**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 patented-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. Offline 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.

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**Functional Overview**

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**Figure 1 Functional Diagram**

**Table 1 Protection Elements (Sheet 1 of 2)**

<table>
<thead>
<tr>
<th>Element ANSI Number</th>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>Undervoltage</td>
<td>6</td>
</tr>
<tr>
<td>32</td>
<td>Directional Power</td>
<td>10</td>
</tr>
<tr>
<td>46</td>
<td>Current Unbalance</td>
<td>1</td>
</tr>
<tr>
<td>50</td>
<td>Instantaneous Overcurrent</td>
<td>3 Phase, 3 Negative-Sequence, 3 Ground</td>
</tr>
<tr>
<td>50BF</td>
<td>Breaker Failure</td>
<td>1</td>
</tr>
<tr>
<td>51S</td>
<td>Selectable Time Overcurrent</td>
<td>10</td>
</tr>
<tr>
<td>59</td>
<td>Overvoltage</td>
<td>6</td>
</tr>
<tr>
<td>60N</td>
<td>Neutral-Current Unbalance</td>
<td>3</td>
</tr>
<tr>
<td>60P</td>
<td>Phase-Current Unbalance</td>
<td>3</td>
</tr>
<tr>
<td>87V</td>
<td>Voltage Differential</td>
<td>3</td>
</tr>
<tr>
<td>87VN</td>
<td>Neutral-Voltage Differential</td>
<td>3</td>
</tr>
<tr>
<td>LOP</td>
<td>Loss of Potential</td>
<td>2</td>
</tr>
</tbody>
</table>
Protection Features

Phase-Voltage Differential Elements

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

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

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.

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>
<thead>
<tr>
<th>Overcurrent Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
</tr>
</tbody>
</table>
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>
<thead>
<tr>
<th>Analog Quantity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VA, VB, VC</td>
<td>L–N Phase Voltage</td>
</tr>
<tr>
<td>VNMAX, VNMIN</td>
<td>Neutral Voltage Min/Max</td>
</tr>
<tr>
<td>VAB, VBC, VCA</td>
<td>L–L Phase Voltage</td>
</tr>
<tr>
<td>VA–VN(^a), VB–VN(^a), VC–VN(^a)</td>
<td>Phase Voltage with Neutral Voltage Subtracted</td>
</tr>
<tr>
<td>VPMAX, VPMIN</td>
<td>Phase Voltage Min/Max</td>
</tr>
<tr>
<td>V1(^a), 3V2(^a), 3V0(^a)</td>
<td>Positive-, Negative-, Zero-Sequence</td>
</tr>
</tbody>
</table>

\(^a\) 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 (46nP) 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\(_{\text{nom}}\) (I\(_{\text{nom}} = 1 \text{ A or 5 A}\))
- 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).
**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.
ACSELERATOR QuickSet Templates

Use the fully licensed version of ACSELERATOR QuickSet 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.
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

