SEL-487V Relay

Capacitor Bank Protection, Automation, and Control

Major Features and Benefits

The SEL-487V Capacitor Bank Protection, Automation, and Control System integrates voltage or reactive power control for grounded and ungrounded capacitor banks with full automation and protection in one device.

- **Protects Grounded and Ungrounded Banks.** The SEL-487V provides sensitive voltage differential or current unbalance protection with compensation adjustment. The compensation adjustment is used to zero out small unbalances that are natural in the bank as well as instrument transformer errors. Instantaneous and time-overcurrent elements and voltage elements provide additional protection for the capacitor bank. The SEL-487V provides breaker failure protection for the capacitor bank breaker using high-speed (less than one cycle) open-pole detection logic that reduces coordination times for critical breaker failure applications.
- **Control.** The SEL-487V-1 is available with control functions for maintaining system voltage, VAR or power factor (PF) levels, and reactor loading. The control functions include auto/manual and local/remote control capabilities with control instability detection for alarm or blocking of control operations. Implement the time-of-day control feature to synchronize capacitor bank insertion with peak VAR demand periods for any weekday or weekend period. Automatically sequence as many as three capacitor bank stages by using the universal sequencing control. This control provides sequencing based upon accumulated operating time, an analog quantity, or a fixed order.
- **Automation.** Take advantage of enhanced automation features that include 32 programmable elements for local control, remote control, protection latching, and automation latching. Local metering and control on the large format front-panel liquid crystal display eliminates the need for separate panel meters and switches. Serial and Ethernet links efficiently transmit key information, including:
  - Metering data
  - Protection element and control I/O status
  - IEEE C37.118 synchrophasors

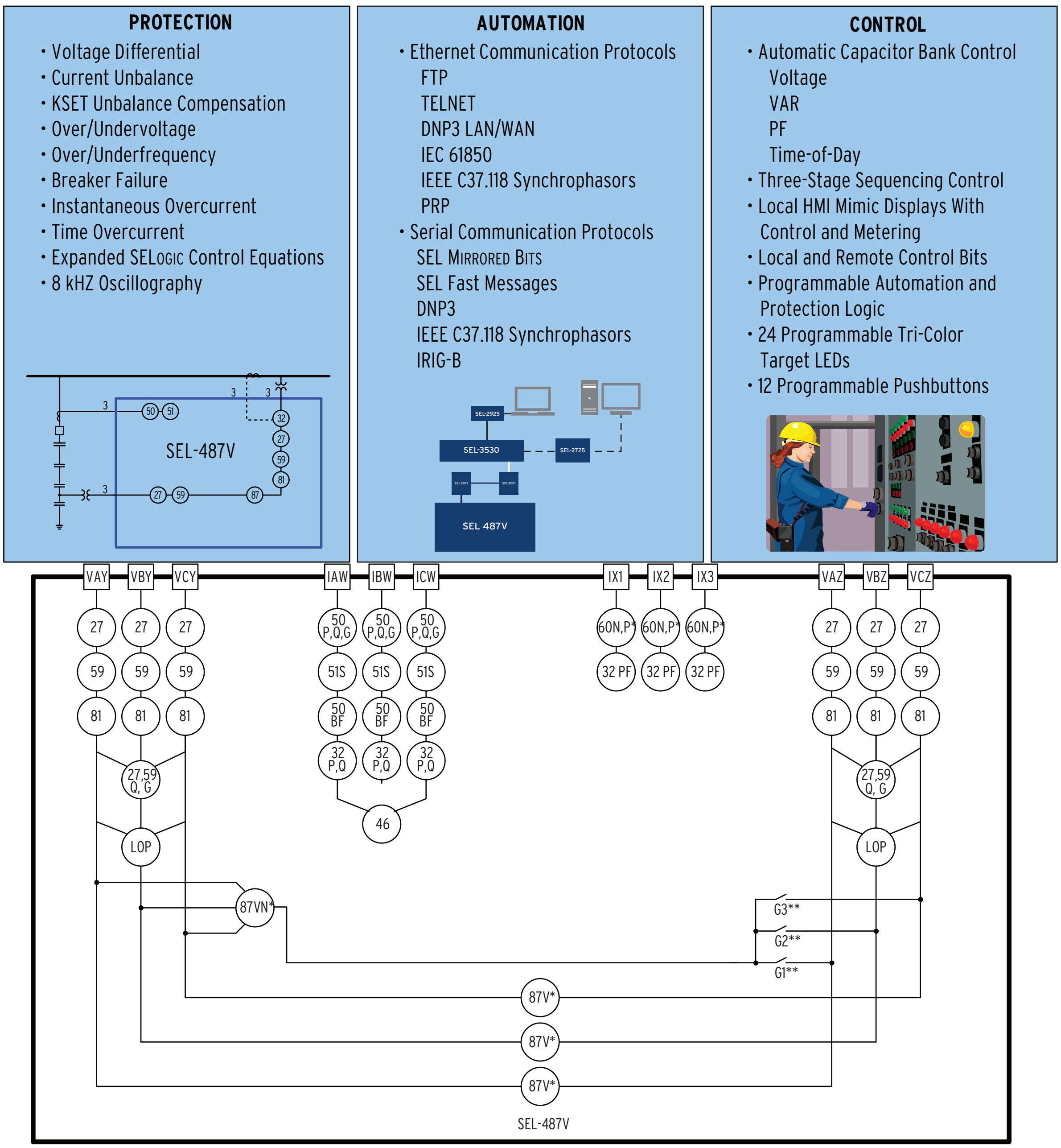
- IEC 61850 GOOSE messages
- Sequential events recorder (SER) reports
- Breaker monitor
- Relay summary event reports
- Time synchronization

Expanded SELOGIC® control equations with math and comparison functions are available for control and protection applications. Incorporate up to 1000 lines of automation logic to speed and improve control actions.

- **Simple Application-Based Settings.** The SEL-487V selects the recommended capacitor bank protection elements based upon capacitor bank nameplate and configuration settings. The relay selects from differential voltage, differential neutral voltage, neutral-current unbalance, and phase-current unbalance protection.
- **Faulted Phase and Section Identification Logic.** Reduce the time needed to identify faulted capacitor bank units with the patent-pending faulted phase and section identification logic. This logic automatically determines the phase (A, B, C) and section (top/bottom or left/right) where the faulty capacitor bank unit is located.
- **Simple Settings Assistance.** Simplify settings calculations for grounded wye capacitor bank applications with the SEL capacitor bank settings assistance software. This software runs as a tool within ACSELERATOR QuickSet® SEL-5030 Software. ACSELERATOR QuickSet and the Settings Assistant are available at no charge from SEL.
- **Synchrophasors.** Make informed system operational decisions based on actual real-time phasor measurements from across your power system. Synchrophasors can determine actual stability margins using a standard spreadsheet, graphics program, or data management system. Record up to 120 seconds of C37.118 binary synchrophasor data, and perform real-time control using remote and local synchrophasor data.
- **Breaker Monitoring and Control.** Schedule breaker maintenance when accumulated breaker duty (independently monitored for each pole of the circuit breaker) indicates possible excess contact wear. Electrical and mechanical operating times are recorded for both the last operation and the average of operations since function reset. Alarm contacts provide notification of substation battery voltage problems even if voltage is low only during trip or close operations. Motor run time monitoring detects failing charging mechanism motors. Control the breaker remotely or locally using optional direct action pushbuttons.
- **Ethernet Access.** Access all relay functions with the optional Ethernet card. Interconnect with automation systems using IEC 61850 or DNP3 protocol directly. Optionally connect to DNP3 networks through an SEL-2032 Communications Processor. File transfer protocol (FTP) is provided for high-speed data collection. Connect to substation or corporate LANs to transmit synchrophasors in the IEEE C37.118-2005 format using TCP or UDP Internet protocols.
- **Simple Network Time Protocol (SNTP).** The relay shall be capable of synchronizing the internal timekeeping to a network time source.
- **IEC 60255-Compliant Thermal Model.** The relay provides a configurable thermal model for the protection of a wide variety of devices.
- **Digital Relay-to-Relay Communications.** Enhanced MIRRORED BITS® communications can monitor relay element conditions between banks within a station, or between stations, using SEL fiber-optic transceivers. Send digital, analog, and virtual terminal data over the same MIRRORED BITS channel.
- **Sequential Events Recorder (SER).** Record the last 1000 entries, including setting changes, power-ups, and selectable logic elements.
- **Comprehensive Metering.** Improve system load profiles by using built-in, high-accuracy metering functions. Power Factor and VAR measurements optimize capacitor bank operation. Minimize equipment needs with full metering capabilities including rms, maximum/minimum, demand/peak, energy, and instantaneous values.
- **Parallel Redundant Protocol (PRP).** Available in SEL-487V relays equipped with Ethernet, PRP provides redundancy by assigning each of the two available Ethernet ports to separate networks carrying identical information.
- **High-Accuracy Time-Stamping.** Time-tag binary COMTRADE event reports with real-time accuracy of better than 10 µs. View system state information to an accuracy of better than a quarter of an electrical degree.
- **Oscillography and Event Reporting.** Record voltages and currents at up to 8 kHz sampling rate. Record up to 24 seconds of 1 kHz COMTRADE event data for each event, and store at least five of these events in nonvolatile memory within the relay. Off line phasor and harmonic analysis features allow investigation of relay and system performance.
- **Harmonic Metering.** The relay provides individual harmonic content from fundamental through the 15th harmonic for all current and voltage channels. Total Harmonic Distortion shall be provided as a percentage of the fundamental.
- **Thermal Overload Protection.** The SEL-487V with the SEL-2600A RTD Module provides dynamic thermal overload protection using SELOGIC control equations.
- **Rules-Based Settings Editor.** Communicate with and set the relay with an ASCII terminal, or use the PC-based ACSELERATOR QuickSet to configure the SEL-487V and analyze fault records with relay element response.

- ➤ **Configurable Synchrophasor Data Streams.** The relay supports up to five unique synchrophasor data streams over Ethernet. Each data stream shall provide selectable voltage and current quantities with configurable data labels.
- ➤ **Auxiliary Trip/Close Pushbuttons.** These optional pushbuttons are electrically isolated from the rest of the relay. They function independently from the relay and do not need relay power.
- ➤ **Directional Elements.** Phase and ground directional elements shall be provided with voltage polarization.

Functional Overview



* Phase Voltage Differential (87V), Neutral Voltage Differential (87VN), and Current Unbalance (60P or 60N) are selected based upon application settings. Only one of these protection methods is used depending upon the capacitor bank configuration.

** Switches G1, G2, G3 are settings that select up to three neutral voltage differential elements in the relay.

Figure 1 Functional Diagram

Table 1 Protection Elements

Element ANSI Number	Description	Quantity
27	Undervoltage	6
32	Directional Power	10
46	Current Unbalance	1
50	Instantaneous Overcurrent	3 Phase, 3 Negative-Sequence, 3 Ground
50BF	Breaker Failure	1
51S	Selectable Time Overcurrent	10
59	Overvoltage	6
60N	Neutral-Current Unbalance	3
60P	Phase-Current Unbalance	3
87V	Voltage Differential	3
87VN	Neutral-Voltage Differential	3
LOP	Loss of Potential	2
CTL	Automatic Voltage Control	3
59T	Inverse-Time Overvoltage Elements	

Protection Features

Phase-Voltage Differential Elements

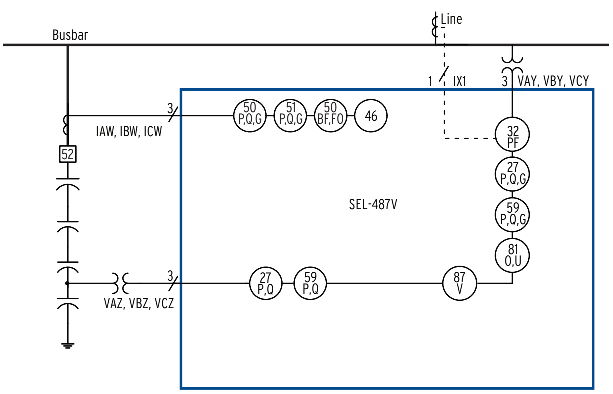


Figure 2 Phase-Voltage Differential One-Line Diagram

The SEL-487V provides three phase-voltage differential elements. These elements are used to measure voltage differences between bus or line phase voltages and the tapped voltage of the grounded wye capacitor bank. Each phase-voltage differential element is provided with a differential voltage-nulling algorithm, referred to as the KSET function. A **KSET** command is issued to the relay via serial or Telnet communications. Once received by the relay, the **KSET** command acts to zero out any existing voltage differential. The KSET function is intended to provide a means for removing small voltage differential levels due to variations in individual capacitor elements from manufacturing, potential transformer, or CCVT measurement error.

Each phase differential element is provided with three levels of detection, each with its own definite-time delay. A low-set alarm level, trip pickup level, and high-level trip pickup are provided.

The phase differential elements are used to detect variations in capacitor bank impedance, due to loss of individual capacitor elements, an entire capacitor can or an entire group of capacitor cans. Two cycle cosine filtering is used to minimize voltage transients due to line switching operations.

Neutral-Voltage Differential Elements

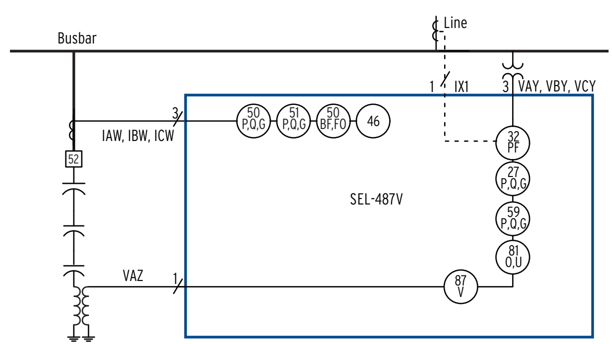


Figure 3 Neutral-Voltage Differential One-Line Diagram

The SEL-487V provides three neutral-voltage differential elements for protection of up to three ungrounded wye capacitor banks. The neutral-voltage differential elements of the SEL-487V calculate zero-sequence voltage from the three-phase potential inputs provided from the line or bus. The zero-sequence voltage is then compared to the zero-sequence voltage measured by a potential transformer connected between the capacitor bank neutral and ground. As with the phase differential elements, the neutral-voltage differential element uses a KSET nulling function to eliminate differential voltage caused by manufacturing tolerances of the capacitor bank and voltage measurement devices. Sensitive measurement of the inputs allows as little as 30 millivolts of differential voltage to be detected.

Each neutral-voltage differential element is provided with three pickup levels with independent definite-time delay. The three levels provide alarm, trip, and catastrophic failure protection for the capacitor bank.

Phase-Current Unbalance Elements

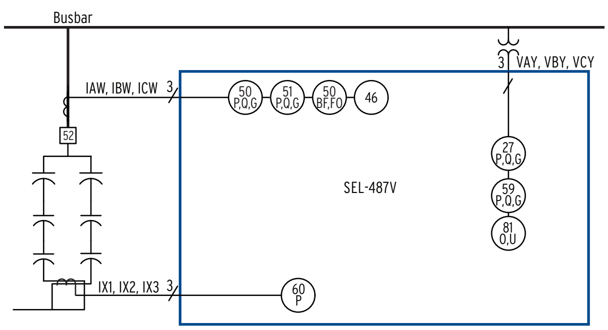


Figure 4 Phase-Current Unbalance One-Line Diagram

The SEL-487V protects grounded and ungrounded double-wye capacitor bank applications with phase-current unbalance detection. The SEL-487V provides three independent phase-current unbalance elements with KSET nulling functions. The phase unbalance elements use the positive-sequence current as a reference to enhance sensitivity and provide a directional indication. Fault direction is indicated based upon the polarity of the phase-current transformer connection to the relay.

