SEL-400G
Advanced Generator Protection System

Protection for hydro, pumped-storage hydro, steam turbine, and combustion gas turbine generators

- Comprehensive generator protection, generator step-up (GSU) protection, autosynchronizing, and disturbance recording are available in a single device.
- The 18 current inputs and 6 voltage inputs let you implement simple or complex schemes.
- Wide-range frequency tracking (5–120 Hz) ensures that all protection functions are secure and dependable.
- SEL Grid Configurator allows you to quickly and confidently create, manage, and deploy settings.
## ANSI Numbers/Acronyms and Functions

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>21P</td>
<td>Phase Mho or Compensator Distance</td>
</tr>
<tr>
<td>24</td>
<td>Volts/Hertz</td>
</tr>
<tr>
<td>25A</td>
<td>Automatic Synchronizer</td>
</tr>
<tr>
<td>27/59</td>
<td>Under-/Overvoltage</td>
</tr>
<tr>
<td>27I/59I</td>
<td>Inverse-Time Undervoltage/Overvoltage</td>
</tr>
<tr>
<td>32</td>
<td>Directional Power</td>
</tr>
<tr>
<td>40</td>
<td>Loss-of-Field</td>
</tr>
<tr>
<td>46</td>
<td>Current Unbalance</td>
</tr>
<tr>
<td>49R</td>
<td>Thermal Overload (Resistance Temperature Detector [RTD])</td>
</tr>
<tr>
<td>49T</td>
<td>Thermal Overload (Thermal Model)</td>
</tr>
<tr>
<td>50BF</td>
<td>Breaker Failure</td>
</tr>
<tr>
<td>50</td>
<td>Overcurrent (Phase, Neutral, Ground, Negative Sequence)</td>
</tr>
<tr>
<td>50BF</td>
<td>Overcurrent (Phase, Neutral, Ground, Negative Sequence)</td>
</tr>
<tr>
<td>50B</td>
<td>Breaker Failure</td>
</tr>
<tr>
<td>64F</td>
<td>Field Ground</td>
</tr>
<tr>
<td>64S</td>
<td>Stator Ground (Harmonic Injection)</td>
</tr>
<tr>
<td>78</td>
<td>Out-of-Step</td>
</tr>
<tr>
<td>81</td>
<td>Frequency (Over, Under, Rate)</td>
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<tr>
<td>87</td>
<td>Three-Phase Current Differential</td>
</tr>
<tr>
<td>IN AD</td>
<td>Inadvertent Energization</td>
</tr>
<tr>
<td>REF</td>
<td>Restricted Earth Fault</td>
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## Additional Functions

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>85 RIO</td>
<td>SEL MIRRORED BITS® Communications</td>
</tr>
<tr>
<td>BF</td>
<td>Breaker Failure</td>
</tr>
<tr>
<td>BRM</td>
<td>Breaker Wear Monitor</td>
</tr>
<tr>
<td>DFR</td>
<td>Event Reports</td>
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<tr>
<td>HMI</td>
<td>Operator Interface</td>
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<tr>
<td>LDP</td>
<td>Load Data Profiling</td>
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<tr>
<td>LGC</td>
<td>SELogic® Control Equations</td>
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<tr>
<td>MET</td>
<td>High-Accuracy Metering</td>
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<tr>
<td>PMU</td>
<td>Synchronphasors</td>
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<tr>
<td>SER</td>
<td>Sequential Events Recorder (SER)</td>
</tr>
<tr>
<td>RTU</td>
<td>Remote Terminal Unit</td>
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</tbody>
</table>

*Optional feature  
*Copper or fiber-optic
Key Features

Comprehensive Generator and Unit Protection
The SEL-400G offers primary and backup protection for generators of all sizes and types, including hydro, pumped-storage hydro, large steam turbine, and combustion gas turbine generators. Two independent universal differential elements provide protection for the generator and GSU transformer in a single relay. The SEL-400G also offers 18 current inputs, 6 voltage inputs, wide-range frequency tracking (5–120 Hz), advanced antimotoring protection, loss-of-field protection, and more.

Stator Winding Ground Fault Protection
The SEL-400G offers passive and active ground fault detection across 100 percent of the stator winding without sacrificing security. The stator winding ground fault protection elements include integrating timers that detect intermittent ground faults and isolate the generator before the fault evolves into a permanent fault, thereby containing generator damage. You can combine the SEL-400G with the SEL-2664S Stator Ground Protection Relay to protect against ground faults at standstill, during startup, and while running by using the multisine frequency injection and neutral overvoltage-based protection.

Rotor/Field Ground Fault Protection
Applying the SEL-2664 Field Ground Module and the SEL-2664S with the SEL-400G allows you to protect your system against rotor/field winding short circuits. The relay can show trends for deteriorating field winding insulation resistance, and it also provides rotor/field winding turn-to-turn fault protection.