<table>
<thead>
<tr>
<th>ENABLED</th>
<th>Relay Powered Properly and Self-Tests Okay</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRIP</td>
<td>Indication that a trip occurred</td>
</tr>
<tr>
<td>87A TRIP</td>
<td>A-Phase Voltage Differential Asserted</td>
</tr>
<tr>
<td>87B TRIP</td>
<td>B-Phase Voltage Differential Asserted</td>
</tr>
<tr>
<td>87C TRIP</td>
<td>C-Phase Voltage Differential Asserted</td>
</tr>
<tr>
<td>27/59 TRIP</td>
<td>Under/Overvoltage Trip</td>
</tr>
<tr>
<td>81 TRIP</td>
<td>Under/Overfrequency Trip</td>
</tr>
<tr>
<td>FLASHOVER</td>
<td>Breaker Flashover Detected</td>
</tr>
<tr>
<td>50/51</td>
<td>Overcurrent Element Asserted</td>
</tr>
<tr>
<td>BRKR FAIL</td>
<td>Breaker Failure Element Asserted</td>
</tr>
<tr>
<td>ABOVE TAP</td>
<td>Differential Fault Above Tap</td>
</tr>
<tr>
<td>BELOW TAP</td>
<td>Differential Fault Below Tap</td>
</tr>
<tr>
<td>87A ALARM</td>
<td>A-Phase Differential Alarm</td>
</tr>
<tr>
<td>87B ALARM</td>
<td>B-Phase Differential Alarm</td>
</tr>
<tr>
<td>87C ALARM</td>
<td>C-Phase Differential Alarm</td>
</tr>
<tr>
<td>27/59 ALARM</td>
<td>Under/Overvoltage Alarm</td>
</tr>
<tr>
<td>81 BLOCKED</td>
<td>Frequency Element Blocked</td>
</tr>
<tr>
<td>PEND F/OVER</td>
<td>Breaker Flashover Pending</td>
</tr>
<tr>
<td>PTY ALARM</td>
<td>Potential Transformer Y Alarm</td>
</tr>
<tr>
<td>PTZ ALARM</td>
<td>Potential Transformer Z Alarm</td>
</tr>
<tr>
<td>IRIG ALARM</td>
<td>IRIG Clock Alarm</td>
</tr>
<tr>
<td>FREQ ALARM</td>
<td>Frequency Tracking Alarm</td>
</tr>
<tr>
<td>LOP</td>
<td>Loss-of-Potential Condition</td>
</tr>
</tbody>
</table>

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.

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.
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.

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.

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.
Magnitudes of Harmonic Inputs (Amps Sec, Volt Sec)

<table>
<thead>
<tr>
<th>H</th>
<th>IAW</th>
<th>IBW</th>
<th>ICW</th>
<th>IAX</th>
<th>IBX</th>
<th>ICX</th>
<th>VAY</th>
<th>VBY</th>
<th>VCY</th>
<th>VAZ</th>
<th>VBZ</th>
<th>VCZ</th>
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</tbody>
</table>

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.

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](image)

**Table 5 Metering Capabilities**

<table>
<thead>
<tr>
<th>Capabilities</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instantaneous Quantities</strong></td>
<td></td>
</tr>
<tr>
<td>Voltages</td>
<td>0–300 V with phase quantities for each of the six voltage sources available as a separate quantity.</td>
</tr>
<tr>
<td>VA, B, C (Y), VA, B, C (Z), V, 3V0, V1, 3V2</td>
<td></td>
</tr>
<tr>
<td><strong>Currents</strong></td>
<td>Phase quantities for each of the two current sources available as a separate quantity or combined as line quantities.</td>
</tr>
<tr>
<td>IA,B,C (W), IA,B,C (X)</td>
<td></td>
</tr>
<tr>
<td>IA,L, IB,L, IC,L (combined currents)</td>
<td></td>
</tr>
<tr>
<td>IGL, I1L, 3I2L (combined currents)</td>
<td></td>
</tr>
<tr>
<td><strong>Power/Energy Metering Quantities</strong></td>
<td></td>
</tr>
<tr>
<td>MW, MWh, MVAR, MVARh, MVA, PF, single-phase, and three-phase</td>
<td>Available for each input set and as combined quantities for the line.</td>
</tr>
<tr>
<td><strong>Demand/Peak Metering</strong></td>
<td></td>
</tr>
<tr>
<td>IAB,C, 3I2, 3I0</td>
<td>Thermal or rolling interval demand and peak demand.</td>
</tr>
<tr>
<td>MW, MVAR, MVA, single-phase</td>
<td>Thermal or rolling interval demand and peak demand.</td>
</tr>
<tr>
<td>MW, MVAR, MVA, three-phase</td>
<td>Thermal or rolling interval demand and peak demand.</td>
</tr>
</tbody>
</table>