Each phase-current unbalance element is provided with three pickup levels, with independent definite-time delay.

Neutral-Current Unbalance Elements

Protect ungrounded capacitor bank configurations with the SEL-487V neutral-current unbalance elements. Three elements are provided for protection of up to three parallel capacitor banks. Each element is provided with three levels of pickup with definite-time delay.

KSET nulling is provided for each neutral-current element, and is activated by issuing the **KSET** command via relay serial port or through Telnet session with the relay.

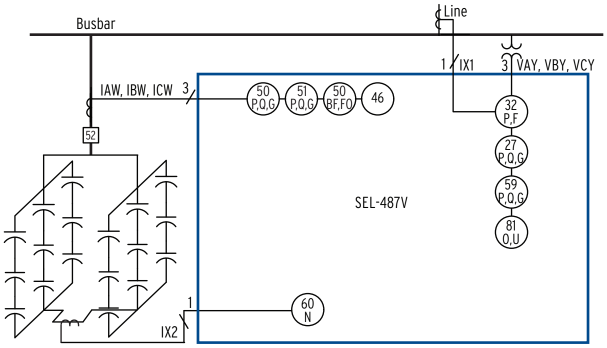


Figure 5 Neutral-Current Unbalance One-Line Diagram

Overcurrent Elements

The SEL-487V calculates instantaneous overcurrent elements for phase, negative-sequence, and zero-sequence currents. The relay offers three levels of phase, negative-, and zero-sequence overcurrent protection for the W terminal current inputs. Torque control is provided for each element.

The SEL-487V also includes ten selectable operating quantity inverse-time overcurrent elements. You can select the operating quantities from the following:

- IA
- IB
- IC
- MAX (IA, IB, IC) (where IA, IB, IC can be fundamental or rms quantities from Terminal W)
- I1
- 3I2
- IG

Individual torque control settings are provided for each time-overcurrent element.

The time-overcurrent curves (listed in *Table 2*) have two reset characteristic choices for each time-overcurrent element. One choice resets the elements if current drops below pickup for one cycle. The other choice emulates the reset characteristic of an electromechanical induction disc relay.

Table 2 Time-Overcurrent Curves

US	IEC
Moderately Inverse	Standard Inverse
Inverse	Very Inverse
Very Inverse	Extremely Inverse
Extremely Inverse	Long-Time Inverse
Short-Time Inverse	Short-Time Inverse

Undercurrent Elements

The relay includes six undercurrent elements, each with two levels, for a total of 12 undercurrent outputs for detecting loss of load conditions. All 12 elements provide both instantaneous and time-delayed outputs. You can use SELOGIC control equations to switch the 12 elements in or out of service.

Voltage Elements

The SEL-487V provides six independent over- and undervoltage elements with two pickup levels. The first pickup level is provided with a definite-time delay. Choose from a wide range of fundamental and rms operating quantities for the Y and Z terminal voltage inputs. *Table 3* shows the voltage inputs available for use as operating quantities.

Table 3 Voltage Element Operating Quantities

Analog Quantity	Description
VA, VB, VC	L–N Phase Voltage
VNMAX, VNMIN	Neutral Voltage Min/Max
VAB, VBC, VCA	L–L Phase Voltage
VA–VN[a], VB–VN[a], VC–VN[a]	Phase Voltage with Neutral Voltage Subtracted
VPMAX, VPMIN	Phase Voltage Min/Max
V1[a], 3V2[a], 3V0[a]	Positive-, Negative-, Zero-Sequence

[a] Fundamental quantities only.

Inverse-Time Overvoltage Elements

Six inverse-time overvoltage elements are provided, and are designed to meet the IEC 60871-1:2005 standard for maximum allowable overvoltage for capacitor banks in service. Selectable operating quantities provide flexibility for the input to the inverse time overvoltage elements, and the built-in logic tracks overvoltage duration with respect to operating time.

Frequency Elements

The SEL-487V provides six frequency elements, driven from either the Y or the Z potential transformers. Any of the six elements may be configured for over- or under-frequency. Each frequency element provides a pickup time delay setting. The frequency elements are supervised by a programmable undervoltage element. The undervoltage element can be set to monitor either Y or Z potential inputs, and will block the assertion of the 81 element when the selected voltage input falls below a programmable undervoltage supervision threshold.

Current Unbalance

The SEL-487V uses the average three-phase terminal current on the W current terminals to calculate the percentage difference between the individual phase current and the terminal average current. If the percentage difference is greater than the set pickup value the phase unbalance element is asserted. To prevent this element from asserting during fault conditions and after a terminal circuit breaker has closed, the final terminal unbalance output (46*n*P) is supervised, using current, fault detectors, and the open-phase detection logic. The current unbalance logic is blocked from operating if any of the following conditions is true:

- The mean terminal current is less than 5% or greater than 200% of I nominal (I_{NOM} = 1 A or 5 A)
- The FAULT Relay Word is asserted
- The circuit breaker has been closed (open phase detection element has deasserted for a settable dropout period)

Breaker Failure Protection

Incorporated into the SEL-487V is a full function breaker failure system. High-speed open-pole detection logic allows you to set the pickup current below minimum load for sensitivity without sacrificing high-speed dropout. Even in cases with delayed current zero in the secondary of the CT caused by trapped flux, high-speed detection of circuit breaker opening is achieved. This feature is essential if breaker failure is initiated on all circuit breaker trips. A reset of less than one cycle reduces coordination times, improving stability.

Breaker Flashover Detection

The SEL-487V provides logic to detect a reignition or restrike (also called flashover) across any one of the three breaker poles of the W terminal breaker after the breaker has opened.

The SEL-487V uses rms current measurement and open-phase detection logic to detect breaker flashover conditions that may exist during capacitor switching operations.

Multiple restrike or reignition conditions are typically indicative of contaminated dielectric material, reduced breaker contact separation, or an improperly rated breaker.

Thermal Overload Protection

The SEL-487V provides three independent IEC thermal models for thermal overload protection of a variety of devices, including in-line reactors used to limit capacitor bank switching transients.

Ambient temperature measurements for the thermal model are provided using the SEL-2600 RTD Module.

Loss-of-Potential (LOP) Logic Supervises Voltage Elements

The SEL-487V includes logic to detect a loss-of-potential (LOP) caused by failures such as blown fuses, which can cause an incorrect operation in voltage elements. Configure the LOP logic to block voltage differential elements under these conditions. The logic checks for a sudden change in positive-sequence voltage without a corresponding change in positive- or zero-sequence current. Tests and field experience show that this principle is very secure and is faster than the tripping elements.

Faulted Phase and Section Identification Logic

The SEL-487V makes sensitive measurements of the magnitude and phase angle of differential quantities generated by the failure of fuses or elements within the capacitor bank. The SEL-487V uses these measurements to automatically determine the faulted phase (A, B, C) and section (top, bottom or left, right) in grounded and ungrounded capacitor bank applications. The faulted phase and section identification logic can be used to provide local or remote indication of the problem area within the capacitor bank so that fault location identification times are reduced. The faulted phase and section identification logic is processed each time a differential alarm, trip, or high-set element asserts.

Six Independent Settings Groups Increase Operation Flexibility

The relay stores six settings groups. Select the active settings group by control input, command, or other programmable conditions. These settings groups can cover a wide range of control contingencies and operating conditions. Selectable settings groups make the SEL-487V ideal for applications requiring frequent settings changes and for adapting to changing system conditions.

Selecting a group also selects logic settings. Program group logic to adjust settings for different operating conditions, such as station maintenance, seasonal operations, emergency contingencies, loading, source changes, and adjacent relay settings changes.

Local Control

The SEL-487V provides dynamic one-line bay diagrams on the front-panel screen with disconnect and breaker control capabilities for predefined user-selectable bay types. The relay is equipped to control as many as ten disconnects and a single breaker, depending on the one-line diagram selected. Operate disconnects and the breaker with ASCII commands, SELOGIC control equations, Fast Operate messages, and from the one-line diagram. The one-line diagram includes user-configurable apparatus labels and as many as six user-definable analog quantities.

One-Line Bay Diagrams

The SEL-487V offers a variety of preconfigured one-line diagrams for common bus and capacitor bank configurations. Once a one-line diagram is selected, the user has the ability to customize the names for all of the disconnect switches, capacitor bank, buses, and breaker. Most one-line diagrams contain analog display points. These display points can be set to any of the available analog quantities with labels, units, and scaling. These values are updated real-time along with the breakers and switch position to give instant status and complete control of a bay.

The operator can see all valuable information on a bay before making a critical control decision. Programmable interlocks help prevent operators from incorrectly opening or closing switches or breakers. The SEL-487V will not only prevent the operator from making an incorrect control decision, but can notify and/or alarm when an incorrect operation is initiated.

Circuit Breaker Operations From the Front Panel

The one-line diagram is selectable from the Bay settings. Additional settings for defining labels and analog quantities are also found in the Bay settings of the relay. One-line diagrams are composed of the following:

- Bay Names and Bay Labels
- Busbar and Busbar Labels
- Breaker and Breaker Labels
- Capacitor Bank Labels
- Disconnect Switches and Disconnect Switch Labels
- Analog Display Points

Figure 6 shows the breaker control screens available when the **ENT** pushbutton is pressed with the circuit breaker highlighted as shown in *Figure 6*(a). After pressing the **ENT** pushbutton with the breaker highlighted and the LOCAL Relay Word bit asserted, the breaker control screen in *Figure 6*(b) is displayed. After entering the screen in *Figure 6*(b), the relay performs the circuit breaker operations as outlined in the SEL-487V *Instruction Manual*. If the LOCAL Relay Word bit is not asserted when the **ENT** pushbutton is pressed, the screen in *Figure 6*(c) is displayed for three seconds, then the relay displays again the screen in *Figure 6* (a).

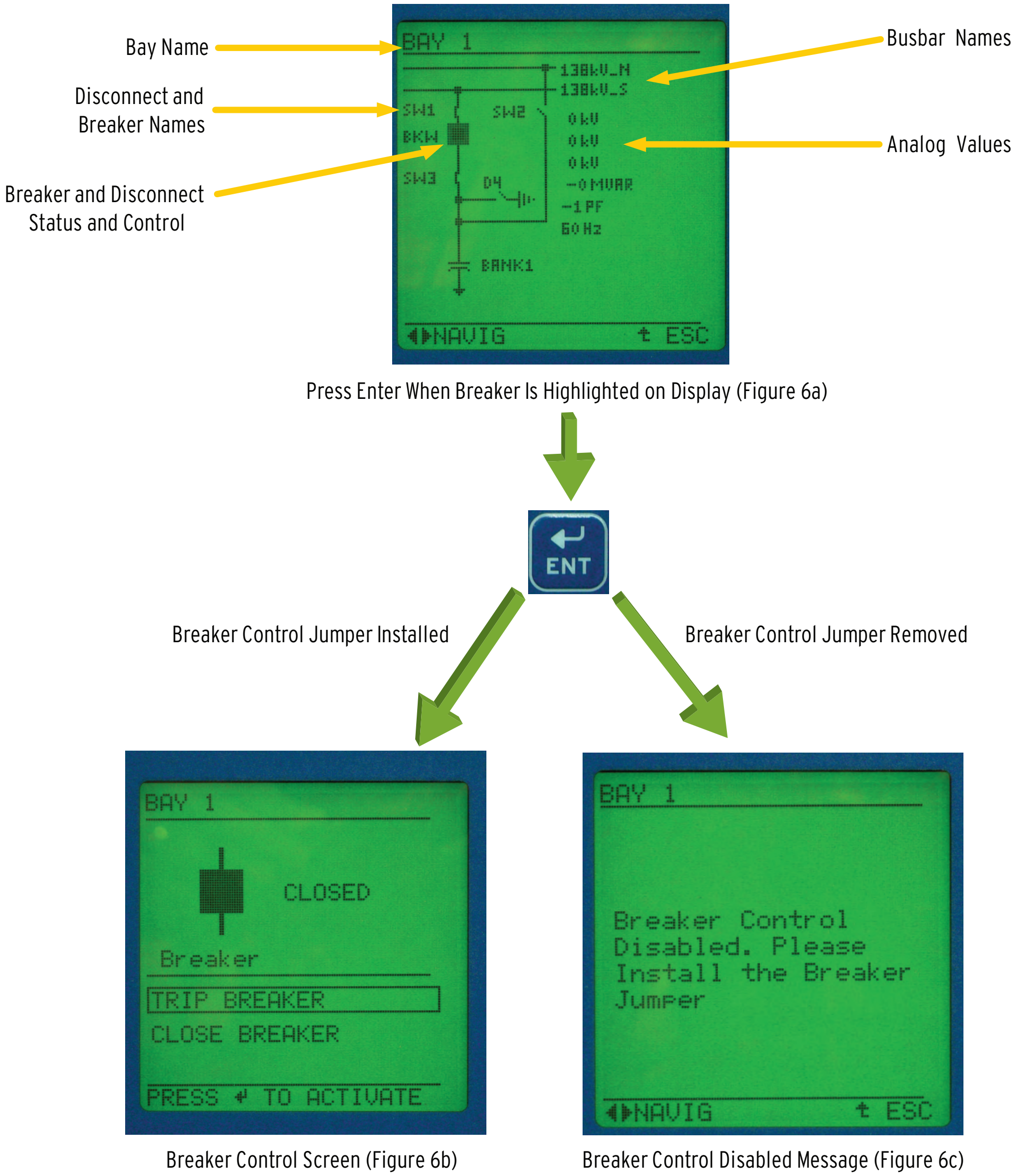


Figure 6 Screens for Circuit Breaker Selection

Rules-Based Settings Editor

ACSELERATOR QuickSet helps develop settings off-line. The system automatically checks interrelated settings and highlights out-of-range settings. Settings created off-line can be transferred by using a PC communications link with the SEL-487V. The ACSELERATOR QuickSet interface supports Server 2008, Windows® 7, and Windows 8 operating systems and can be used to open COMTRADE files from SEL and other products. Convert binary COMTRADE files to ASCII format for portability and ease of use. View real-time phasors and harmonic values.

ACSELERATOR QuickSet Relay Settings Interface

There are two ways to enter relay settings with the ACSELERATOR QuickSet settings interface. The standard style settings are displayed in traditional form under the relay form. ACSELERATOR QuickSet also provides an interactive relay setting entry method. The interactive method works by clicking on the one-line diagram labels. This action automatically displays all the settings for the device selected. This method provides an easy way of organizing and verifying all settings associated with the device.

Figure 7 illustrates the interactive relay settings form in ACSELERATOR QuickSet. Click on an apparatus in the one-line diagram, and a form with apparatus-specific settings is displayed.

