele.
VEC E	Mostar reporte de reinicio del relé.
Comandos del Nivel del Acceso C	
PAS C	Cambiar la contraseña del Nivel de Acceso C.