SEL-487E
Transformer Protection Relay

High-speed transformer differential protection for up to five terminals

- Advanced differential protection and three restricted earth fault (REF) elements minimize damage and expensive repairs to transformers.
- Through-fault, thermal, and circuit breaker monitoring provide comprehensive substation asset management.
- Industry-leading synchrophasors monitor the overall system status.
- SEL Time-Domain Link (TiDL®) and Sampled Values (SV) technologies transform the way you modernize your substation.
**Functional Overview**

**ANSI Number/Acronyms and Functions**

<table>
<thead>
<tr>
<th>Number</th>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>16 SEC</td>
<td>Access Security (Serial, Ethernet)</td>
</tr>
<tr>
<td>24</td>
<td>24</td>
<td>Volts/Hertz</td>
</tr>
<tr>
<td>25</td>
<td>25</td>
<td>Synchronism Check</td>
</tr>
<tr>
<td>27</td>
<td>27</td>
<td>Undervoltage</td>
</tr>
<tr>
<td>32</td>
<td>32</td>
<td>Directional Power</td>
</tr>
<tr>
<td>46</td>
<td>46</td>
<td>Current Unbalance</td>
</tr>
<tr>
<td>49</td>
<td>49</td>
<td>Thermal</td>
</tr>
<tr>
<td>50BF</td>
<td>50BF</td>
<td>Breaker Failure Overcurrent</td>
</tr>
<tr>
<td>50N</td>
<td>50N</td>
<td>Neutral Overcurrent</td>
</tr>
<tr>
<td>50 (P,G,Q)</td>
<td>50 (P,G,Q)</td>
<td>Overcurrent (Phase, Ground, Neg. Seq.)</td>
</tr>
<tr>
<td>51N</td>
<td>51N</td>
<td>Neutral Time-Overcurrent</td>
</tr>
<tr>
<td>51 (P,G,Q)</td>
<td>51 (P,G,Q)</td>
<td>Time-Overcurrent (Phase, Ground, Neg. Seq.)</td>
</tr>
<tr>
<td>59</td>
<td>59</td>
<td>Overvoltage</td>
</tr>
<tr>
<td>67 (P,G,Q)</td>
<td>67 (P,G,Q)</td>
<td>Directional Overcurrent (Phase, Ground, Neg. Seq.)</td>
</tr>
<tr>
<td>81 (O,U)</td>
<td>81 (O,U)</td>
<td>Over-/Underfrequency</td>
</tr>
<tr>
<td>85 RIO</td>
<td>85 RIO</td>
<td>SEL Mirrored Bits Communications</td>
</tr>
<tr>
<td>87 (U,R,Q)</td>
<td>87 (U,R,Q)</td>
<td>Transformer Differential (Unrestrained, Restrained, Neg. Seq.)</td>
</tr>
<tr>
<td>DFR</td>
<td>DFR</td>
<td>Event Reports</td>
</tr>
<tr>
<td>ENV</td>
<td>ENV</td>
<td>SEL-2600</td>
</tr>
<tr>
<td>HMI</td>
<td>HMI</td>
<td>Operator Interface</td>
</tr>
<tr>
<td>LGC</td>
<td>LGC</td>
<td>Expanded SELOGIC Control Equations</td>
</tr>
<tr>
<td>MET</td>
<td>MET</td>
<td>High-Accuracy Metering</td>
</tr>
<tr>
<td>PMU</td>
<td>PMU</td>
<td>Synchrophasors</td>
</tr>
<tr>
<td>REF</td>
<td>REF</td>
<td>Restricted Earth Fault</td>
</tr>
<tr>
<td>RTU</td>
<td>RTU</td>
<td>Remote Terminal Unit</td>
</tr>
<tr>
<td>SER</td>
<td>SER</td>
<td>Sequential Events Recorder</td>
</tr>
</tbody>
</table>

**Additional Functions**

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRM</td>
<td>Breaker Wear Monitor</td>
</tr>
<tr>
<td>LDP</td>
<td>Load Data Profiling</td>
</tr>
<tr>
<td>SBM</td>
<td>Station Battery Monitor</td>
</tr>
<tr>
<td>SIP</td>
<td>Software-Invertible Polarities</td>
</tr>
<tr>
<td>SV</td>
<td>IEC 61850-9-2 Sampled Values Technology*</td>
</tr>
<tr>
<td>THM</td>
<td>IEC 60255-Compliant Thermal Model</td>
</tr>
<tr>
<td>TDL</td>
<td>Time-Domain Link Technology*</td>
</tr>
<tr>
<td>TRM</td>
<td>Transformer Monitor</td>
</tr>
</tbody>
</table>

*Copper or fiber-optic  *Optional feature

†SV subscriber relays have no analog input boards and instead receive voltages and current through Ethernet.
Key Features

Multiwinding Protection
Configure the SEL-487E Transformer Protection Relay for differential protection in transformer applications using up to five restraint currents. This includes single transformers with tertiary windings. Three independent REF elements offer protection for grounded-wye windings. You can invert individual or grouped CT or PT polarities to account for field wiring or protection zone changes.