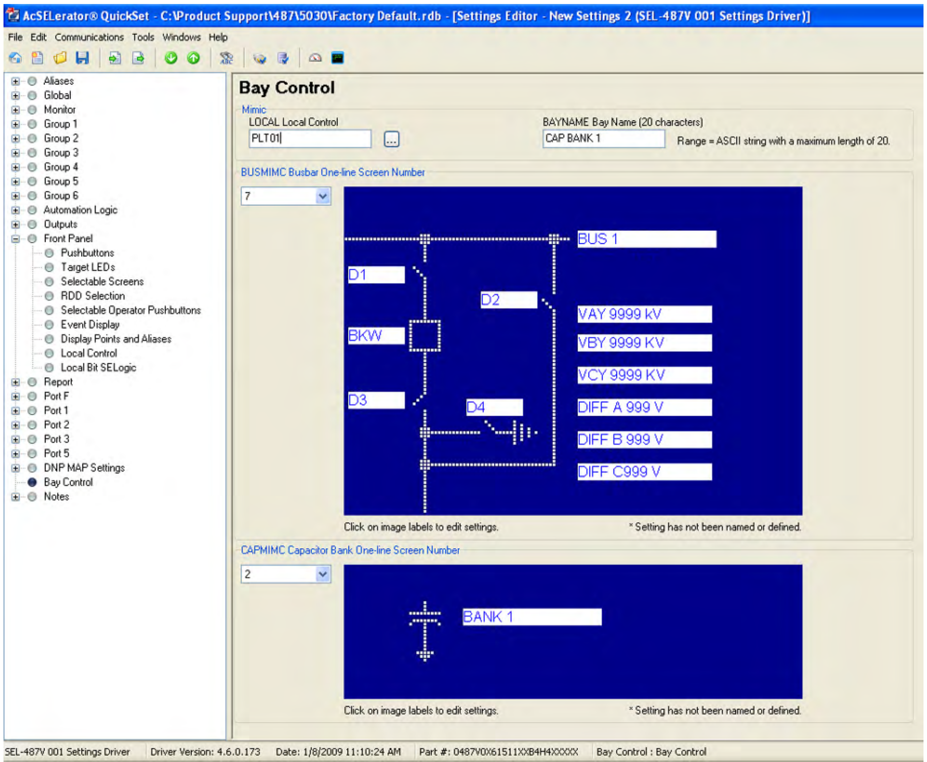


Figure 7 Interactive Relay Settings Form

ACSELERATOR QuickSet Templates

Use the fully licensed version of ACSELERATOR Quick-Set to create custom views of settings, called Application Designs, to reduce complexity, decrease the chance of errors, and increase productivity.

- ➤ Lock and hide unused settings
- ➤ Lock settings to match your standard for protection, I/O assignment, communication, and SELOGIC control equations
- ➤ Enforce settings limits narrower than the device settings
- ➤ Define input variables based on the equipment nameplate or manufacturer's terminology or scaling and calculate settings from these "friendlier" inputs
- ➤ Use settings comments to guide users and explain design reasoning

Front-Panel Display

The liquid crystal display (LCD) shows event, metering, settings, and relay self-test status information. The target LEDs display relay target information as described in *Figure 8* and explained in *Table 4*.

The LCD is controlled by the navigation pushbuttons (*Figure 9*), automatic messages the relay generates, and user-programmed analog and digital display points. The rotating display scrolls through the bay screen, alarm points, display points, and metering screens. Each display remains for a user-programmed time (1–15 seconds) before the display continues scrolling. Any message generated by the relay because of an alarm condition takes precedence over the rotating display.

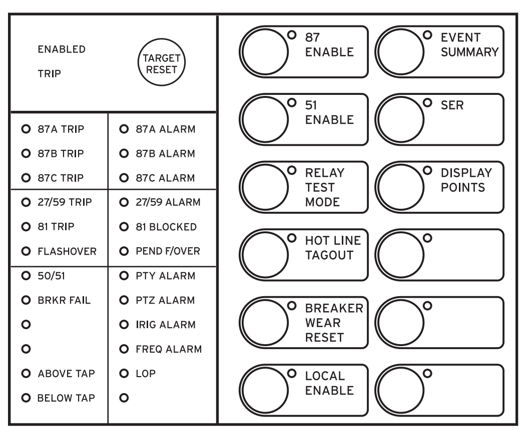


Figure 8 Factory-Default Status and Trip Target LEDs (12 Pushbutton, 24 Target Option)

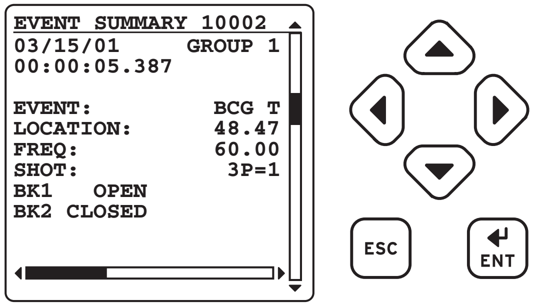


Figure 9 Factory-Default Front-Panel Display and Pushbuttons

Close-up views of the front panel of the SEL-487V are shown in *Figure 8*, *Figure 9*, and *Figure 10*. The front panel includes a 128 pixel by 128 pixel, 3 in. by 3 in. LCD screen, LED target indicators, and pushbuttons with indicating LEDs for local control functions. The asserted and deasserted colors for the LEDs are programmable. Configure any of the direct-acting pushbuttons to navigate directly to an HMI menu item, such as events, bay display, alarm points, display points, or the SER.

Status and Trip Target LEDs

The SEL-487V includes programmable status and trip target LEDs, as well as programmable direct-action control pushbuttons/LEDs on the front panel. These targets are shown in *Figure 8* and *Figure 10* and are explained in *Table 4*.

Table 4 Description of Factory-Default Target LEDs
(Sheet 1 of 2)

ENABLED	Relay Powered Properly and Self-Tests Okay
TRIP	Indication that a trip occurred
87A TRIP	A-Phase Voltage Differential Asserted
87B TRIP	B-Phase Voltage Differential Asserted
87C TRIP	C-Phase Voltage Differential Asserted
27/59 TRIP	Under/Overvoltage Trip
81 TRIP	Under/Overfrequency Trip
FLASHOVER	Breaker Flashover Detected
50/51	Overcurrent Element Asserted
BRKR FAIL	Breaker Failure Element Asserted
ABOVE TAP	Differential Fault Above Tap
BELOW TAP	Differential Fault Below Tap
87A ALARM	A-Phase Differential Alarm
87B ALARM	B-Phase Differential Alarm
87C ALARM	C-Phase Differential Alarm
27/59 ALARM	Under/Overvoltage Alarm
81 BLOCKED	Frequency Element Blocked
PEND F/OVER	Breaker Flashover Pending

Table 4 Description of Factory-Default Target LEDs
(Sheet 2 of 2)

ENABLED	Relay Powered Properly and Self-Tests Okay
PTY ALARM	Potential Transformer Y Alarm
PTZ ALARM	Potential Transformer Z Alarm
IRIG ALARM	IRIG Clock Alarm
FREQ ALARM	Frequency Tracking Alarm
LOP	Loss-of-Potential Condition

The SEL-487V features a versatile front panel that you can customize to fit your needs. SELOGIC control equations and slide-in configurable front-panel labels change the function and identification of target LEDs and operator control pushbuttons and LEDs. The blank slide-in label set is included with the SEL-487V. Label sets can be printed from a laser printer using templates supplied with the relay or hand labeled on supplied blank labels.

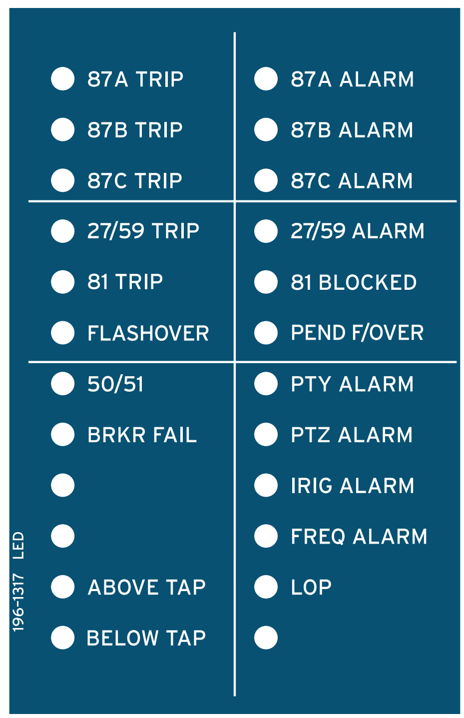


Figure 10 Programmable Status and Trip Target LEDs

Advanced Display Points

Create custom screens showing metering values, special text messages, or a mix of analog and status information. *Figure 11* shows an example of how display points can be used to show circuit breaker information and current metering. As many as 96 display points can be created. All display points occupy only one line on the display at all times. The height of the line is programmable as either single or double (see *Figure 11*). These screens become part of the autoscrolling display when the front panel times out.

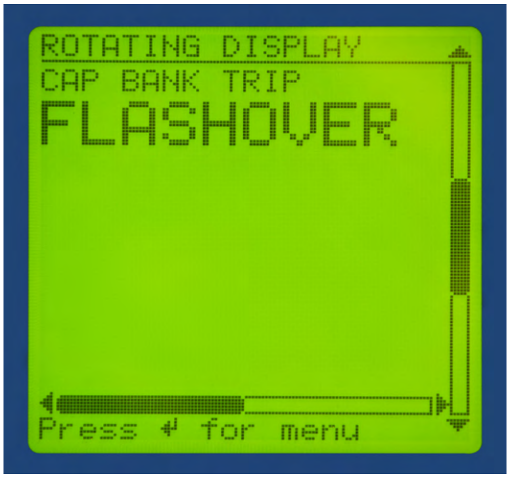


Figure 11 Sample Display Points Screen

Alarm Points

You can display messages on the SEL-487V front-panel LCD that indicates alarm conditions in the power system. The relay uses alarm points to place these messages on the LCD.

Figure 12 shows a sample alarm points screen. The relay is capable of displaying up to 66 alarm points. The relay automatically displays new alarm points while in manual-scrolling mode and in autoscrolling mode. The alarm points message is user-configurable through SER settings and can be triggered using inputs, communications, or conditional logic using powerful SELOGIC control equations. The asterisk next to the alarm point indicates an active alarm. The inactive alarms can be cleared using the front-panel navigation buttons.

Figure 12 Sample Alarm Points Screen

Auxiliary Trip/Close Pushbuttons and Indicating LEDs

Optional auxiliary trip and close pushbuttons (see *Figure 19* and *Figure 20*) and indicating LEDs allow breaker control independent of the relay. The auxiliary trip/close pushbuttons are electrically separate from the relay, operating even if the relay is powered down. Make the extra connections at Terminals 201 through 208. See *Figure 21* through *Figure 22* for a rear-panel view. *Figure 13* shows one possible set of connections.

The auxiliary trip/close pushbuttons incorporate an arc suppression circuit for interrupting dc trip or close current. To use these pushbuttons with ac trip or close circuits, disable the arc suppression for either pushbutton by changing jumpers inside the SEL-487V. The operating voltage ranges of the breaker **CLOSED** and breaker **OPEN** indicating LEDs are also jumper selectable.

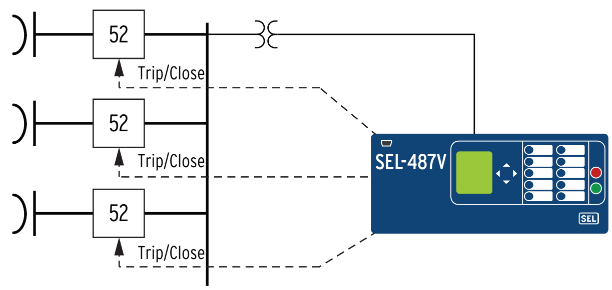


Figure 13 Universal Sequencer Capacitor Bank Staging

Universal Sequencer

The Universal Sequencer provides for the automatic sequencing of as many as three capacitor bank stages. The Universal Sequencer accumulates either time in service or an analog quantity and prioritizes bank insertion to the bank with the lowest accumulated value. Bank removal can prioritize banks with the highest or lowest accumulated value or by a predetermined sequence.

Monitoring and Metering

Complete Metering Capabilities

The SEL-487V provides extensive metering capabilities as listed in *Table 5*.

Voltage Sag, Swell, Interruption Records

The SEL-487V can perform automatic voltage disturbance monitoring for three-phase systems. The sag/swell/interruption (SSI) recorder uses the SSI Relay Word bits to determine when to start (trigger) and when to stop recording. The SSI recorder uses nonvolatile memory, so de-energizing the relay will not erase any stored SSI data.

The recorded data are available through the SSI report, which includes date, time, current, voltage, and voltage sag/swell/interruption (VSSI) element status during voltage disturbances, as determined by programmable settings VINT, VSAG, and VSWELL. When the relay is recording a disturbance, entries are automatically added to the SSI report at one of four rates, depending on the length of the disturbance:

- once per quarter cycle
- once per cycle
- once per 64 cycles
- once per day

Event Reporting and Sequential Events Recorder (SER)

Event reports and SER features simplify post-fault analysis and help improve your understanding of both simple and complex protective scheme operations. These features also aid in testing and troubleshooting bay settings and control schemes. Oscillograms are available in binary COMTRADE and ASCII COMTRADE formats.

Oscillography and Event Reporting

In response to a user-selected internal or external trigger, the voltage, current, and element status information contained in each event report confirms relay, scheme, and system performance for every fault. Decide how much resolution analog data are necessary when an event report is triggered: 8 kHz, 4 kHz, 2 kHz, or 1 kHz. The relay stores from 24 seconds of data per fault at 1 kHz resolution to 3 seconds per fault at 8 kHz resolution. Reports are stored in nonvolatile memory. Bay settings operational in the bay at the time of the event are appended to each event report. The relay stores at least five events at the maximum report length.

Event Summary

Each time the SEL-487V generates a standard event report, it also generates a corresponding event summary. This is a concise description of an event that includes bay/terminal identification, event date and time, fault location, phase voltages, fault type at time of trip, and trip and close times.

With an appropriate setting, the relay will automatically send an event summary in ASCII text to one or more serial ports each time an event report is triggered.