Easy Communications
Choose from multiple copper or fiber-optic Ethernet ports, serial communications, and several protocols, including MIRRORED BITS communications, IEC 61850, and the Parallel Redundancy Protocol (PRP). Multiple Modbus TCP sessions are available for custom configuration of your application. You can also use DNP3 serial or DNP3 LAN/WAN protocols.

Next-Generation SEL Configuration Software
SEL Grid Configurator—a software tool that allows engineers and technicians to quickly and confidently create, manage, and deploy settings for SEL relays—is included with the SEL-400G. It is the next evolution in SEL protective relay and meter configuration software, delivering a modern user experience.
Product Overview

Easy-to-use keypad aids simple navigation.

Front-panel display allows operators to control and view the status of disconnects and breakers.

Front-panel, tricolor 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.

User-selectable mimic screens show the system configuration in one-line diagram format.

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

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

Communications protocols include FTP, Telnet, synchrophasors, DNP3 LAN/WAN, PRP, the IEEE 1588 Precision Time Protocol Version 2 (PTPv2),* and IEC 61850 Edition 2.

Use one front and three rear EIA-232 ports for Mirrored Bits communications, DNP3, SCADA, and engineering access.

Choose from a horizontal panel-mount or rack-mount chassis.

The 18 current and 6 voltage channels support differential protection for up to 6 three-phase terminals, 3 independent REF elements, and voltage elements.
Applications

Dual Differential and Dual Frequency Zones
Two independent universal elements provide protection for two protection zones, which allows independent protection of both the generator and GSU transformer with a single SEL-400G. Implemented with an external fault detector, the two zones are sensitive to internal faults while secure against external faults. Wide-range frequency tracking (5–120 Hz) ensures that all protection functions are secure and dependable across a wide range of system frequencies or generator speeds. This provides protection during events such as unit overspeed, inverter driven startup, or variable-speed pumped storage.

Pumped Storage Logic
In addition, pumped-storage logic enables pumped-storage hydropower protection without the need for external relays to switch CT wiring, which lowers costs and improves reliability. The SEL-400G internally rolls the phasing of selected CTs to correct the phase change introduced in the primary circuit during pump operation, or it corrects the transposition introduced by the reversing switch in a pumped-storage application.

Rotor/Field Winding Protection
Detecting field-winding-to-ground faults allows you to take appropriate action before a generator sustains serious damage from severe vibration. With the field ground protection element, the first fault will trigger an alarm and a second fault results in a trip signal.

Stator Ground Fault Protection
The 64G1, 64G2, and 64G3 elements provide 100 percent stator winding ground fault protection through passive methods. With the SEL-2664S, the SEL-400G offers active protection even at standstill. Adding the neutral voltage connection provides protection for most machines, based on fundamental-frequency and third-harmonic neutral voltage measurements. Connecting the neutral current input provides protection for solidly grounded or resistance-grounded machines. Voltage injection provided by the SEL-2664 allows you to monitor field ground insulation resistance. You can protect generators from damage by responding to low field ground insulation resistance warnings.
Loss-of-Field Protection
To protect the generator during loss-of-field events, the SEL-400G offers two impedance-based schemes: a negative offset Zone 2 scheme with two mho elements and a positive offset Zone 2 scheme (or qualified trip scheme) supervised by undervoltage and directional elements.

The SEL-400G also includes a capability-based method for loss-of-field protection. This method is based on the real and reactive power plane and works by coordinating with the generator capability curve, steady-state stability limit, and under-excitation limiter.

Dependable Directional Power Element
The wide-range frequency tracking capability ensures that the directional power elements are secure and dependable across a wide range of system frequencies or generator speeds and can be used for backup protection. It includes four elements, can be assigned to a dedicated CT, and has a biased option. This provides extra dependability when motoring power is very low and reactive power is high.

Antimotoring Protection
Steam and combustion turbines can be vulnerable to turbine or generator damage when motoring. The SEL-400G offers advanced antimotoring protection, including four sensitive power elements with independent time delays to sense motoring. It also provides a biased characteristic that ensures both security and dependability when motoring during significant reactive power output conditions.

Out-of-Step (OOS) Blocking and Tripping
When a generator loses synchronism with the utility system, it must be separated immediately to avoid widespread outages and equipment damage. The SEL-400G provides robust OOS tripping capabilities with two detection schemes: a single-blinder scheme and a double-blinder scheme. In addition, a pole slip counter feature enables precise tripping.

Automatic Generator Control
The SEL-400G, in combination with the SEL PowerMAX® Power Management and Control System, can balance generation loading, control the tie line power flow, and maintain the bus voltage. The SEL generation control system regulates generator power outputs and manages utility interties to maximize system stability, minimize electrical disturbances, and mitigate load-shedding requirements.