High-Speed, Adaptive Differential Protection
Implement a two-stage slope that automatically adapts to internal or external fault conditions, even with CT saturation and heavily distorted waveforms, for fast, sensitive, dependable, and secure differential protection. The adaptive differential element responds to internal fault conditions in less than 1.5 cycles.

Diverse Transformer Applications
Protect large transformers and autotransformers with breaker-and-a-half high- and low-side connections. You can configure the SEL-487E for a typical two-winding transformer application and use the remaining three-phase current inputs for feeder backup protection.

Sensitive Turn-to-Turn Fault Detection
The patented negative-sequence differential element detects turn-to-turn faults involving as little as 2 percent of the total winding, helping avoid catastrophic transformer failure.

Dependable Backup Protection
Provide backup protection with five phase, negative-sequence, and zero-sequence overcurrent elements and ten configurable time-overcurrent elements. By setting up breaker failure protection with subsidence detection, you can rapidly detect breaker failure and minimize system coordination times.

Generator Step-Up Protection
Protect generator step-up (GSU) transformers with built-in temperature measurement (requires the SEL-2600 RTD Module) that monitors generator and transformer winding temperatures simultaneously. In addition, the volts/hertz element provides overexcitation protection for loaded and unloaded generator operating conditions. By setting the directional power elements to detect forward and reverse power flow conditions, you can monitor and protect the GSU transformer in prime-power, standby, base-load, and peak-shaving applications. Built-in synchronism-check elements verify the generator breaker synchronization.

Advanced Asset Monitoring
Track transformer wear with through-fault and thermal monitoring. Advanced breaker monitoring reduces inefficient and costly breaker maintenance. You can also monitor substation dc power systems for out-of-tolerance voltage levels or excessive voltage ripple.

Station Phasor Measurement Unit (PMU)
Improve power quality with IEEE C37.118 synchrophasors from all 24 analog channels (6 voltage and 18 current sources) in your relay. Using synchrophasors over serial or Ethernet communications, you can easily detect reactive loop flows, turn state estimation into state measurement, and provide early warning of potential system instability. Real-time control is possible by receiving synchrophasor messages from two PMUs, and you can take action based on time-synchronized local and remote measurements.

Digital Secondary System Technologies
Modernize your substation by applying SEL TiDL technology or SEL SV technology. Both of these digital secondary system solutions replace copper wires with fiber-optic cables to increase safety, reduce costs associated with using copper wires, and limit the impact of electromagnetic interference.

TiDL is a simple and secure digital secondary system solution that is easy to implement, with no external time source or network engineering required. Apply the TiDL-enabled SEL-487E-3/-4 in the control house with the SEL-2240 Axion® TiDL node in the yard, which provides remote I/O, digitizes analog signals, and sends the signals over fiber-optic cables to the relay.

SEL SV is the only digital secondary system solution in the world that combines protection in the merging unit with the flexibility of IEC 61850-9-2 to increase power system reliability. Apply the SEL-487E-5 with SEL SV technology to receive IEC 61850-9-2 SV data over fiber-optic cables from SEL merging units or other SV-compliant units.
Product Overview

Easy-to-use keypad aids simple navigation.

Programmable operator pushbuttons with user-configurable labels allow front-panel customization.

LCD allows you to control and view the status of disconnects and breakers.

Front-panel LEDs indicate custom alarms and provide fast and simple information to assist dispatchers and line crews with rapid power restoration.

EIA-232 front serial port is quick and convenient for system setup and local access.
Choose from power supply options such as 24–48 Vdc; 48–125 Vdc or 110–120 Vac; or 125–250 Vdc or 110–240 Vac.

Connectorized® hardware configuration or a Euro connector with low-energy analog (LEA) voltage inputs provide flexibility for different line voltage sensors or optical voltage transformers.

*Optional feature.