Harmonic and THD Metering

Accurately measure harmonic current and voltage content up to the 15th harmonic with the SEL-487V Harmonic Metering Function. The **MET H** command provides harmonic content measurement for individual harmonics from fundamental through the 15th harmonic. Individual harmonic content measurement is also available as a percent of the fundamental, and the SEL-487V also provides percent total harmonic distortion (%THD) as an analog quantity for use in custom protection and automation logic.

```
=>>MET H <Enter>

Relay 1                                    Date: 03/17/2013  Time: 12:39:56.328
Station A                                  Serial Number: 1120820717

Magnitudes of Harmonic Inputs (Amps Sec, Volt Sec)
 H  IAW   IBW   ICW   IAX   IBX   ICX    VAY    VBY    VCY    VAZ    VBZ    VCZ
 1  1.00  1.00  1.00  0.00  0.00  0.00   60.00  60.00  60.00  0.00   0.00   0.00
 2  0.00  0.00  0.00  0.00  0.00  0.00   0.01   0.00   0.00   0.00   0.00   0.00
 3  0.50  0.50  0.50  0.00  0.00  0.00   19.79  19.76  19.81  0.00   0.00   0.00
 4  0.00  0.00  0.00  0.00  0.00  0.00   0.00   0.00   0.00   0.00   0.00   0.00
 5  0.50  0.50  0.50  0.00  0.00  0.00   19.75  19.73  19.76  0.00   0.00   0.00
 6  0.00  0.00  0.00  0.00  0.00  0.00   0.00   0.00   0.00   0.00   0.00   0.00
 7  0.00  0.00  0.00  0.00  0.00  0.00   0.00   0.00   0.00   0.00   0.00   0.00
 8  0.00  0.00  0.00  0.00  0.00  0.00   0.00   0.00   0.00   0.00   0.00   0.00
 9  0.00  0.00  0.00  0.00  0.00  0.00   0.00   0.00   0.00   0.00   0.00   0.00
10  0.00  0.00  0.00  0.00  0.00  0.00   0.01   0.00   0.00   0.00   0.00   0.00
11  0.00  0.00  0.00  0.00  0.00  0.00   0.01   0.00   0.00   0.00   0.00   0.00
12  0.00  0.00  0.00  0.00  0.00  0.00   0.00   0.00   0.00   0.00   0.00   0.00
13  0.00  0.00  0.00  0.00  0.00  0.00   0.00   0.00   0.00   0.00   0.00   0.00
14  0.00  0.00  0.00  0.00  0.00  0.00   0.00   0.00   0.00   0.00   0.00   0.00
15  0.00  0.00  0.00  0.00  0.00  0.00   0.00   0.00   0.00   0.00   0.00   0.00

FREQ (Hz) 60.000          Frequency Tracking = Y
```

Sequential Events Recorder (SER)

This feature provides a broad perspective of relay element operation. Items that trigger an SER entry are selectable and can include input/output change of state, element pickup/dropout, recloser state changes, etc. The relay SER stores the latest 1,000 entries.

Analog Signal Profiling

The SEL-487V provides analog signal profiling for up to 20 analog quantities. Any analog quantity measured or calculated by the SEL-487V can be selected for analog signal profiling. Signal sampling rates of 1, 5, 15, 30, and 60 minutes can be selected through settings. The analog signal profile report provides a comma-separated variable (CSV) list that can be loaded into any spreadsheet or database for analysis and graphical display.

SELOGIC enable/disable functions can start and stop signal profiling based on Boolean or analog comparison conditions.

High-Accuracy Timekeeping

With a combination of IRIG-B and a global positioning satellite, the SEL-487V time-tags oscillography to within 10 µs accuracy. This high accuracy can be combined with the high sampling rate of the relay to synchronize data from across the system with an accuracy of better than 1/4 electrical degree. This allows examination of the power system state at given times, including load angles, system swings, and other system-wide events. Triggering can be via external signal (contact or communications port), set time, or system event. Optimal calibration of this feature requires a knowledge of primary input component (VT and CT) phase delay and error.

A single IRIG-B time-code input synchronizes the SEL-487V time to within ±1 ms of the time-source input. A convenient source for this time code is the SEL-2032 Communications Processor (via Serial Port 1 on the SEL-487V).

SNTP Time Synchronization

Use simple network time protocol (SNTP) to cost-effectively synchronize SEL-487V relays equipped with Ethernet communication to as little as ±5 ms over standard Ethernet networks. Use SNTP as a primary time source, or as a backup to a higher accuracy IRIG-B time input to the relay.

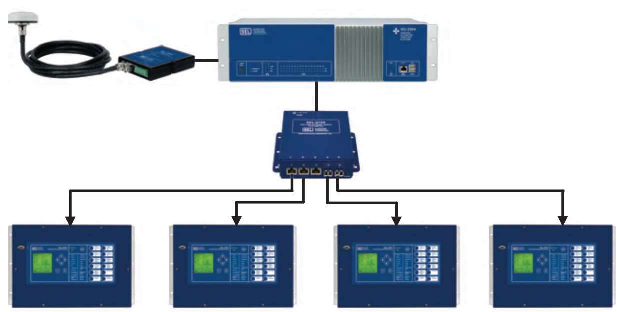


Figure 14 SNTP Diagram

Substation Battery Monitor for DC Quality Assurance

The SEL-487V measures and reports the substation battery voltage. Programmable threshold comparators and associated logic provide alarm and control of batteries and charger. The relay also provides battery system ground detection. Monitor these thresholds with an SEL communications processor and trigger messages, telephone calls, or other actions.

The measured dc voltage is reported in the METER display via serial port communications, on the LCD, and in the event report. The event report data provides an oscillographic display of the battery voltage. Monitor the substation battery voltage drops during trip, close, and other control operations.

Breaker Monitor Feature Allows for Wear-Based Breaker Maintenance Scheduling

Circuit breakers experience mechanical and electrical wear at each operation. Effective scheduling of breaker maintenance takes into account the manufacturer's published data of contact wear versus interruption levels and operation count. The SEL-487V breaker monitor feature compares the breaker manufacturer's published data to the integrated actual interrupted current and number of operations.

- Every time the breaker trips, the relay integrates interrupted current. When the result of this integration exceeds the threshold set by the breaker wear curve (*Figure 15*), the bay can alarm via an output contact or the optional front-panel display. With this information, you can schedule breaker maintenance in a timely, economical fashion.
- Monitor last an average mechanical and electrical interruption time per pole. You can easily determine if operating time is increasing beyond reasonable tolerance to schedule proactive breaker maintenance. You can activate an alarm point if operation time goes beyond a preset value.
- Breaker motor run time and breaker inactivity are also recorded for each breaker operation.

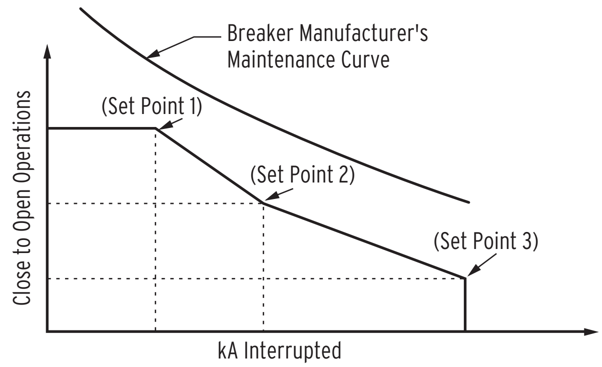


Figure 15 Breaker Contact Wear Curve and Settings

Table 5 Metering Capabilities

Capabilities	Description
Instantaneous Quantities	
Voltages VA, B, C (Y), VA, B, C (Z), V, 3V0, V1, 3V2	0–300 V with phase quantities for each of the six voltage sources available as a separate quantity.
Currents $I_{A,B,C}$ (W), $I_{A,B,C}$ (X) I_AL, I_BL, I_CL (combined currents) IGL, I1L, 3I2L (combined currents)	Phase quantities for each of the two current sources available as a separate quantity or combined as line quantities.
Power/Energy Metering Quantities	
MW, MWh, MVAR, MVARh, MVA, PF, single-phase, and three-phase	Available for each input set and as combined quantities for the line.
Demand/Peak Metering	
$I_{A,B,C}$, 3I2, 3I0	Thermal or rolling interval demand and peak demand.
MW, MVAR, MVA, single-phase	Thermal or rolling interval demand and peak demand.
MW, MVAR, MVA, three-phase	Thermal or rolling interval demand and peak demand.

Automation

Flexible Control Logic and Integration Features

SEL-487V control logic:

- Replaces traditional panel control switches
- Eliminates RTU-to-bay wiring
- Replaces traditional latching relays
- Replaces traditional indicating panel lights
- Performs real-time control using synchrophasor data

Eliminate traditional panel control switches with 32 local control points. Set, clear, or pulse local control points with the front-panel pushbuttons and display. Program the local control points to implement your control scheme via SELOGIC control equations. The local control points provide functions such as trip testing, enabling/disabling reclosing, and tripping/closing circuit breakers.

Eliminate RTU-to-bay wiring with 32 remote control points. Set, clear, or pulse remote control points via serial port commands. Incorporate the remote control points into your control scheme via SELOGIC control equations. Remote control points can be applied to SCADA-type control operations (e.g., trip, close, settings group selection).

Replace traditional latching relays for such functions as remote control enable with 32 latching control points. Program latch set and latch reset conditions with SELOGIC control equations. Set or reset the latch control points via control inputs, remote control points, local control points, or any programmable logic condition. The latch control points retain states when the relay loses power.

Replace traditional indicating panel lights and switches with 24 latching target LEDs and 12 programmable pushbuttons with LEDs. Define custom messages (i.e., BREAKER OPEN, BREAKER CLOSED, CONTROL ENABLED) to report power system or relay conditions on the large format LCD. Control which messages are displayed via SELOGIC control equations by driving the LCD display via any logic point in the relay.

Perform real-time control logic using synchrophasor data by using local or remote synchrophasor data that is available as analog quantities to SELOGIC. Local synchrophasor data provided by the host relay, or remote data received as C37.118 serial data are accessible. Voltage and current magnitudes and angles, frequency, and rate-of-change of frequency (df/dt) are provided.

Open Communications Protocols

The SEL-487V does not require special communications software. ASCII terminals, printing terminals, or a computer supplied with terminal emulation and a serial communications port are all that is required. *Table 6* lists a brief description of the terminal protocols.

Table 6 Open Communications Protocols

Type	Description
ASCII	Plain-language commands for human and simple machine communications. Use for metering, setting, self-test status, event reporting, and other functions.
Compressed ASCII	Comma-delimited ASCII data reports. Allows external devices to obtain bay data in an appropriate format for direct import into spreadsheets and database programs. Data are checksum protected.
Extended Fast Meter, Fast Operate, and Fast SER	Binary protocol for machine-to-machine communication. Quickly updates SEL-2032 Communications Processors, RTUs, and other substation devices with metering information, bay element, I/O status, time-tags, open and close commands, and summary event reports. Data are checksum protected. Binary and ASCII protocols operate simultaneously over the same communications lines so that control operator metering information is not lost while a technician is transferring an event report.
Ymodem	Support for reading event, settings, and oscillography files.
Optional DNP3 Level 2 Outstation	Distributed Network Protocol with point remapping. Includes access to metering data, protection elements, contact I/O, targets, SER, relay summary event reports, and settings groups
IEEE C37.118	Phasor measurement protocol.
IEC 61850	Ethernet-based international standard for interoperability between intelligent devices in a substation.
PRP	Parallel Redundancy Protocol provides redundant Ethernet network capabilities for seamless operation in the event of loss to one network.
SNTP	Ethernet-based simple network time protocol for time synchronization among relays.

SELOGIC Control Equations With Expanded Capabilities and Aliases

Expanded SELOGIC control equations put advanced logic in the hands of the engineer. Assign the relay's contact inputs to suit your application, logically combine selected elements for various control functions, and assign outputs to your logic functions.

Programming SELOGIC control equations consists of combining relay elements, inputs, and outputs with SELOGIC control equation operators (*Table 7*). Any element in the Relay Word can be used in these equations. The SEL-487V is factory set for use without additional logic in most situations. For complex or unique applications, these expanded SELOGIC functions allow superior flexibility.

The alias capability assigns more meaningful SELOGIC variable names to relay Word Bits and analog quantities. This improves the readability of customized programming. As many as 200 aliases are provided to rename any digital or analog quantity. The following is an example of possible applications of SELOGIC control equations using aliases:

```
=>>SET T <Enter>
1: PMV01,THETA
```
(assign the alias "THETA" to math variable PMV01)
```
2: PMV02,TAN
```
(assign the alias "TAN" to math variable PMV02)
```
=>>SET L <Enter>
1: # CALCULATE THE TANGENT OF THETA
2: TAN:=SIN(THETA)/COS(THETA)
```
(use the aliases in an equation)

Add programmable control functions to your relay and automation systems. New functions and capabilities enable using analog values in conditional logic statements. The following are examples of possible applications of SELOGIC control equations with expanded capabilities.

- Scale analog values for SCADA retrieval.
- Initiate remedial action sequence based on load flow before fault conditions.
- Interlock breakers and disconnect switches.
- Restrict breaker tripping in excessive duty situations without additional relays.
- Construct a compensated overvoltage element for open line overvoltage protection.
- Hold momentary change-of-state conditions for SCADA polling.
- Provide a combination of frequency or rate-of-change frequency functions.

Table 7 SELOGIC Control Equation Operators

Operator Type	Operators	Comments
Boolean	AND, OR, NOT	Allows combination of measuring units.
Edge Detection	F_TRIG, R_TRIG	Operates at the change of state of an internal function.
Comparison	>, >=, =, <=, <, < >	
Arithmetic	+, -, *, /	Uses traditional math functions for analog quantities in an easily programmable equation.
Numerical	ABS, SIN, COS, LN, EXP, SQRT	
Precedence Control	( )	Allows multiple and nested sets of parentheses.
Comment	# or (* *)	Provides for easy documentation of control and protection logic.

Relay-to-Relay Digital Communication (MIRRORED BITS)

The SEL patented MIRRORED BITS technology provides bidirectional relay-to-relay digital communication (*Figure 16*). In the SEL-487V, MIRRORED BITS can operate simultaneously on any two serial ports for three-terminal power system operation.

This bidirectional digital communication creates additional outputs (transmitted MIRRORED BITS) and additional inputs (received MIRRORED BITS) for each serial port operating in the MIRRORED BITS communications mode. Communicated information can include digital, analog, and virtual terminal data. Virtual terminal allows the operator access to remote relays through the local relay MIRRORED BITS port. These MIRRORED BITS can be used to transfer information between the SEL-487V and other system voltage regulation devices to provide enhanced system voltage and power factor control. The dual-port MIRRORED BITS communications are capable of high-speed communications-assisted schemes for the protection and control of capacitor bank applications.

Communication

The SEL-487V offers the following serial communication features:

- Four independent EIA-232 serial ports.
- Full access to event history, relay status, and meter information.
- Strong password protection for settings and group switching.
- DNP3 Level 2 Server.
- Patented SEL Fast Message interleaving of ASCII and binary data for SCADA communications, including access to SER, relay element targets, event data, and more.
- Communication of synchronized phasor measurement data using either SEL Fast Messaging for Synchrophasors or IEEE C37.118-2005 Standard for Synchrophasors for Power Systems.

Network Connection and Integration

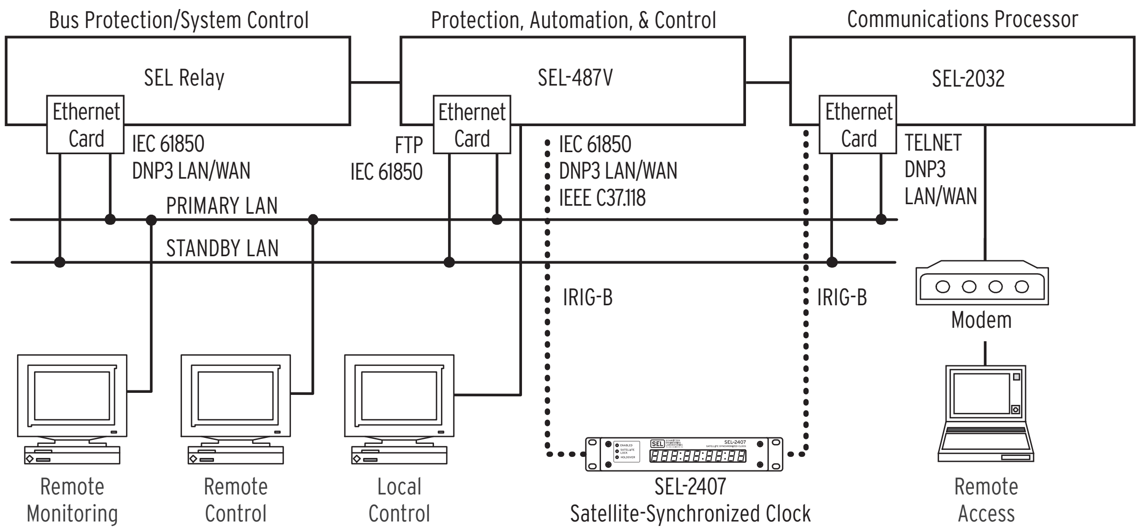


Figure 16 Network Connection and Integration

Connect the SEL-487V to Local Area Networks (LANs) using the Ethernet option. The Ethernet option allows connection of the SEL-487V to a single or dual LAN (see *Figure 18*). The integrated Ethernet card supports both copper or fiber connections with fail-over protection.

