



# SEL-700G Family of Generator and Intertie Protection Relays



## SEL-700G0, SEL-700G1

Basic to Comprehensive Protection

Small, Medium, and Large Generators



## SEL-700GT

Intertie Protection

Intertie and Generator



## SEL-700GW

Basic Dual-Feeder Overcurrent Protection

Wind Generator

## Major Features and Benefits

The SEL-700G family of protection relays provides unsurpassed protection, integration, and control features in a flexible, compact, and cost-effective package.

- **Basic Generator Protection Features (SEL-700G0):** Ground differential; sensitive restricted earth fault; thermal overload; phase, negative-sequence, residual-ground, and neutral-ground overcurrent elements for backup; residual-ground and neutral-ground time-overcurrent elements; directional residual-ground and neutral-ground overcurrent elements; current unbalance element; voltage-controlled, voltage-restrained time-overcurrent element for backup protection; breaker failure protection for three-pole breaker; under- and overvoltage elements; loss-of-potential element; volts/hertz or overexcitation protection; directional power elements; loss-of-field; over- and underfrequency protection elements; off-frequency time accumulators; rate-of-change-of-frequency elements; inadvertent energization protection; RTD protection (requires internal or external SEL-2600 RTD option); field ground using an SEL-2664 Field Ground Module.
- **Optional Generator Protection Features (SEL-700G0+, SEL-700G1, SEL-700G1+):** Generator synchronism-check elements; synchronism-check under- and overvoltage elements; autosynchronism; backup compensator distance elements; out-of-step elements; 100% stator ground protection elements; and dual-slope current differential protection with harmonic blocking and restraint elements to provide sensitive and secure protection. The high-security mode provides additional security against CT saturation during external events including external transformer energization, external faults, etc.
- **Intertie Protection Features (SEL-700GT):** Phase, negative-sequence, and residual-ground overcurrent elements; phase, negative-sequence, and residual-ground time-overcurrent elements; phase, negative-sequence and residual-ground directional overcurrent elements; breaker failure protection for three-pole breaker; under- and overvoltage elements; loss-of-potential element; directional power elements; over- and underfrequency

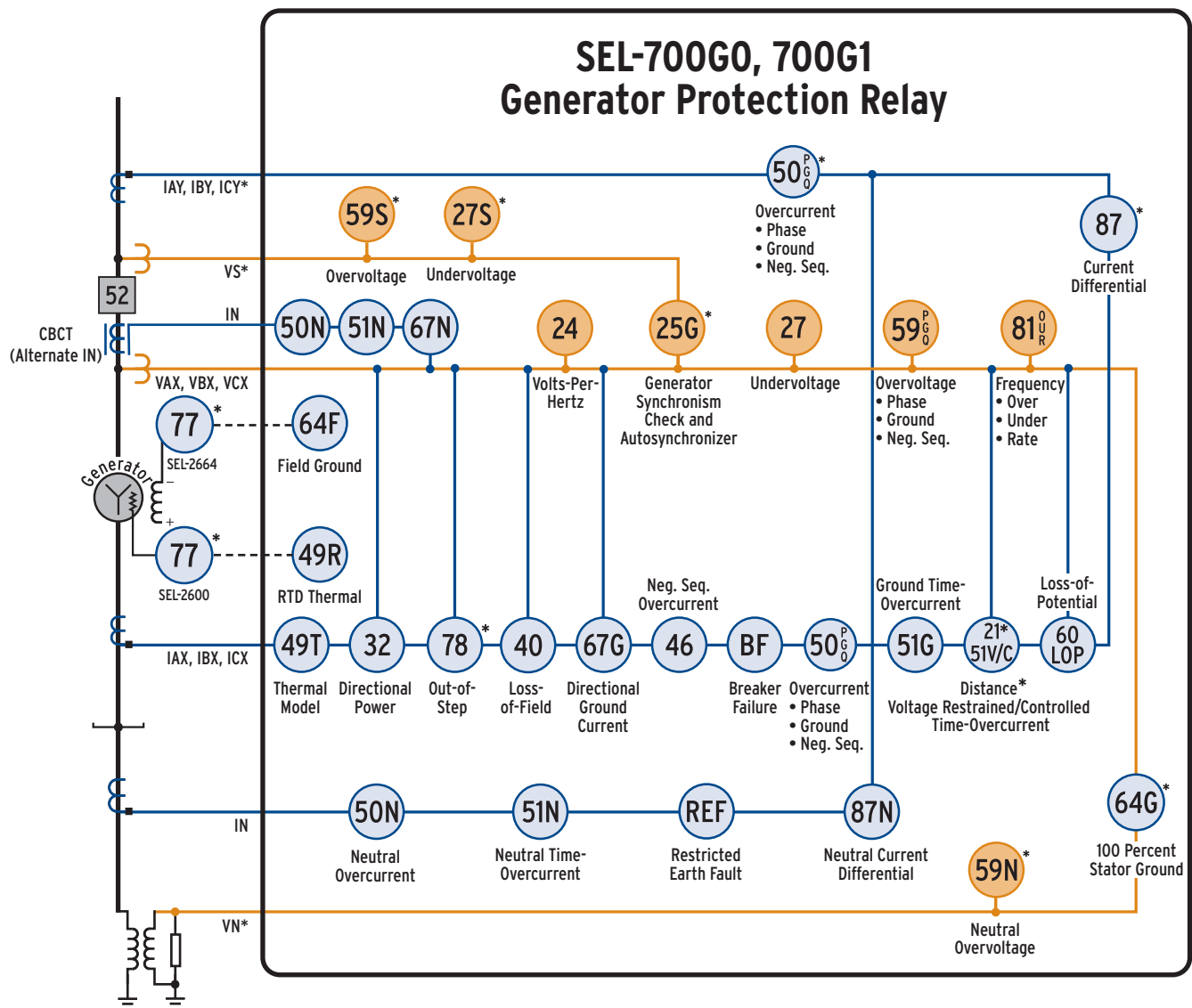
protection elements; rate-of-change-of-frequency elements; tie synchronism-check elements; synchronism-check under and overvoltage elements; autosynchronism; and RTD protection (requires internal or external SEL-2600 RTD option).