**For PTPv2 implementation, Ports 5A and 5B must be ordered as an option.
Applications

Multiwinding Differential Transformer Protection
Provide current differential protection for up to five 3-phase terminals with an adaptive-slope percentage restraint for transformers at power plants, transmission substations, distribution substations, and industrial plants. The adaptive differential element includes two slope settings. During normal operating conditions, Slope 1 provides a fast response to internal faults. For external faults, the relay switches from Slope 1 to Slope 2 to provide a high-security mode and avoid misoperation from CT saturation. When the operating quantities exceed the differential slope characteristic and fall in the operate region, the filtered differential element asserts. You can use the remaining 3-phase current inputs for feeder backup protection.

Combine harmonic-blocking and -restraint functions in parallel to provide secure operation and optimum operating speed during inrush conditions. Second- and fourth-harmonic blocking provide security during energization, while fifth-harmonic blocking provides security for overexcitation conditions. Fast subcycle external fault detection supervision adds security during external faults that have CT saturation.

Use the waveform-based inrush detection method to augment the harmonic-blocking and -restraint functions to prevent differential element operation during an inrush condition with low second-harmonic content. Low harmonic content is typical for newer transformers with cores that are made out of an improved iron core type, which has a different B-H characteristic (linear for high values of field intensity) than traditional transformers. In addition to the inrush detection algorithm, the waveform-based method also has a bidirectional differential overcurrent scheme that differentiates between an internal fault and an inrush condition.

Protection Using Any Combination of Nominal CT Inputs
You can order any combination of nominal CT inputs at 5 A and 1 A for each transformer winding, including the following examples:
- 1 A on high-voltage side, 5 A on low-voltage side.
- 1 A on high-voltage side, 5 A on low-voltage side, 1 A on tertiary side.

Support up to 35:1 CT ratio mismatch without a loss of performance.
Possible applications include:
- Breaker-and-a-half installation.
- Busbar protection for up to five terminals with mismatched CT ratios.
Comprehensive Time-Overcurrent Protection

Eliminate the need to change settings groups to accommodate different time-overcurrent pickup and time dial settings. The programmable time-delay and pickup levels in the selectable time-overcurrent elements allow the pickup and time-delay settings to change instantly, without needing to switch settings groups. You can choose from ten time-overcurrent curves.

Programming the time-delay and pickup levels as math variables allows the numeric value of the pickup and time-delay settings to change based on any number of conditions, without the short delay of having to change relay settings groups. For example, you can change pickup and time-delay settings dynamically in a parallel-transformer application based on single- or parallel-transformer configurations. Another example would be to change feeder time-overcurrent element pickup and coordination delays based on distributed generation being connected downstream of a transformer.

Flexible Backup Protection Using Directional Overcurrent Control Elements

When voltage inputs are connected to the SEL-487E, directional elements can supervise phase and ground overcurrent elements on a per-winding basis. The phase and ground directionally controlled overcurrent elements provide backup protection for transformer differential or feeder overcurrent relays. Voltage-polarized directional elements supervise currents that are on the same side of the transformer as the selected polarizing voltages.

Thermal Protection and Monitoring

The SEL-487E provides the IEEE C57.91 and IEC 60255-149 thermal models for protection and monitoring the thermal response of top-oil and hotspot temperatures. Use the IEC thermal element to trip a breaker, or use either the IEC or the IEEE thermal elements to activate a control action or issue an alarm when the transformer is in danger of excessive insulation aging or loss of life. The relay includes three loss-of-insulation-life alarms: loss of life per day, total loss of life, and insulation aging factor.
Flexible Communications
An Ethernet card option provides two copper or fiber ports for redundancy. Available Ethernet communications protocols include FTP, Telnet, the Simple Network Time Protocol (SNTP), DNP3 LAN/WAN, IEC 61850 Edition 2, IEEE C37.118 synchrophasors, the IEEE 1588 PTPv2, and PRP. All four independent EIA-232 serial ports support SEL Fast Messages, SEL ASCII, Compressed ASCII, SEL Fast Operate, SEL Fast Meter, SEL Fast SER, enhanced SEL Mirrored Bits communications, DNP3 Level 2 Outstation plus dial out, Virtual Terminal, and communications with the SEL-2600 (SEL-2800 Fiber-Optic Transceiver required).

Through-Fault Monitoring
Track transformer wear with through-fault monitoring. You can gather current levels, the through-fault duration, and the date/time of each through fault. Through-fault currents can cause transformer winding displacement, leading to mechanical damage and increased transformer thermal wear. Monitoring cumulative through-fault duty helps you schedule proactive maintenance.