Ethernet

Telnet applications allow simple terminal communications with SEL relays and other devices. Transfer data at high speeds (10 Mbps or 100 Mbps) for fast HMI updates and file uploads. Ethernet communications use File Transfer Protocol (FTP) applications for easy and fast file transfers.

Provide operations with situational awareness of the power system using IEEE C37.118-2005 *Standard for Synchrophasors for Power Systems*. Communicate with SCADA and other substation IEDs using DNP3 or IEC 61850 logical nodes and GOOSE messaging.

Choose Ethernet connection media options for primary and standby connections:

- ➤ 10/100BASE-T twisted pair network
- ➤ 100BASE FX fiber-optic network

Telnet and FTP

Order the SEL-487V with Ethernet communications and built-in Telnet and File Transfer Protocol (FTP) that come standard with Ethernet to enhance relay communication sessions. Telnet can access relay settings, as well as metering and event reports remotely using the ASCII interface. Transfer settings files to and from the relay via the high-speed Ethernet port with FTP.

IEEE C37.118 Synchrophasors

The latest IEEE synchrophasor protocol provides a standard method for communicating synchronized phasor measurement data over Ethernet or serial media. The integrated Ethernet card in the SEL-487V provides two independent connections using either TCP/IP, UDP/IP, or a combination thereof. Each connection supports unicast data for serving data to a single client. Each data stream can support up to 60 frames per second.

DNP3 LAN/WAN

The DNP3 LAN/WAN option provides the SEL-487V with DNP3 Level 2 server functionality over Ethernet. Custom DNP3 data maps can be configured for use with specific DNP3 masters.

HTTP Web Server

When equipped with Ethernet communication, the relay can serve read-only web pages displaying certain settings, metering, and status reports. As many as four users can access the embedded HTTP server simultaneously.

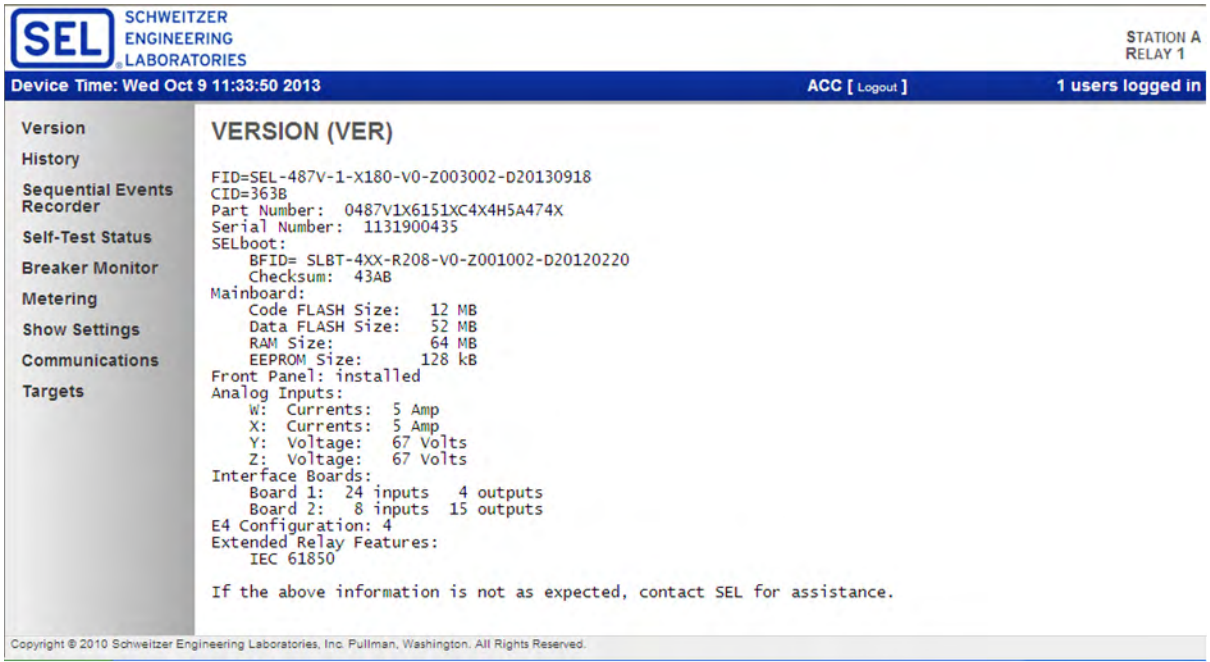


Figure 17 SEL-487V HTTP Web Server Settings Screen

IEC 61850 Ethernet Communications

IEC 61850 Ethernet-based communications provide interoperability between intelligent devices within the substation. Logical nodes using IEC 61850 allow standardized interconnection of intelligent devices from different manufacturers for monitoring and control of the substation. Reduce wiring between various manufacturers' devices and simplify operating logic with IEC 61850. Eliminate system RTUs by streaming monitoring and control information from the intelligent devices directly to remote SCADA client devices.

The SEL-487V can be ordered with embedded IEC 61850 protocol operating on 10/100 Mbps Ethernet. IEC 61850 Ethernet protocol provides relay monitoring and control functions including:

- As many as 24 incoming GOOSE messages. The incoming GOOSE messages can be used to control up to 50 control bits in the relay with <3 ms latency from device to device. These messages provide binary control inputs and analog values to the relay for high-speed control functions and monitoring.
- As many as eight outgoing GOOSE messages. Outgoing GOOSE messages can be configured for Boolean or analog data. Boolean data and designated remote analog outputs are provided with <3 ms latency from device to device. Apply outgoing GOOSE messages for high-speed control and monitoring of external breakers, switches, and other devices.
- IEC 61850 Data Server. The SEL-487V, equipped with embedded IEC 61850 Ethernet protocol, provides data according to predefined logical node objects. As many as six simultaneous client associations are supported by each relay. Relevant Relay Word bits are available within the logical node data, so status of relay elements, inputs, outputs, or SELogic equations can be monitored using the IEC 61850 data server provided in the relay.

AcSELerator Architect® SEL-5032 Software manages the logical node data for all IEC 68150 devices on the network. This Microsoft® Windows®-based software provides easy-to-use displays for identifying and binding IEC 61850 network data between logical nodes using IEC 61850 compliant Configured IED Description (CID) files. CID files are used by AcSELerator Architect to describe the data that will be provided by the IEC 61850 logical node within each relay.

Custom Control Capabilities

Customize control capabilities, adding stability and security to your system.

Expanded SELogic control equations can create advanced stability enhancements such as VAR-flow controlled time undervoltage load shedding.

Combine frequency elements with voltage supervision for added security with underfrequency load-shedding systems.

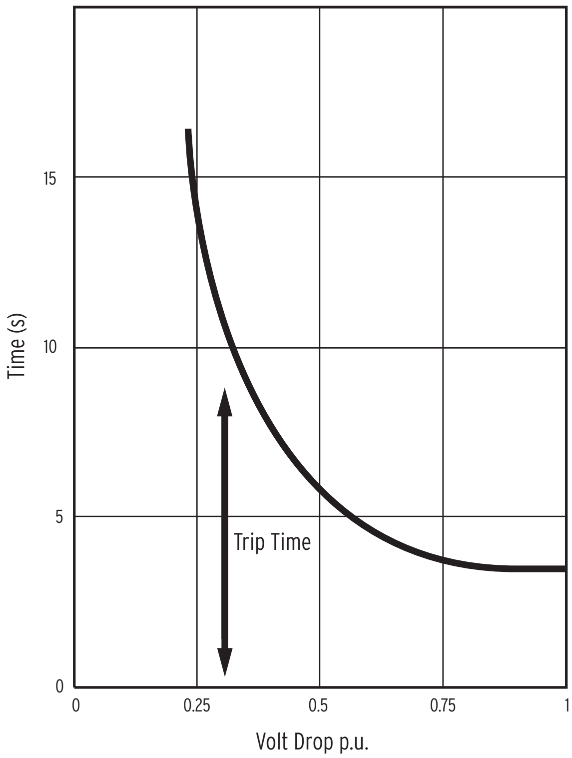


Figure 18 VAR-Flow Controlled Time Undervoltage Load Shedding

Control Inputs and Outputs

The standard SEL-487V includes five independent and two common inputs, two Form A and three Form C standard interrupting outputs, and three Form A high-current interrupting outputs. The following additional input/output (I/O) boards are currently available.

- 8 independent inputs, 13 standard Form A, and 2 standard Form C contact outputs.
- 8 independent inputs and 8 high-speed, high-current interrupting Form A contact outputs.
- 8 independent inputs, 13 high-current interrupting Form A outputs, and 2 standard Form C contact outputs.
- 24 inputs, 6 high-speed outputs, and 2 standard Form A contact outputs.

Assign the control inputs for control functions, monitoring logic, and general indication. Each control output is programmable using SELOGIC control equations. One board can be added to the 4U chassis, and two additional I/O boards can be added to the 5U chassis.

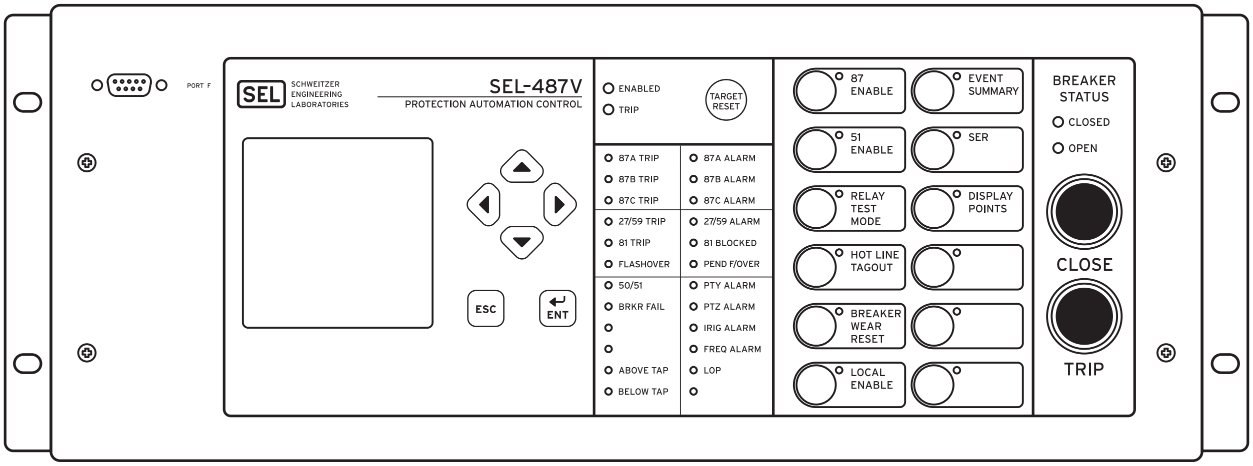
Breaker Control

The SEL-487V contains analog voltage inputs for multiple sources and control inputs to indicate both breaker and disconnect position, as well as the logic required to provide breaker control. This includes separate monitoring functions as well as separate elements for tripping and closing the breaker. All analog values are monitored on a per-phase basis to allow station control access to complete information for individual components of the system.

Backup Protection

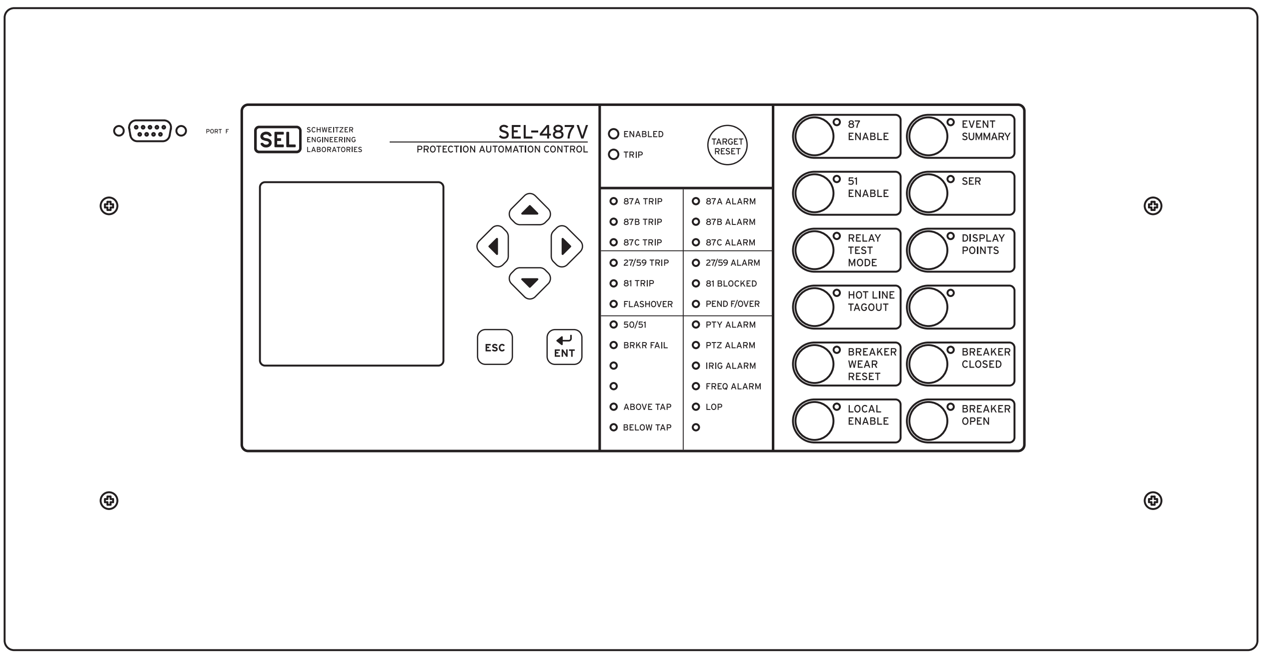
Add reliability and dependability by providing independent backup protection without increasing relay count. The SEL-487V can provide primary differential voltage or current unbalance protection with backup voltage and overcurrent protection on the capacitor bank.