**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 enabled 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>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCII</td>
<td>Plain-language commands for human and simple machine communications. Use for metering, setting, self-test status, event reporting, and other functions.</td>
</tr>
<tr>
<td>Compressed ASCII</td>
<td>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.</td>
</tr>
<tr>
<td>Extended Fast Meter, Fast Operate, and Fast SER</td>
<td>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.</td>
</tr>
<tr>
<td>Ymodem</td>
<td>Support for reading event, settings, and oscillography files.</td>
</tr>
<tr>
<td>Optional DNP3 Level 2 Outstation</td>
<td>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</td>
</tr>
<tr>
<td>IEEE C37.118</td>
<td>Phasor measurement protocol.</td>
</tr>
<tr>
<td>IEC 61850</td>
<td>Ethernet-based international standard for interoperability between intelligent devices in a substation.</td>
</tr>
<tr>
<td>PRP</td>
<td>Parallel Redundancy Protocol provides redundant Ethernet network capabilities for seamless operation in the event of loss to one network.</td>
</tr>
<tr>
<td>SNTP</td>
<td>Ethernet-based simple network time protocol for time synchronization among relays.</td>
</tr>
</tbody>
</table>

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:
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

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

### 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.
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.
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.
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.

---

**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.

---

**Figure 18** VAR-Flow Controlled Time Undervoltage Load Shedding

![Graph showing Volt Drop p.u. vs Trip Time](image-url)
Front- and Rear-Panel Diagrams

4U Horizontal Rack Mount With Auxiliary Trip and Close Pushbuttons

5U Horizontal Panel Mount

Figure 19  Typical SEL-487V Horizontal Front-Panel Diagrams
Figure 20  Typical SEL-487V Vertical Front-Panel Diagrams
### Figure 21  4U Rear-Panel Options

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

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 paragraph 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: 67–250 V_{LN}
Operational Voltage Range: 0–300 V_{LN}

Ten-Second Thermal Rating: 600 Vac
Burden: ≤0.1 VA @ 125 V

AC Voltage Outputs

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 (Ui):

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

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:
 Interface Boards:
- 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

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

Communications Ports

EIA-232:
- 1 front and 3 rear

Serial Data Speed:
- 300–57600 bps

Communications Card Slot for Optional Ethernet Card

Ordering Options: 10/100BASE-T

Connector Type: RJ45

Ordering Option: 100BASE-FX Fiber-Optic

Connector Type: LC

Fiber Type: Multimode
Wavelength: 1300 nm
Source: LED
Min. TX Power: –19 dBm
Max. TX Power: –14 dBm
RX Sensitivity: –32 dBm
Sys. Gain: 13 dB

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: ≤2.8 Vdc
Logic Low Threshold: ≥0.8 Vdc
Input Impedance: >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.

<table>
<thead>
<tr>
<th>Connection Type</th>
<th>Min. Wire Size</th>
<th>Max. Wire Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grounding (Earthing)</td>
<td>14 AWG (2.5 mm²)</td>
<td>N/A</td>
</tr>
<tr>
<td>Current Connection</td>
<td>16 AWG (1.5 mm²)</td>
<td>10 AWG (5.3 mm²)</td>
</tr>
<tr>
<td>Potential (Voltage)</td>
<td>18 AWG (0.8 mm²)</td>
<td>14 AWG (2.5 mm²)</td>
</tr>
<tr>
<td>Contact I/O</td>
<td>18 AWG (0.8 mm²)</td>
<td>10 AWG (5.3 mm²)</td>
</tr>
</tbody>
</table>

Type Tests

Installation Requirements
Overvoltage Category: 3
Pollution Degree: 2

Safety
Product Standards
IEC 60255-27:2013
IEEE C37.90-2005
21 CFR 1040.10

Dielectric Strength:
IEC 60255-27:2013, Section 10.6.4.3
2.5 kVac, 50/60 Hz for 1 min: Analog Inputs, Contact Outputs, Digital Inputs
3.6 kVdc for 1 min: Power Supply, Battery Monitors
2.2 kVdc for 1 min: IRIG-B
1.1 kVdc for 1 min: Ethernet