Circuit Breaker Monitoring
The SEL-487E features advanced circuit breaker monitoring. The relay processes phase currents, circuit breaker auxiliary contacts, and substation dc battery voltages to detect out-of-tolerance and maximum-life circuit breaker parameters. These parameters include interrupted current, operating times, and contact wear. By using SEL-487E monitoring, maintenance personnel can determine the extent of a developing circuit breaker problem and select an appropriate response to correct the issue.
Synchrophasor Data for All CT and PT Channels

Improve power system quality and save money with SEL synchrophasors that are simultaneously available from all 24 analog channels (6 voltage and 18 current sources). With synchrophasors over serial or Ethernet communications, you can easily detect reactive loop flows, turn state estimation into state measurement, and provide early warning of potential system instability.

Simplify your system architecture and improve system operations with UDP multicast synchrophasor data. Configurable data streams allow you to select analog and binary information for up to five independent IEEE C37.118 data streams over Ethernet.

Real-Time Control

Improve system stability and reduce remote control requirements with real-time control. Direct relay-to-relay communication of synchrophasor values lets you apply remote measurements to local control. You can employ real-time values from remote transmission ends to control circuit breakers, static VAR compensators (SVCs), and power system stabilizers. The SEL-487E can control devices based on the voltage or current magnitude and phase angle, real or reactive power, or rate of change of the input quantities.

Share synchrophasor data between two or three SEL-487E Relays for special protection schemes or custom logic. Remote measurements are available in SELlogic control equations for protection or automation.

Station-Wide Synchrophasor Application

The SEL-487E is also a station-wide synchrophasor measurement and recording system. With 120 seconds of IEEE C37.118 binary synchrophasor data recording for all 24 analog channels, it can serve as a central PMU in any substation or power generation facility. The SEL-487E measures voltage magnitudes and current phase angle relationships at generators and transformers, which are key source nodes for stability studies and load angle measurements.
TiDL Technology

In a TiDL solution, Axion TiDL nodes are placed in the yard close to the primary equipment to digitize discrete I/O signals and analog data and then transport them over a fiber-optic cable to the TiDL-enabled SEL-487E-3/-4 in the control house.

This innovative technology uses point-to-point connections and a nonroutable protocol, providing a simple and secure solution. Because it does not require an external time source or Ethernet switches, it is easy to implement with no network engineering required.

TiDL combines the proven protection of the SEL-400 series relays with the modularity of the Axion, reducing training requirements and providing a scalable and flexible solution. It also provides built-in time synchronization and synchronous sampling, ensuring protection is available in the relay regardless of whether or not an external time signal is available.
SEL-487E-3/-4 With TiDL Technology

LEDs indicate a valid configuration and successful commissioning.

4U chassis with horizontal mounting options (panel or rack) accommodates your application needs.

LEDs indicate the connection status to a remote Axion TiDL node on a per-port basis.

Eight 100 Mbps fiber-optic ports allow the TiDL-enabled relay to connect with eight remote Axion TiDL nodes and to receive remote analog and digital data.

Commission button usage prompts the relay to communicate with the Axion TiDL nodes.
SEL SV Technology

In an SEL SV solution, the SEL-487E-5 Relay (subscriber) in the control house receives digitized analog signals from an SV merging unit (publisher) in the yard via a fiber-based Ethernet network. The system uses precise time synchronization via IRIG-B or PTP.

The SEL-487E-5 offers the traditional protection available in the SEL-487E-3/-4 and can also receive SV data. Because all SEL SV devices are compliant with IEC 61850-9-2 and the UCA 61850-9-2LE guideline, they can be used with primary equipment that generates similar SV streams, with other manufacturers’ SV-compliant units, or with SEL merging units that offer built-in protection (such as the SEL-401 Merging Unit and the SEL-421-7 Protection, Automation, and Control Merging Unit).

SEL SV technology allows you to create a robust and flexible Ethernet-based point-to-multipoint network using tools such as software-defined networks or VLANs to fit your application needs. You can use the SEL-2740S Software-Defined Network Switch to provide centralized traffic engineering and improve Ethernet performance. The switch acts as a transparent PTP clock that supports the IEEE C37.238 power system profile, ensuring submicro-second time synchronization of the end devices.
SEL-487E-5 With SV Technology

The 4U chassis has various mounting options to accommodate hardware needs.

Select fiber-optic, copper, or mixed Ethernet with separate ports for SV data and engineering access.