Front- and Rear-Panel Diagrams



4U Horizontal Rack Mount With Auxiliary Trip and Close Pushbuttons

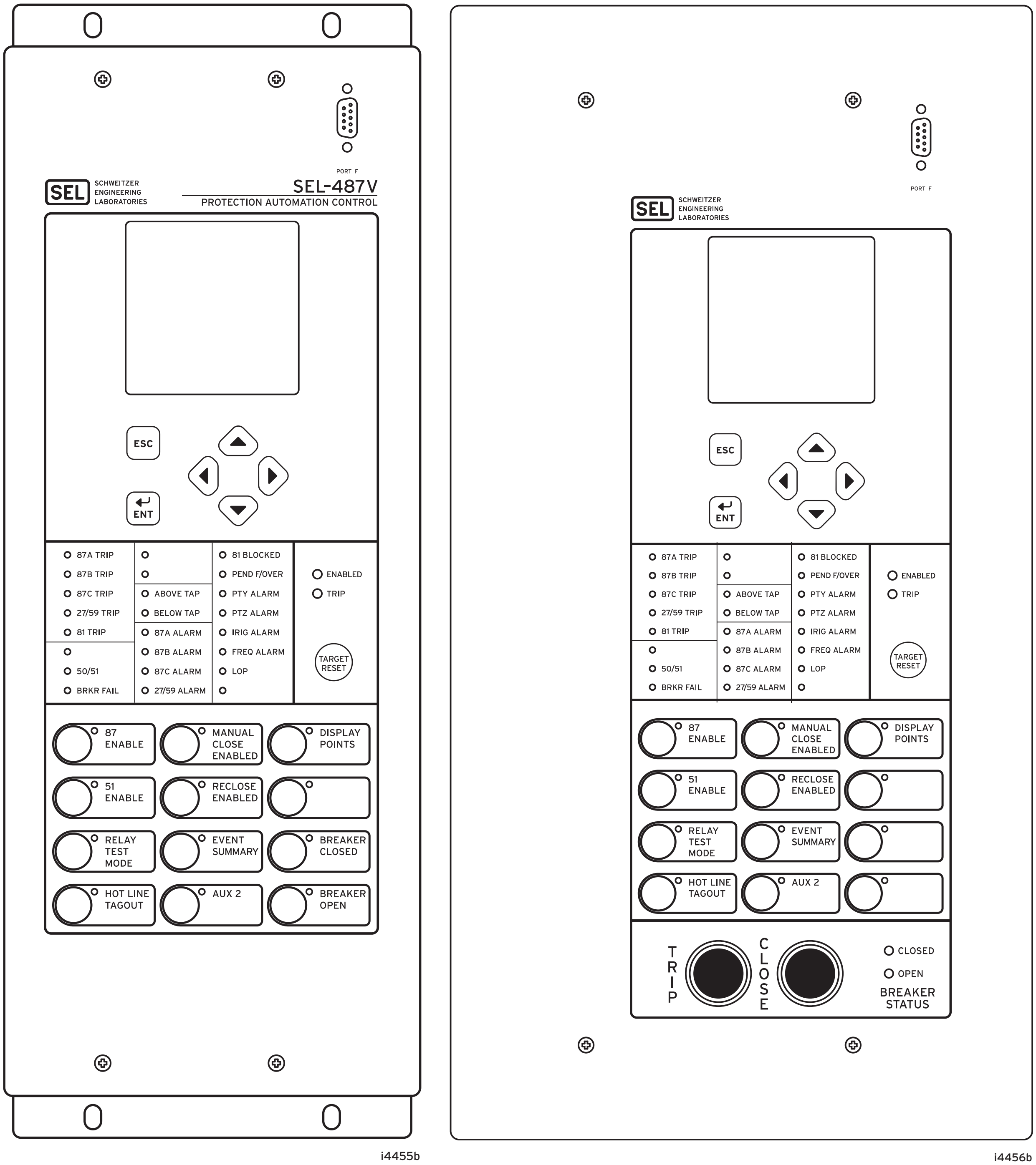
i4453a



5U Horizontal Panel Mount

i4454b

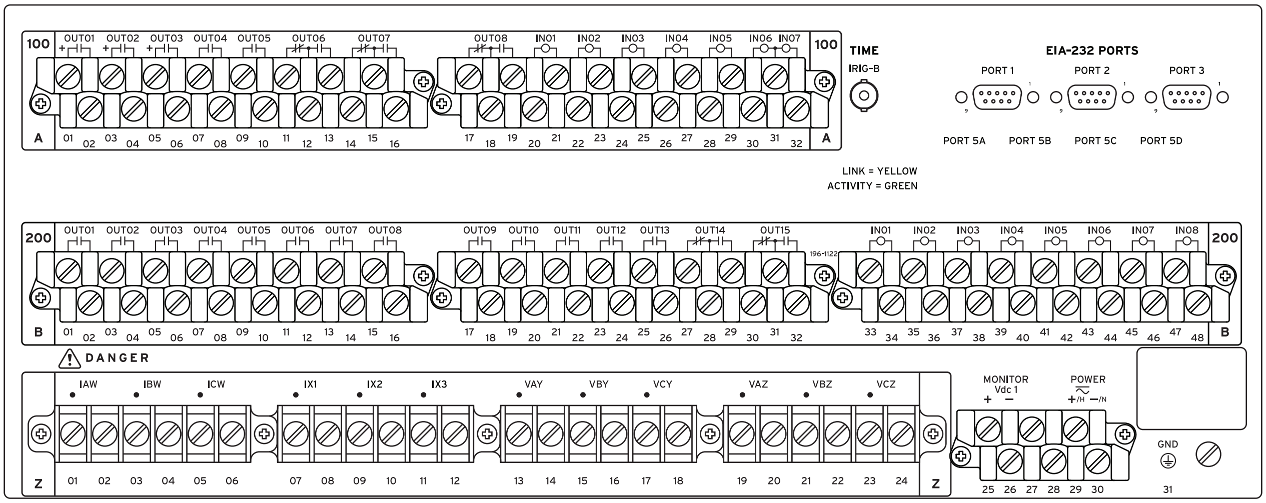
Figure 19 Typical SEL-487V Horizontal Front-Panel Diagrams



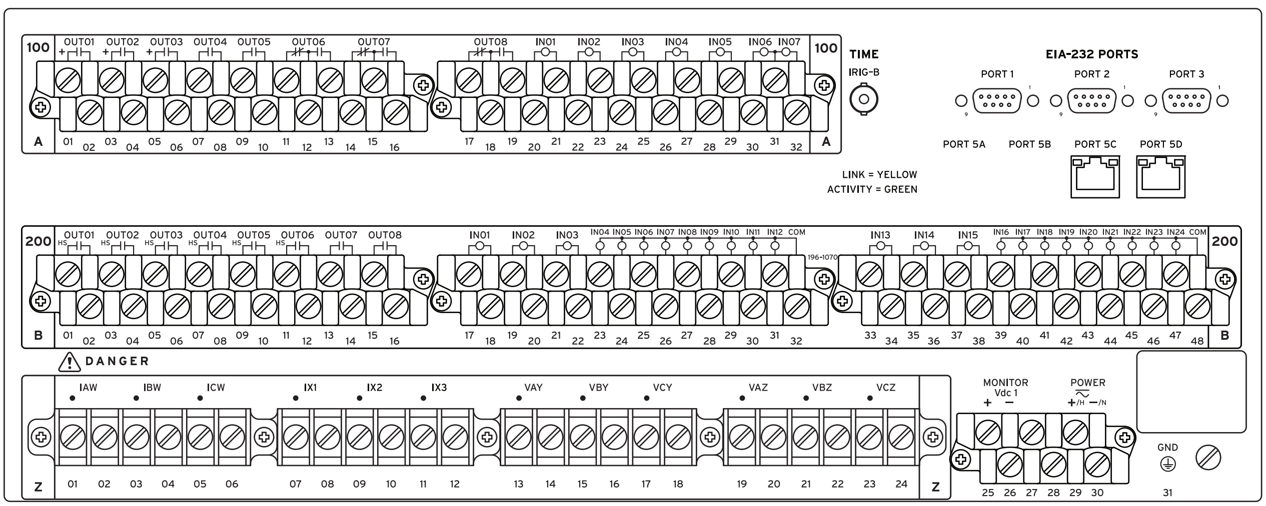
4U Vertical Rack Mount

5U Vertical Panel Mount With Auxiliary Trip and Close Pushbuttons

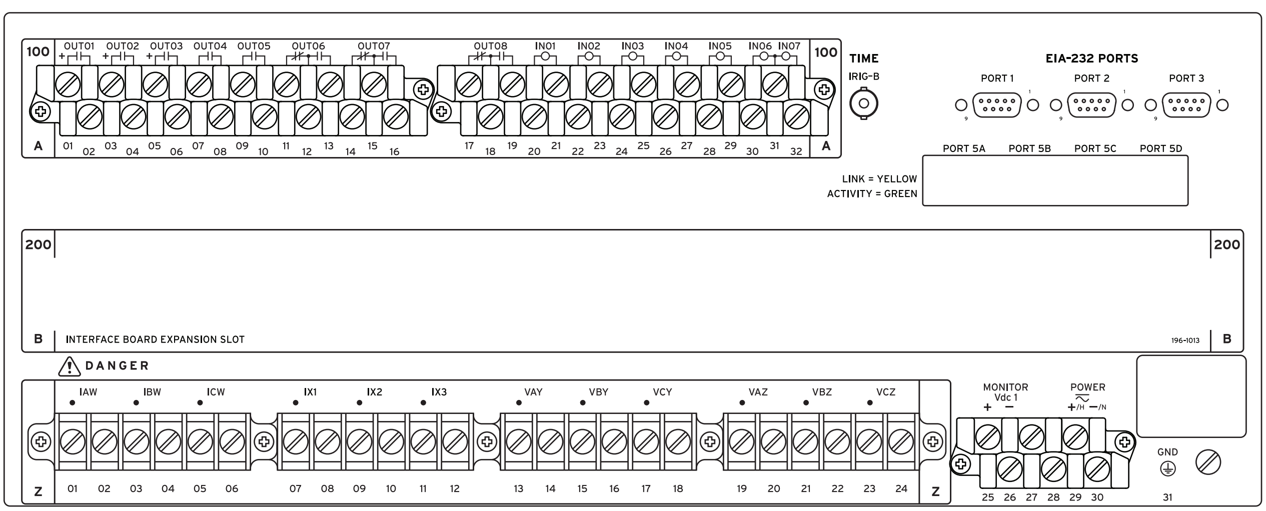
Figure 20 Typical SEL-487V Vertical Front-Panel Diagrams



4U With INT2 I/O Interface Board

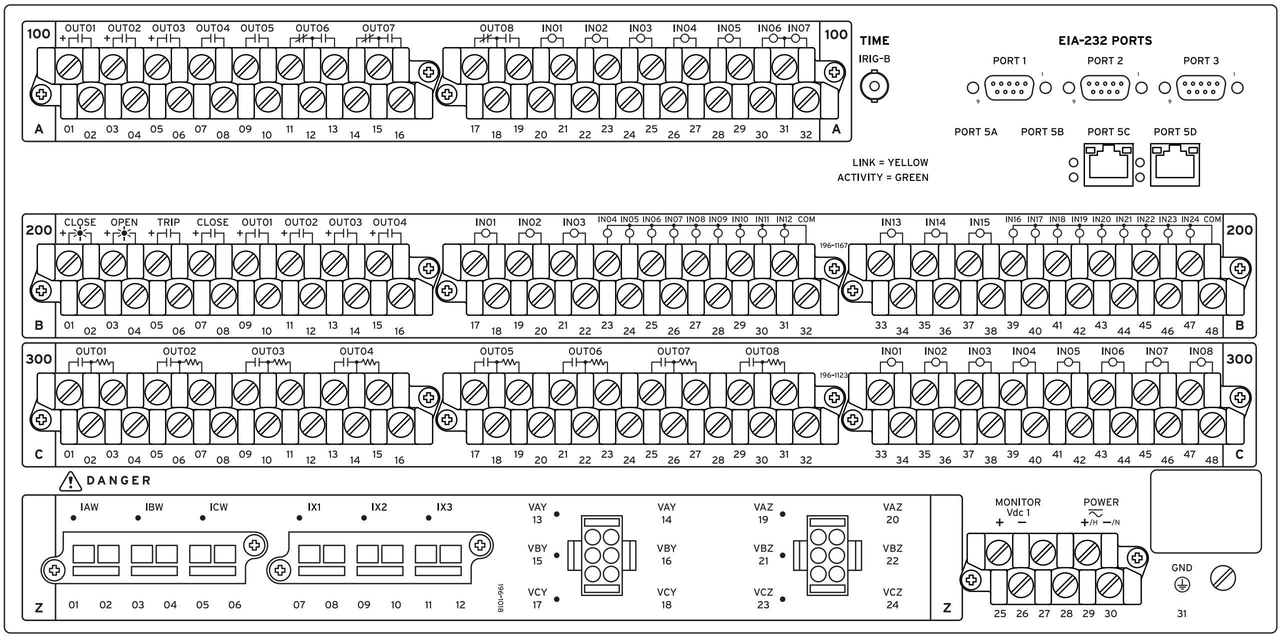


4U With INT4 I/O Interface Board



4U With Main Board and No I/O Interface Board

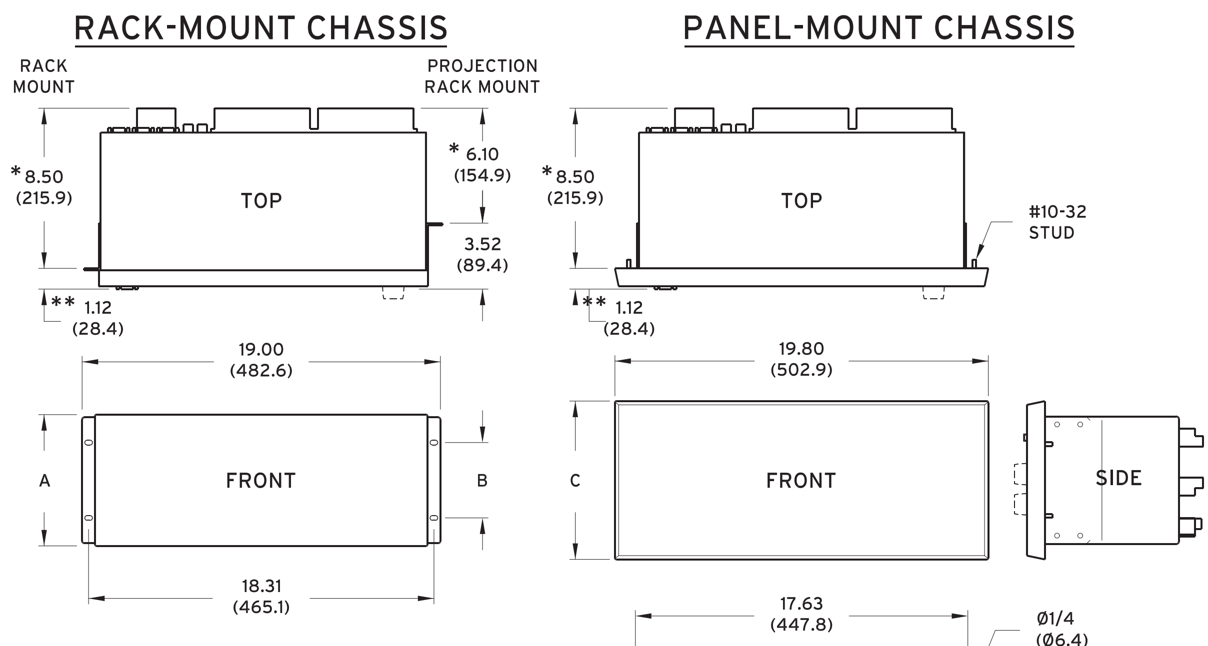
Figure 21 4U Rear-Panel Options



5U Connectorized, With INT3 and INT8 Interface Boards and Ethernet Option

Figure 22 5U Connectorized With INT3 and INT8 Interface Boards and Ethernet Option

Relay Dimensions



DIMENSION	ONE I/O BOARD (4U)	TWO I/O BOARD (5U)
A	6.97 (177.0)	8.72 (221.5)
B	4.00 (101.6)	5.75 (146.0)
C	8.40 (213.4)	10.15 (257.8)
D	6.85 (174.0)	8.60 (218.4)

* ADD 0.30 (7.6) FOR CONNECTORIZED RELAYS

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

i9204c

Figure 23 SEL-487V Dimensions for Rack- and Panel-Mount Models (Horizontal Mounting Shown; Dimensions Also Apply to Vertical Mounting)

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

47 CFR 15B Class A
This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference in which case the user will be required to correct the interference at his own expense.