Impulse Withstand:
IEC 60255-27:2013, Section 10.6.4.2
Common Mode:
±1.0 kV: Ethernet
±2.5 kV: IRIG-B
±5.0 kV: All other ports
Differential Mode:
0 kV: Analog Inputs, Ethernet, IRIG-B, Digital Inputs
±5.0 kV: Standard Contact Outputs, Power Supply Battery Monitors
+5.0 kV: Hybrid Contact Outputs

Insulation Resistance:
IEC 60255-27:2013, Section 10.6.4.4
>100 MΩ @ 500 Vdc

Protective Bonding:
IEC 60255-27:2013, Section 10.6.4.5.2
<0.1 Ω @ 12 Vdc, 30 A for 1 min

Object Penetration:
Protection Class: IP30

Max Temperature of Parts and Materials:
IEC 60255-27:2013, Section 7.3
Flammability of Insulating Materials:
IEC 60255-27:2013, Section 7.6
Compliant
### Electromagnetic (EMC) Immunity

**Product Standards:**
- IEC 60255-26:2013
- IEC 60255-27:2013
- IEEE C37.90-2005
- IEEE C37.90.1-2012
- IEC 61000-4-18:2006 + A:2010
- IEEE C37.90.1-2012
- IEEE C37.90.1-2012
- IEEE C37.90.3-2001

**Surge Withstand Capability (SWC):**
- ±1.0 kV
- ±2.5 kV

**Fast Transient, Common and Differential Mode:**
- ±1.0 kV
- ±2.5 kV

**Electrostatic Discharge (ESD):**
- ±8 kV
- ±15 kV

**Radiated RF Immunity:**
- ±10 V/m (>35 V/m, 80% AM, 1 kHz)
  - Sweep: 10 MHz to 1 GHz
- ±2 kV: communication ports
- ±2 kV: all other ports
  - Spot: 80, 160, 450, 900 MHz
- ±2 kV: communication ports (Ethernet)

**Ferrite Core:**
- ±4 kV: communication ports

**Power Supply Immunity:**
- ±2 kV: communication ports
- ±2 kV: all other ports

**Conducted Immunity:**
- ±1 kV: 24–48 Vdc power supply
- ±1 kV: communication ports (except Ethernet)

**Shock Resistance:**
- ±1 kV
- ±2 kV: communication ports (except Ethernet)

**Seismic:**
- ±1 kV: 24–48 Vdc power supply
- ±1 kV: communication ports (except Ethernet)

**Bump Response:**
- ±1 kV: 24–48 Vdc power supply
- ±1 kV: communication ports (except Ethernet)

**Vibration Response:**
- ±1 kV: 24–48 Vdc power supply
- ±1 kV: communication ports (except Ethernet)

### EMC Compatibility

**Product Standards:**
- IEC 62055-26:2013
- IEC 62055-27:2013
- ICES-003

**Emissions:**
- 47 CFR Part 15.109
- 47 CFR Part 15.107
- ICES-003, Issue 6

**Conducted:**
- Class A

**Radiated:**
- Class A

### Environmental

**Product Standards:**
- IEC 60255-27:2013

**Cold, Operational:**
- Test Ad: 16 hours at −40°C

**Cold, Storage:**
- Test Ad: 16 hours at −40°C

**Dry Heat, Operational:**
- Test Bd: 16 hours at +80°C

**Dry Heat, Storage:**
- Test Bd: 16 hours at +80°C

**Damp Heat, Cyclic:**
- Test Db: +25 °C to +55°C, 6 cycles (12 + 12-hour cycle), 95% RH

**Damp Heat, Steady State:**
- Test Dd: +25 °C to +55°C, 6 cycles (12 + 12-hour cycle), 95% RH

**Cyclic Temperature:**
- Test Nc: –40°C to +80°C, 5 cycles

**Vibration Resistance:**
- Class 2 Endurance, Class 2 Response

**Shock Resistance:**
- Class 1 Shock Withstand, Class 1 Bump Withstand, Class 2 Shock Response

**Seismic:**
- Class 2 Quake Response
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
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