Choose from power supply options such as 24–48 Vdc; 48–125 Vdc or 110–120 Vac; or 125–250 Vdc or 110–240 Vac.
Accessibility and Communications

**Built-In Web Server**
Access basic SEL-487E information on a standard Ethernet network with the built-in web server. From there you can view the relay status, Sequential Events Recorder (SER) data, metering information, and settings with easy access within a local network. For increased security, web server access requires a relay password and the information is limited to a read-only view.

**MIRRORED BITS Communications**
This field-proven technology provides simple and powerful bidirectional digital communications between devices. MIRRORED BITS communications can transmit/receive information between relays for better coordination.

**Ethernet-Based Communications**
An Ethernet card option provides two copper, fiber, or mixed ports for failover redundancy. Simplify the Ethernet network topology and reduce external equipment with dual Ethernet ports that offer a switched mode for looped Ethernet networks. Available Ethernet communications protocols include FTP, Telnet, DNP3 LAN/WAN, IEEE 1588 PTPv2, IEC 61850 Edition 2, IEEE C37.118 synchrophasors, and PRP.
Setting and Commissioning Software

Save Time and Eliminate Costly Errors With SEL Commissioning Assistant Software

SEL Commissioning Assistant Software recommends matrix compensation settings after automatically identifying incorrect field wiring and improper CT configurations, such as incorrect CT polarities, inconsistent CT ratios, or crossed phases.

Apply the Commissioning Assistant in Five Easy Steps
1. Define the system one-line diagram.
2. Assign any two windings to conduct a test.
3. Validate the current flow, CT ratios, and polarity.
4. Run the test to start the matrix calculation process.
5. Document and implement the correct compensation matrix recommended for the transformer application.

Simplify the SEL-487E Configuration Process With the Graphical Logic Editor (GLE)

With the GLE, you can view SELOGIC control equations graphically and document settings files for easier validation and commissioning. You can also convert existing SELOGIC control equations to easy-to-read diagrams and save diagrams with your ACCELERATOR QuickSet® SEL-5030 Software settings.

The GLE capability in QuickSet makes it easy to design new SELOGIC control equations with the convenient diagram navigation tool, drag-and-drop interface, function block diagrams, and automatic layout function. You can manage your control diagrams with a full element palette. The GLE aids in reducing design errors and reducing the time and expense of commissioning relays.
# SEL-487E Specifications

## General

| **AC Current Inputs** (18 total) | 5 A nominal  
|                               | 1 A nominal  
|                               | 1 A/5 A nominal (Y terminal only [REF]) |
| **AC Voltage Inputs** (6 total) | 300 V_LN continuous, 600 Vac for 10 seconds |
| **LEA Voltage Inputs** | 0–8 V_LN continuous, 300 Vac for 10 seconds |
| **Serial** | 1 front-panel and 3 rear-panel EIA-232 serial ports  
|            | 300–57,600 bps |
| **Ethernet** | Communications protocols include FTP, Telnet, synchrophasors, DNP3 LAN/WAN, PRP, PTPv2, and IEC 61850 Edition 2 (optional).  
|              | Choose from the following port options:  
|              | Two 10/100BASE-T twisted-pair network ports  
|              | Two 100BASE-FX fiber-optic network ports  
|              | One 10/100BASE-T twisted-pair network port and one 100BASE-FX fiber-optic network port |
| **TiDL Ports** | Fiber-optic ports: 8  
|                | Range: ~2 km  
|                | Data rate: 100 Mbps |
| **SV Ports** | Choose from the following communications port options:  
|              | Four 10/100BASE-T twisted-pair network ports  
|              | Four 100BASE-FX fiber-optic network ports  
|              | Two 10/100BASE-T twisted-pair network ports and two 100BASE-FX fiber-optic network ports  
|              | Subscriber: As many as 4 SV data streams  
|              | Data rate: 80 samples per cycle |
| **Precise-Time Input** | Demodulated IRIG-B time input and PTPv2 |
| **Synchrophasors** | IEEE C37.118 standard  
|                   | Up to 60 messages per second |
| **Processing** | AC voltage and current inputs: 8,000 samples per second  
|                 | Protection and control processing: 8 times per power system cycle |
| **Power Supply** | 24–48 Vdc  
|                  | 48–125 Vdc or 110–120 Vac  
|                  | 125–250 Vdc or 110–240 Vac |
| **Operating Temperature** | −40° to +85°C (−40° to +185°F)  
|                          | Note: LCD contrast is impaired for temperatures below −20°C (−4°F) and above +70°C (+158°F). |