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

CE Mark

General

AC Current Input (Secondary Circuit)

Sampling Rate: 8 kHz

Note: Current transformers are Measurement Category II.

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

1 A Nominal: 18.2 A

5 A Nominal: 91 A

Continuous Thermal Rating

1 A Nominal: 3 A
4 A (+55°C)

5 A Nominal: 15 A
20 A (+55°C)

Saturation Current (Linear) Rating

1 A Nominal: 20 A

5 A Nominal: 100 A

A/D Current Limit

Note: Signal clipping may occur beyond this limit.

1 A Nominal: 49.5 A

5 A Nominal: 247.5 A

One-Second Thermal Rating

1 A Nominal: 100 A

5 A Nominal: 500 A

One-Cycle Thermal Rating

1 A Nominal: 250 A peak

5 A Nominal: 1250 A peak

Burden Rating

1 A Nominal: ≤0.1 VA at 1 A

5 A Nominal: ≤0.5 VA at 5 A

AC Voltage Inputs

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

Rated Voltage Range: 0–300 V_{LN}

Ten-Second Thermal Rating: 600 Vac

Burden Rating: ≤0.1 VA at 125 V

Frequency and Rotation

Nominal Frequency

Rating: 50 ±5 Hz
60 ±5 Hz

Phase Rotation: ABC or ACB

Frequency Tracking Range: 40–65 Hz
<40 Hz = 40 Hz
>65 Hz = 65 Hz

Maximum Slew Rate: 15 Hz/s

Power Supply

48–125 Vdc or 110–120 Vac

Rated Voltage: 48–125 Vdc, 110–120 Vac

Operational Voltage Range: 38–140 Vdc
85–140 Vac

Rated Frequency: 50/60 Hz

Operational Frequency Range: 30–120 Hz

Vdc Input Ripple: 15% per IEC 60255–26:2013

Interruption: 14 ms at 48 Vdc, 160 ms at 125 Vdc per IEC 60255-26:2013

Burden: <35 W, <90 VA

125–250 Vdc or 110–240 Vac

Rated Voltage: 125–250 Vdc, 110–240 Vac

Operational Voltage Range: 85–300 Vdc
85–264 Vac

Rated Frequency: 50/60 Hz

Operational Frequency Range: 30–120 Hz

Vdc Input Ripple: 15% per IEC 60255–26:2013

Interruption: 46 ms at 125 Vdc, 250 ms at 250 Vdc per IEC 60255–26:2013

Burden: <35 W, <90 VA

Control Outputs

Standard

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

Make: 30 A at 250 Vdc

Thermal: 50 A for 1 s

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

Pickup/Dropout Time: ≤6 ms, resistive load

Breaking Capacity (10,000 Operations):

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

Cyclic Capacity (2.5 Cycle/Second):

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

Update Rate: 1/8 cycle

High-Current Interrupting

Rated Insulation Voltage (U_i): 300 Vac
470 Vdc

Rated Carry: 6 A continuous carry at 70°C
4 A continuous carry at 85°C

Note: DC control signals only.

Rated Make: 30 A at 250 Vdc

Thermal Rating: 50 A for 1 s

MOV Protection (Maximum Voltage): 330 Vdc

Pickup/Dropout Time: ≤6 ms, resistive load

Inductive Breaking Capacity (10,000 Operations):

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

Cyclic Capacity (4 Cycles in 1 Second, Followed by 2 Minutes Idle for Thermal Dissipation):

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

Mechanical Durability: 10,000 no-load operations

High-Speed, High-Current Interrupting

Rated Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
Rated Make:	30 A at 250 Vdc
Thermal:	50 A for 1 s
Pickup Time:	≤10 µs, resistive load
Dropout Time:	≤8 ms, resistive load

Breaking Capacity (10,000 Operations):

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

Cyclic Capacity (4 Cycles in 1 Second, Followed by 2 Minutes Idle for Thermal Dissipation):

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

Mechanical Durability:	10,000 no-load operations
Minimum Current Rating:	10 mA
Update Rate:	1/8 cycle

Note: Per IEC 60255-23:1994, using the simplified method of assessment
Note: Make rating per IEEE C37.90-2005.
Note: Per IEC 61810-1:2005.

Control Inputs
Optoisolated (Use With AC or DC Signals)

General

Sampling Rate:	2 kHz
Main Board:	5 inputs with no shared terminals 2 inputs with shared terminals
INT 2, INT7, and INT8 Interface Boards:	8 inputs with no shared terminals
INT 3 and INT 4:	6 inputs with no shared terminals 18 inputs with shared terminals (2 groups of 9 inputs, with each group sharing one terminal)
Voltage Options:	48, 110, 125, 220, 250 V

DC Thresholds (Dropout Thresholds Indicate Level-Sensitive Option)

48 Vdc	Pickup 38.4–60.0 Vdc Dropout <28.8 Vdc
110 Vdc:	Pickup 88.0–132.0 Vdc Dropout <66.0 Vdc
125 Vdc:	Pickup 105–150 Vdc Dropout <75 Vdc
220 Vdc:	Pickup 176–264 Vdc Dropout <132 Vdc
250 Vdc:	Pickup 200–300 Vdc Dropout <150 Vdc
Current Draw:	5 mA at nominal voltage 8 mA at 110 V option
Rated Frequency:	50 ± 5 Hz, 60 ± 5 Hz

AC Thresholds (Ratings Met Only When Recommended Control Input Settings Are Used—See Table 2.1)

48 Vac:	Pickup 32.8–60.0 Vac rms Dropout <20.3 Vac rms
110 Vac:	Pickup 75.1–132.0 Vac rms Dropout <46.6 Vac rms
125 Vac:	Pickup 89.6–150.0 Vac rms Dropout <53.0 Vac rms
220 Vac:	Pickup 150.3–264.0 Vac rms Dropout <93.2 Vac rms
250 Vac:	Pickup 170.6–300.0 Vac rms Dropout <106 Vac rms
Current Draw:	<5 mA at nominal voltage <8 mA at 110 V option

Auxiliary Breaker Control Pushbuttons

Quantity:	2
Pushbutton Functions:	One (1) pushbutton shall be provided to open the breaker. One (1) pushbutton shall be provided to close the breaker.

Resistive DC or AC Outputs With Arc Suppression Disabled:

Make:	30 A
Carry:	6 A continuous carry
1 s Rating:	50 A
MOV Protection (Maximum Voltage):	250 Vac/330 Vdc

Breaking Capacity (10,000 Operations):

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

High Interrupt DC Outputs With Arc Suppression Enabled:

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

Breaking Capacity (10,000 Operations):

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

Breaker Open/Closed LEDs:

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

Note: With nominal control voltage applied, each LED draws 8 mA (max.). Jumpers may be set to 125 Vdc for 110 Vdc input and set to 250 Vdc for 220 Vdc input.
Note: Per IEC 60255-23:1994, using the simplified method of assessment.
Note: Make rating per IEEE C37.90-2005.
Note: Per IEC 61810-2:2005.

Communications Ports

EIA-232

1 Front and 3 Rear Serial Data Speed:	300–57600 bps Communications card slot for optional Ethernet card
Ordering Options:	100BASE-FX fiber-optic Ethernet
Mode:	Multi
Wavelength (nm):	1300

Source

LED Connector Type:	LC
Min. TX Pwr. (dBm):	–19
Max TX Pwr. (dBm):	–14
RX Sens. (dBm):	–32

Sys. Gain (dB): 13

Class 1 LED Product

Safety (Optional Ethernet Card)

IEC 60825-1:2007
ANSI Z136.1-2007, Class 1

Time Inputs

IRIG-B Input—Serial Port 1

Input:	Demodulated IRIG-B
Rated I/O Voltage:	5 Vdc
Operating Voltage Range:	0–8 Vdc
Logic High Threshold:	≤2.8 Vdc
Logic Low Threshold:	≥0.8 Vdc
Input Impedance:	2.5 kΩ

IRIG-B Input—BNC Connector

Input:	Demodulated IRIG-B
Rated I/O Voltage:	5 Vdc
Operating Voltage Range:	0–8 Vdc
Logic High Threshold:	≤2.2 Vdc
Logic Low Threshold:	≥0.8 Vdc
Input Impedance:	50 Ω or >1 kΩ
Dielectric Test Voltage:	0.5 kVac

Operating Temperature

–40° to +85°C (–40° to +185°F)

Note: LCD contrast impaired for temperatures below –20°C and above +70°C. Stated temperature ranges not applicable to UL applications.

Humidity

5% to 95% without condensation

Weight (Maximum)

3U Rack Unit:	8.00 kg (17.5 lb)
4U Rack Unit:	9.8 kg (21.5 lb)
5U Rack Unit:	11.6 kg (25.5 lb)

Terminal Connection

Rear Screw-Terminal Tightening Torque, #8 Ring Lug

Minimum:	1.0 Nm (9 in-lb)
Maximum:	2.0 Nm (18 in-lb)

User terminals and stranded copper wire should have a minimum temperature rating of 105°C. Ring terminals are recommended.

Wire Size and Insulation

Wire sizes for grounding (earthing), current, voltage, and contact connections are dictated by the terminal blocks and expected load currents. You can use the following table as a guide in selecting wire sizes. The grounding conductor should be as short as possible and sized equal to or greater than any other conductor connected to the device, unless otherwise required by local or national wiring regulations.

Connection Type	Min. Wire Size	Max. Wire Size
Grounding (Earthing) Connection	14 AWG (2.5 mm^2)	N/A
Current Connection	16 AWG (1.5 mm^2)	10 AWG (5.3 mm^2)
Potential (Voltage) Connection	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)
Contact I/O	18 AWG (0.8 mm^2)	10 AWG (5.3 mm^2)
Other Connection	18 AWG (0.8 mm^2)	10 AWG (5.3 mm^2)

Type Tests

Electromagnetic Compatibility (EMC)

Emissions:	IEC 60255-25:2000

Electromagnetic Compatibility Immunity

Conducted RF Immunity:	IEC 60255-22-6:2001, 10 Vrms IEC 61000-4-6:2008, 10 Vrms
Electrostatic Discharge Immunity:	IEC 60255-22-2:2008 IEC 61000-4-2:2008 Levels 2, 4, 6, and 8 kV contact; Levels 2, 4, 8, and 15 kV air IEEE C37.90.3-2001 Levels 2, 4, and 8 kV contact; Levels 4, 8, and 15 kV air
Fast Transient/Burst Immunity:	IEC 60255-22-4:2008 4 kV at 5 kHz and 2 kV at 5 kHz (Comm. Ports) IEC 61000-4-4:2011 4 kV at 5 kHz and 2 kV at 5 kHz
Magnetic Field Immunity:	IEC 61000-4-8:2001 900 A/m for 3 seconds 100 A/m for 60 seconds
Power Supply Immunity:	IEC 61000-4-11:2004 IEC 60255-11:2008 IEC 61000-4-29:2000
Radiated Digital Radio Telephone RF Immunity:	ENV 50204:1995 10 V/m at 900 MHz and 1.89 GHz
Radiated Radio Frequency Immunity:	IEC 60255-22-3:2007, 10 V/m IEC 61000-4-3:2010, 10 V/m IEEE C37.90.2-2004, 35 V/m
Surge Immunity:	IEC 60255-22-5:2008 IEC 61000-4-5:2005 1 kV line-to-line, 2 kV line-to-earth
Damped Oscillatory Magnetic Field:	IEC 61000-4-10:2001 Severity Level: 100 A/m
Surge Withstand Capability Immunity:	IEC 60255-22-1:2007 2.5 kV peak common mode 1.0 kV peak differential mode IEEE C37.90.1-2002 2.5 kV oscillatory 4 kV fast transient waveform

Environmental Tests

Cold:	IEC 60068-2-1:2007 Test Ad: 16 hours at –40°C
Damp Heat, Cyclic:	IEC 60068-2-30:2005 Test Db: 25°C to 55°C, 6 cycles (12 + 12-hour cycle), 95% humidity
Dry Heat:	IEC 60068-2-2:2007 Test Bd: 16 hours at +85°C
Vibration Resistance:	IEC 60255-21-1:1988 Class 2 Endurance, Class 2 Response
Shock Resistance:	IEC 60255-21-2:1988 Class 1 Shock Withstand, Bump Withstand Class 2 Shock Response
Seismic:	IEC 60255-21-3:1993 Class 2 Quake Response
Object Penetration:	IEC 60529:2001 + CRGD:2003 Protection Class: IP30

Safety

Dielectric Strength:	IEC 60255-5:2000 IEEE C37.90-2005 2500 Vac on control inputs, control outputs, and analog inputs 3100 Vdc on power supply
Impulse:	IEC 60255-5:2000 IEEE C37.90-2005 0.5 J, 5 kV

Event Reports

High-Resolution Data

Rate:	8000 samples/second 4000 samples/second 2000 samples/second 1000 samples/second
Output Format:	Binary COMTRADE

Note: Per IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems, IEEE C37.111-1999.