Phase-Current Unbalance Elements
Number of Elements: 3
Pickup Range: Magnitude: 0.005 to 20.00 per unit (INOM)
Pickup Accuracy, Steady-State: 0.05 per unit ± 1% of set point
Maximum Pickup/Dropout Time: 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 (INOM)
Pickup Accuracy, Steady-State: 0.05 per unit ± 1% of set point
Maximum Pickup/Dropout Time: 10 cycles for 0.002 < I < 0.05 per unit
Time-Delay Range: 0.00–16000.00 cycles
Reset Time Range: 0.00–16000.00 cycles
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 (INOM)
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 (5I)

<table>
<thead>
<tr>
<th>Pickup Range (Adaptive within the range)</th>
<th>5 A nominal: 0.25–16.00 A secondary, 0.01 A steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 A nominal: 0.05–3.20 A secondary, 0.01 A steps</td>
<td></td>
</tr>
</tbody>
</table>

Accuracy (Steady-State)

| 5 A nominal: | ±0.05 A ± 3% of setting |
| 1 A nominal: | ±0.01 A ± 3% of setting |

Transmit 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 |

Transmit Overreach: ±5% of pickup

Maximum Delay: 1.5 cycles

Phase-to-Phase Under- and Overvoltage Elements

Elements based on the calculated phase-to-phase voltages

| Pickup Range: | 0.25–520 V_LL in 0.01 steps |
| Accuracy: | ±3% of setting, ± 0.5 V |

Transmit 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 |

Transmit Overreach

| 5 A nominal: | ±5%, ± 0.10 A |
| 1 A nominal: | ±5%, ± 0.02 A |

Maximum Pickup Time: 1.5 cycles

Maximum Drop 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: | 24–250 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)

| Pickup Range: | 24–250 Vdc |
| Operational Voltage Range: | 0–350 Vdc |
| Input Sampling Rate: | 2 kHz |
| Processing Rate: | (metering only) |
| 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) |

| 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) |

| 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 | \( I_{\text{NOM}} = 1 \, \text{A} \) |
| Magnitude Accuracy: | ±0.2%, ± 0.8 mA |
| Phase Accuracy: | ±0.2° |
| Current Range: | 0.5–3.0 |

| Quantity: IA, IB, IC Per Terminal | \( I_{\text{NOM}} = 5 \, \text{A} \) |
| 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

<table>
<thead>
<tr>
<th>InNom</th>
<th>Magnitude Accuracy</th>
<th>Phase Accuracy</th>
<th>Current Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 A</td>
<td>±0.3% ± 0.8 mA</td>
<td>±0.3°</td>
<td>0.1–20.0</td>
</tr>
<tr>
<td>5 A</td>
<td>±0.3% ± 4.0 mA</td>
<td>±0.3°</td>
<td>0.5–100.0</td>
</tr>
</tbody>
</table>

### Quantity: VA, VB, VC Per Terminal

<table>
<thead>
<tr>
<th>Voltage Range</th>
<th>Magnitude Accuracy</th>
<th>Phase Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>5–33.5 V</td>
<td>±2.5% ± 1 V</td>
<td>±1°</td>
</tr>
<tr>
<td>33.5–300 V</td>
<td>±0.1%</td>
<td>±0.5°</td>
</tr>
</tbody>
</table>