The automatic MVAR and voltage control system maintains MVAR flows on interties and system bus voltages by controlling load tap changers, generator field and large synchronous motor exciters, synchronous and static condensers, and capacitor banks.
Autosynchronization

Use the additional, built-in automatic synchronizer function to automatically synchronize the frequency, voltage, and phase angle of the generator and connect to the power system. You can synchronize up to three breakers and choose from three pulse control options. Control actions as well as governor and automatic voltage regulator responses are available on event or disturbance reports. Autosynchronization eliminates the need for expensive external synchronizing equipment.

Resistance Temperature Detector (RTD)-Based Thermal Protection

Acquire thermal data for alarm, monitoring, and trip functions in the SEL-400G with an external 12 RTD SEL-2600 RTD Module.

Synchrophasor Measurement

Combine the SEL-400G with an SEL IRIG-B time source to measure the system angle in real time with a timing accuracy of ±10 μs. You can measure instantaneous voltage and current phase angles in real time to improve system operation.
Accessibility and Communications

**Built-In Web Server**
Access basic SEL-400G 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**
The standard Ethernet card provides two copper, fiber, or mixed ports for failover redundancy. Dual Ethernet ports, with a switched mode for looped Ethernet networks, simplify the Ethernet network topology and reduce external equipment. Available Ethernet communications protocols include FTP, Telnet, DNP3 LAN/WAN, IEEE 1588 PTP, IEC 61850 Edition 2, IEEE C37.118 synchrophasors, the Simple Network Time Protocol (SNTP), and PRP.

**Modbus TCP**
The Modbus TCP option provides Modbus functionality over Ethernet. It allows a Modbus master device to acquire metering, monitoring, and event data from the relay; control relay output contacts; read the SEL-400G self-test status; and learn the present condition of all the relay protection elements. Up to two Modbus TCP sessions can be configured with one custom Modbus map.
SEL Grid Configurator Software

A Powerful New Configuration Tool
Grid Configurator allows you to quickly and confidently create, manage, and deploy settings for SEL power system devices. It features a modern interface designed for ease of use, with powerful protection visualization and comprehensive reporting to reduce device deployment complexity.

Easy Device Configuration
A user-configurable device hierarchy allows you to quickly identify power system devices, such as relays, meters, and distribution controllers. The spreadsheet-style editor makes finding and editing one or many settings simple. Powerful compare and merge features allow you to manage settings across multiple devices or groups within a single screen.

Powerful Protection Visualization
The Device Overview feature provides an immediate high-level summary of how you are using your devices’ capabilities. You can also see a graphical configuration for many relay protection functions.

Comprehensive Reporting
With Grid Configurator, viewing and downloading reports for an entire substation at once is simple. You can filter by date, report type, or device type and download the reports to your laptop with a click.

Quick Settings Deployment
Grid Configurator makes it simple to send settings to multiple networked devices at once—no more moving cables from device to device. It provides a report at the end of the process to let you know if there were any concerns during download.

Grid Configurator’s visualization tools help you easily adjust a device’s protection elements.
# SEL-400G Specifications

## General

| AC Current Inputs (18 total) | 15 inputs with 5 A or 1 A ordering options  
| 3 inputs with 0.2 A, 1 A, or 5 A ordering options |
| AC Voltage Inputs (6 total) | 300 Vac continuous, 600 Vac for 10 seconds |
| Output Contacts | The relay supports Form A and C outputs. |
| Optoisolated Control Inputs | DC/ac control signals: 24, 48, 110, 125, 220, and 250 V  
As many as 26 inputs are allowed in ambient temperatures of 85°C (185°F) or less.  
As many as 34 inputs are allowed in ambient temperatures of 75°C (167°F) or less.  
As many as 44 inputs are allowed in ambient temperatures of 65°C (149°F) or less. |
| Serial | 1 front-panel and 3 rear-panel EIA-232 serial ports  
300~57,600 bps |
| Ethernet | Communications protocols include Modbus TCP, FTP, TCP/IP, Telnet, synchrophasors, DNP3 LAN/WAN, PRP, PTPv2, and IEC 61850.  
Choose from the following port options:  
10/100BASE-T twisted pair network ports  
100BASE-FX fiber-optic network ports |
| Precise-Time Input | Demodulated IRIG-B time input and PTPv2 |
| Frequency and Phase Rotation | System frequency: 50, 60 Hz  
Phase rotation: ABC, ACB  
Frequency tracking: 5~120 Hz (requires ac voltage inputs) |
| Autosynchronizing | Frequency matching: ±0.1% plus ±4.2 ms at 60 Hz  
Voltage matching: VAY, VBY, VCY, VABY, VBCY, BCAY, or angle from VAY or VABY |
| Power Supply | 24/48 Vdc  
48/125 Vdc or 120 Vac  
125/250 Vdc or 120/240 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).