Event Reports

Length:	15/30 cycles
Maximum Duration:	Five records of 24 seconds each at 1000 samples/second
Resolution:	1/4 and 1/8 samples/cycle
Digital Inputs:	2 kHz

Event Summary

Storage:	100 summaries

Breaker History

Storage:	128 histories

Sequential Events Recorder

Storage:	1000 entries
Trigger Elements:	250 relay elements

Processing Specifications

AC Voltage and Current Inputs

8000 samples per second, 3 dB low-pass analog filter cut-off frequency at 646 Hz, ±5%

Digital Filtering

Two-Cycle and Full-cycle cosine after low-pass analog filtering

Protection and Control Processing

4, 8, and 32 times per power system cycle

Control Points

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

Relay Element Pickup Ranges and Accuracies

Phase-Voltage Differential Elements

Number of Elements:	3
Levels:	3 (Sensitive, Alarm, and Trip)
Pickup Range:	Magnitude: 0.1 V to 300.00 V
Pickup Accuracy, Steady-State:	±0.1% of set point
Maximum Pickup/Dropout Time:	2.5 cycles
Timers:	3 levels with individual timers for each level (0.00 to 6000.00 seconds with 0.01 second resolution)
Time-Delay Range:	0.00–64000 cycles
Time-Delay Accuracy:	±0.1% ± 4.2 ms at 60 Hz
Reset Time Range:	0.00–64000 cycles
Torque Control:	SELOGIC® control equation
K Factor (Compensation) Range:	0.0000 to 1.9999 with 0.0001 resolution

Neutral-Voltage Differential Elements

Number of Elements:	3
Levels:	3 (Sensitive, Alarm, and Trip)
Pickup Range:	Magnitude: 0.1 V to 300.00 V Angle: –179.00 to 180.00 degrees
Pickup Accuracy, Steady-State:	±0.1% of set point
Maximum Pickup/Dropout Time:	2.5 cycles
Timers:	3 levels with individual timers for each level (0.00 to 6000.00 seconds with 0.01 second resolution)
Time-Delay Range:	0.00–64000 cycles
Time-Delay Accuracy:	±0.1% ± 4.2 ms at 60 Hz
Reset Time Range:	0.00–64000 cycles
Torque Control:	SELOGIC control equation
K Factor (Compensation) Range:	0.00 to 300.00 with 0.01 resolution

Phase-Current Unbalance Elements

Number of Elements:	3
Pickup Range:	Magnitude: 0.005 to 20.00 per unit (I_{NOM})
Pickup Accuracy, Steady-State:	0.05 per unit ± 1% of set point
Maximum Pickup/Dropout Time:	2.5 cycles for I > 0.05 per unit 10 cycles for 0.002 < I < 0.05 per unit
Time-Delay Range:	0.00–16000 cycles
Reset Time Range:	0.00–16000 cycles
Time-Delay Accuracy:	±0.1% ± 4.2 ms at 60 Hz
Torque Control:	SELOGIC® control equation

Neutral-Current Unbalance Elements

Number of Elements:	3
Pickup Range:	Magnitude: 0.005 to 20.00 per unit (I_{NOM})
Pickup Accuracy, Steady-State:	0.05 per unit ± 1% of set point
Maximum Pickup/Dropout Time:	2.0 cycles for I > 0.05 per unit 10 cycles for 0.002 < I < 0.05 per unit
Time-Delay Range:	0.00–400.0 s
Reset Time Range:	0.00–400.00 s
Time-Delay Accuracy:	±0.1% ± 4.2 ms at 60 Hz
Torque Control:	SELOGIC control equation

Three Phase-Current Unbalance Elements

Number of Elements:	3 (W current channels only)
Pickup Range:	0.00 to 2.00 per unit (I_{NOM})
Pickup Accuracy, Steady-State:	±1% of set point
Maximum Pickup/Dropout Time:	1.5 cycles
Time-Delay Range:	0.00–400.0 s
Time-Delay Accuracy:	±0.1% ± 4.2 ms at 60 Hz

Open-Phase Detection Logic

Number of Elements:	3 (W current channels only)
Pickup Range	
1 A nominal:	0.05–1.00 A
5 A nominal:	0.25–5.00 A
Maximum Pickup/Dropout Time:	0.625 cycles

Instantaneous/Definite-Time Overcurrent Elements (50)

Phase- and Negative-Sequence, Ground-Residual Elements

Pickup Range	
5 A nominal:	0.25–100.00 A secondary, 0.01 A steps
1 A nominal:	0.05–20.00 A secondary, 0.01 A steps
Accuracy (Steady-State)	
5 A nominal:	±0.05 A plus ±3% of setting
1 A nominal:	±0.01 A plus ±3% of settings
Transient Overreach (phase and ground residual)	
5 A nominal:	±5% of setting, ±0.10 A
1 A nominal:	±5% of setting, ±0.02 A
Transient Overreach (negative-sequence)	
5 A nominal:	±6% of setting, ±0.10 A
1 A nominal:	±6% of setting, ±0.02 A
Time-Delay Range:	0.00–16000.00 cycles, 0.250 cycle steps
Timer Accuracy:	±0.250 cycle ±0.1% of setting
Maximum Pickup/Dropout Time:	1.5 cycles

Adaptive-Time Overcurrent Elements (51)

Pickup Range (Adaptive within the range)	
5 A nominal:	0.25–16.00 A secondary, 0.01 A steps
1 A nominal:	0.05–3.20 A secondary, 0.01 A steps
Accuracy (Steady-State)	
5 A nominal:	±0.05 A ±3% of setting
1 A nominal:	±0.01 A ±3% of settings
Transient Overreach	
5 A nominal:	±5% of setting, ±0.10 A
1 A nominal:	±5% of setting, ±0.20 A
Time Dial Range (Adaptive within the range)	
U.S.:	0.50–15.00, 0.01 steps
IEC:	0.05–1.00, 0.01 steps
Curve Timing Accuracy:	±1.50 cycles plus ±4% of curve time (for current between 2 and 30 multiples of pickup). Curves operate on definite-time for current greater than 30 multiples of pickup.
Reset:	1 power cycles or Electromechanical Reset Emulation time

Phase Under- and Overvoltage Elements

Based on maximum of the VA, VB, and VC phase voltages

Pickup Range:	0.25 V–300 V_{LN} in 0.01 steps
Accuracy:	±3% of setting, ± 0.5 V
Transient Overreach:	±5% of pickup
Maximum Delay:	1.5 cycles

Phase-to-Phase Under- and Overvoltage Elements

Elements based on maximum of the calculated phase-to-phase voltages

Pickup Range:	0.25–520 V_{LL} in 0.01 steps
Accuracy:	±3% of setting, ± 0.5 V
Transient Overreach:	±5% of pickup
Maximum Delay:	1.5 cycles

Sequence Under- and Overvoltage

Pickup Range:	0.25 V–300 V_{LN} in 0.01 steps
Pickup Accuracy, Steady State:	±5% of setting, ± 1 V
Pickup Accuracy, Transient Overreach:	±5%
Maximum Pickup/Dropout Time:	1.5 cycles

Under- and Overfrequency Elements

Pickup Range:	40.01–69.99 Hz, 0.01 Hz steps
Accuracy, Steady State plus Transient:	±0.005 Hz for frequencies between 40.00 and 70.00 Hz
Maximum Pickup/Dropout Time:	3.0 cycles
Time-Delay Range:	0.04–400.0 s, 0.01 s increments
Time-Delay Accuracy:	±0.1% ± 0.0042 s
Pickup Range, Undervoltage Blocking:	20.00–200.00 V_{LN} (Wye)
Pickup Accuracy, Undervoltage Blocking:	±2% ± 2 V
Maximum Pickup/Dropout Time:	2.625 cycles

Breaker Failure Instantaneous Overcurrent

Setting Range	
5 A nominal:	0.50–50 A, 0.01 A steps
1 A nominal:	0.10–10.0 A, 0.01 A steps
Accuracy	
5 A nominal:	±0.05 A ± 3% of setting
1 A nominal:	±0.01 A ± 3% of settings
Transient Overreach	
5 A nominal:	±5%, ± 0.10 A
1 A nominal:	±5%, ± 0.02 A
Maximum Pickup Time:	1.5 cycles
Maximum Dropout Time:	Less than 1 cycle
Maximum Reset Time:	Less than 1 cycle
Timer Setting Range:	0–6000 cycles, 0.125 cycle steps
Time-Delay Accuracy:	±0.1% of setting ± 0.125 cycle

Directional Over- and Underpower Element

Pickup Range:	3-phase: OFF, 1–900 W (secondary) in 1 W steps Single phase: OFF, 0.30–900 W (secondary) in 0.1 W steps
Pickup Accuracy:	±3% of setting and ±5 W, power factor > ±0.5 at nominal frequency
Time-Delay Range:	0–16,000 cycles, 0.125 cycle increment
Time-Delay Accuracy:	±0.1% of setting, ±0.125 cycle

Bay Control

Breakers:	1
Disconnects (Isolators):	10 (maximum)
Timers Setting Range:	1–99999 cycles, 1-cycle steps
Time-Delay Accuracy:	±0.1% of setting, ± 0.125 cycle

Station DC Battery System Monitor

Rated Voltage:	15–300 Vdc
Operational Voltage Range:	0–350 Vdc
Input Sampling Range:	2 kHz

Processing Rate: 1/8 cycle

Operating Time: ≤1.5 seconds (element dc ripple)
≤1.5 cycles (all elements but dc ripple)

Setting Range

DC Settings: 1 Vdc steps (OFF, 15–300 Vdc)

AC Ripple Setting: 1 Vac steps (1–300 Vac)

Pickup Accuracy: ±10%, ± 2 Vdc (dc ripple)
±3%, ± 2 Vdc (all elements but dc ripple)

Metering Accuracies

All metering accuracies are based on an ambient temperature of 20°C and nominal frequency.

Absolute Phase-Angle Accuracy: IA, IB, and IC per terminal: ±0.5° (both 1 and 5 A)
VA, VB, and VC per terminal: ±0.125°

Currents

Quantity: IA, IB, IC Per Terminal

I_{NOM} = 1 A

Magnitude Accuracy: ±0.2%, ± 0.8 mA

Phase Accuracy: ±0.2°

Current Range: 0.5–3.0

I_{NOM} = 5 A

Magnitude Accuracy: ±0.2%, ± 4.0 mA

Phase Accuracy: ±0.2°

Current Range: 2.5–15.0

Quantity: 3I0 (IG), I1 and 3I2 (Calculated) Per Terminal

I_{NOM} = 1 A

Magnitude Accuracy: ±0.3%, ± 0.8 mA

Phase Accuracy: ±0.3°

Current Range: 0.1–20.0

I_{NOM} = 5 A

Magnitude Accuracy: ±0.3%, ± 4.0 mA

Phase Accuracy: ±0.3°

Current Range: 0.5–100.0

Quantity: VA, VB, VC Per Terminal

Voltage Range: 5–33.5 V

Magnitude Accuracy: ±2.5% ± 1 V

Phase Accuracy: ±1.0°

Voltage Range: 33.5–300 V

Magnitude Accuracy: ±0.1%

Phase Accuracy: ±0.5°

Quantity: 3V0, V1, V2 Per Terminal

Voltage Range: 5–33.5 V

Magnitude Accuracy: ±2.5% ± 1 V

Phase Accuracy: ±1.0°

Voltage Range: 33.5–300 V

Magnitude Accuracy: ±0.1%

Phase Accuracy: ±0.5°

Quantity: VAB, VBC, VCA (Calculated, Per Terminal)

Voltage Range: 5–33.5 V

Magnitude Accuracy: ±2.5% ± 1 V

Phase Accuracy: ±1.0°

Voltage Range: 33.5–300 V

Magnitude Accuracy: ±0.1%

Phase Accuracy: ±0.5°

Quantity: MW (P), Per Phase (Wye), Three Phase (Wye) Per Terminal

Accuracy: ±1%

Range: (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 (single phase)

Accuracy: ±0.7%

Range: (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 (three phase)

Quantity: MVAR (Q), Per Phase (Wye), Three Phase (Wye) Per Terminal

Accuracy: ±1%

Range: (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 (single phase)

Accuracy: ±0.7%

Range: (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 (three phase)

Quantity: MVA (S), Per Phase (Wye), Three Phase (Wye) Per Terminal

Accuracy: ±1%

Range: (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 (single phase)

Accuracy: ±0.7%

Range: (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 (three phase)

Quantity: PF, Per Phase (Wye), 3-ϕ (Wye) Per Terminal

Accuracy: ±1%

Range: (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 (single phase)

Accuracy: ±0.7%

Range: (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 (three phase)

Frequency Accuracy

Accuracy: 0.01 Hz

Range: 40–65 Hz

Magnitude Accuracy

Accuracy: ±1%

Range: 40–65 Hz

Power Supply Voltage Range

100–275 Vdc

Accuracy: ±1%

RMS Metering

Voltage Metering Function: VAY, VBY, VCY, VAZ, VBZ, VCZ (4-wire wye connected)

Range: 2–300 V (PT)

Magnitude Accuracy (at 20°C and Nominal Frequency): ±1.2%

Current Metering Function: IAW, IBW, ICW

Range: 0.05–20.0 • I_{NOM} (I_{NOM} = 1 A, 5 A)

Magnitude Accuracy (at 20°C and Nominal Frequency): ±0.2% ± 0.5 mA

Unbalance Metering

Quantity: Differential Voltage dVA, dVB, dVC, dVG1, dVG2, dVG3

Accuracy: ±1.0%

Range: ±0.01 V to ±100.00 V

Quantity:	Unbalance Current 60N/60P
Magnitude Accuracy:	±0.3%
Phase Accuracy:	±0.3°
Current Range:	at 0.001 to 5.000 • I_{NOM}

K Compensation Factors

Magnitude Accuracy:	±1.0% ± 0.002 • KSET
Phase Angle Accuracy:	±0.3°

Optional RTD Elements (RTD Temperature Measurement From SEL-2600 Series RTD Module)

12 RTD inputs via SEL-2600 Series RTD Module and SEL-2800

Fiber-Optic Transceiver

Monitor Ambient or Other Temperatures

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

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

Synchrophasor Metering

12 channels (6 voltage and 6 current)

20 messages per second via SEL Fast Message protocol

As many as 60 messages per second via IEEE Standard C37.118 protocol

Voltage Accuracy:	Range 30–150 V ±1% Total Vector Error (TVE) as specified in C37.118 at fnom ± 5 Hz
Current Accuracy (Current range 0.1–20 o I_{NOM}):	±1% TVE at fnom ± 5 Hz
Voltage Magnitude Accuracy:	±0.1%
Voltage Angle Accuracy:	±0.125°

Breaker Monitoring

Running Total of Interrupted Current (kA) per Pole:	±5% ± 0.02 • I_{NOM}
Percent kA Interrupted for Trip Operations:	±5%
Percent Breaker Wear per Pole:	±5%
Compressor/Motor Start and Run Time:	±1 day
Time Since Last Operation:	±1 day

Battery System Monitoring

Pickup Range:	15–300 Vdc, 1 Vdc steps
Pickup Accuracy:	±3% of setting, ± 2 Vdc (all elements except dc ripple) ±10% of setting, ± 2 Vdc (dc ripple element)
Maximum Pickup/Dropout Time:	±1.5 cycles (all elements except dc ripple) ±1.5 seconds (dc ripple element)
Sampling Rate:	1/8 cycle

Voltage Sag/Swell/Interruption Reporting

Pickup Range

Sag:	10.00%–95.00%
Swell:	105.00%–180.00%
Interruption:	5.00%–95.00%

Recording Rates and Duration

Fast:	4 samples/cycle	4 cycle dur.
Medium:	1 sample/cycle	176 cycle dur.
Slow:	1 sample/64 cycles	4096 cycle dur.
Daily:	1 sample/day	Indefinite

Control Functions (SEL-487V-1)

Voltage Control

Dead-Band Range:	10.00–300.00 V sec.
Dead-Band Control Delay:	1–6000 s
Stall-Time Delay:	1–6000 s

Power Factor Control

Dead-Band Range:	0.01–0.99
Dead-Band Control Delay:	1–6000 s
Stall-Time Delay:	1–6000 s
Minimum Operating Power:	±1 W or ±1 VAR sec.

VAR Control

Dead-Band Range:	–1000.00 to +1000.00 VAR sec.
Dead-Band Control Delay:	1–6000 s
Stall-Time Delay:	1–6000 s
Minimum Operating Power:	±1 W or ±1 VAR sec.

Time-of-Day Control

Minimum Resolution:	±1 minute

Universal Sequencer

Accumulation Period:	1–9999 minutes
Resolution:	±1 minute
Accumulated Value:	0–2147483646
Resolution:	±1

Notes

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