### Quantity: 3V0, V1, V2 Per Terminal

<table>
<thead>
<tr>
<th>Voltage Range</th>
<th>Magnitude Accuracy</th>
<th>Phase Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>5–33.5 V</td>
<td>±2.5% ± 1 V</td>
<td>±1°</td>
</tr>
<tr>
<td>33.5–300 V</td>
<td>±0.1%</td>
<td>±0.5°</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Voltage Range</th>
<th>Magnitude Accuracy</th>
<th>Phase Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>5–33.5 V</td>
<td>±2.5% ± 1 V</td>
<td>±1°</td>
</tr>
<tr>
<td>33.5–300 V</td>
<td>±0.1%</td>
<td>±0.5°</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Accuracy</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>±1%</td>
<td>(0.1–1.2) • InNom, 33.5–300 Vac, PF = 1, 0.5 (single phase)</td>
</tr>
<tr>
<td>±0.7%</td>
<td>(0.1–1.2) • InNom, 33.5–300 Vac, PF = 1, 0.5 (three phase)</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Accuracy</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>±1%</td>
<td>(0.1–1.2) • InNom, 33.5–300 Vac, PF = 1, 0.5 (single phase)</td>
</tr>
<tr>
<td>±0.7%</td>
<td>(0.1–1.2) • InNom, 33.5–300 Vac, PF = 1, 0.5 (three phase)</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Accuracy</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>±1%</td>
<td>(0.1–1.2) • InNom, 33.5–300 Vac, PF = 1, 0.5 (single phase)</td>
</tr>
<tr>
<td>±0.7%</td>
<td>(0.1–1.2) • InNom, 33.5–300 Vac, PF = 1, 0.5 (three phase)</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Accuracy</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>±1%</td>
<td>(0.1–1.2) • InNom, 33.5–300 Vac, PF = 1, 0.5 (single phase)</td>
</tr>
<tr>
<td>±0.7%</td>
<td>(0.1–1.2) • InNom, 33.5–300 Vac, PF = 1, 0.5 (three phase)</td>
</tr>
</tbody>
</table>

### Frequency Accuracy

<table>
<thead>
<tr>
<th>Accuracy</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01 Hz</td>
<td>40–65 Hz</td>
</tr>
</tbody>
</table>

### 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 • InNom (InNom = 1 A, 5 A)
- Magnitude Accuracy at 20°C and Nominal Frequency: ±0.2% ± 0.5 mA

### Unbalance Metering

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Accuracy</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differential Voltage dV A, dVB, dVC, dVG1, dVG2, dVG3</td>
<td>±1.0%</td>
<td>Unbalance Current 60N/60P ±0.01 V to ±100.00 V</td>
</tr>
<tr>
<td>Magnitude Accuracy</td>
<td>±0.3%</td>
<td></td>
</tr>
<tr>
<td>Phase Accuracy</td>
<td>±0.3°</td>
<td></td>
</tr>
</tbody>
</table>

### K Compensation Factors

<table>
<thead>
<tr>
<th>Magnitude Accuracy</th>
<th>Phase Angle Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>±1.0% ± 0.002 • KSET</td>
<td>±0.3°</td>
</tr>
</tbody>
</table>

### 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

#### Synchrophasors

- Number of Synchrophasor Data Streams: 5
- Number of Synchrophasors for Each Stream: 12 phase synchrophasors (6 voltage and 6 currents), 4 positive-sequence synchrophasors (2 voltage and 2 currents)
- Number of User Analogs for Each Stream: 16 (any analog quantity)
Number of User Digitals for Each Stream: 64 (any Relay Word bit)


Synchrophasor Data Rate: As many as 60 messages per second

Synchrophasor Accuracy:
- Voltage Accuracy: ±1% Total Vector Error (TVE) Range 30–150 V, f_{NOM} ±5 Hz
- Current Accuracy: ±1% Total Vector Error (TVE) Range (0.1–20) • I_{NOM}, f_{NOM} ±5 Hz

Synchrophasor Data Recording: Records as much as 120 s IEEE C37.232 File Naming Convention

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