- **Optional Intertie Protection Features (SEL-700GT+).** Addition of basic generator protection features, as shown above for the SEL-700G0, to create intertie and generator protection. The relay also includes generator synchronism-check and autosynchronism functions.
- **Wind Generator Protection Features (SEL-700GW).** The SEL-700GW is configured with two sets of phase, negative-sequence, and residual-ground overcurrent elements, and phase, negative-sequence, and residual-ground time-overcurrent elements to provide dual-feeder protection in a multiwind generator network application. The relay also includes three-pole breaker failure protection for two breakers.
- **Generator Monitoring.** Monitor ambient and generator winding temperature using optional analog inputs or RTDs and protect the generator from thermal damage. Use off-frequency time accumulators and protect steam turbine blades from fatigue failures because of off-frequency vibration.
- **Operator Controls.** Four programmable front-panel pushbuttons each with two programmable LEDs allow for a wide variety of uses, including easy trip and close control and status indications for a breaker. Implement local and remote operator control schemes using 32 local and 32 remote control bits.
- **Relay and Logic Settings Software.** ACSELERATOR QuickSet<sup>®</sup> SEL-5030 Software reduces engineering costs for relay settings and logic programming. The tools in ACSELERATOR QuickSet make it easy to develop SELOGIC<sup>®</sup> control equations. Use the built-in phasor display to verify proper CT polarity and phasing. Use the synchroscope to watch the autosynchronism controls.
- **Metering and Reporting.** Built-in metering functions eliminate separately mounted metering devices. Analyze Sequential Events Recorder (SER) reports and oscillographic event reports for rapid commissioning, testing, and post-fault diagnostics. Unsolicited SER protocol allows station-wide collection of binary SER messages.
- **Additional Standard Features.** Includes Modbus<sup>®</sup> RTU, Event Messenger support, MIRRORING BITS<sup>®</sup> communications, load profile report, support for 12 external RTDs (SEL-2600 module), IRIG-B input, advanced SELOGIC, configurable labels, IEEE C37.118-compliant synchrophasor protocol, and fiber-optic serial port.
- **Optional Features.** Select from a wide offering of optional features, including SNTP (Simple Network Time Protocol), IEC 61850, Modbus<sup>®</sup> TCP/IP, DNP3 LAN/WAN, DNP3 Serial, 10 internal RTDs, expanded digital/analog I/O, voltage/current inputs, additional EIA-232 or EIA-485 communications ports, and single or dual, copper wire or fiber-optic Ethernet ports.

### Intertie Standards and Compliance

The SEL-700GT Intertie Protection Relay provides comprehensive multifunction protection, control, and monitoring for intertie applications as well as intertie generator applications. The SEL-700GT relay capabilities meet or exceed the protection and control requirements specified in the ANSI/IEEE Std 1547-2003, *Standard for Interconnecting Distributed Resources with Electric Power Systems*.

# Functional Overview

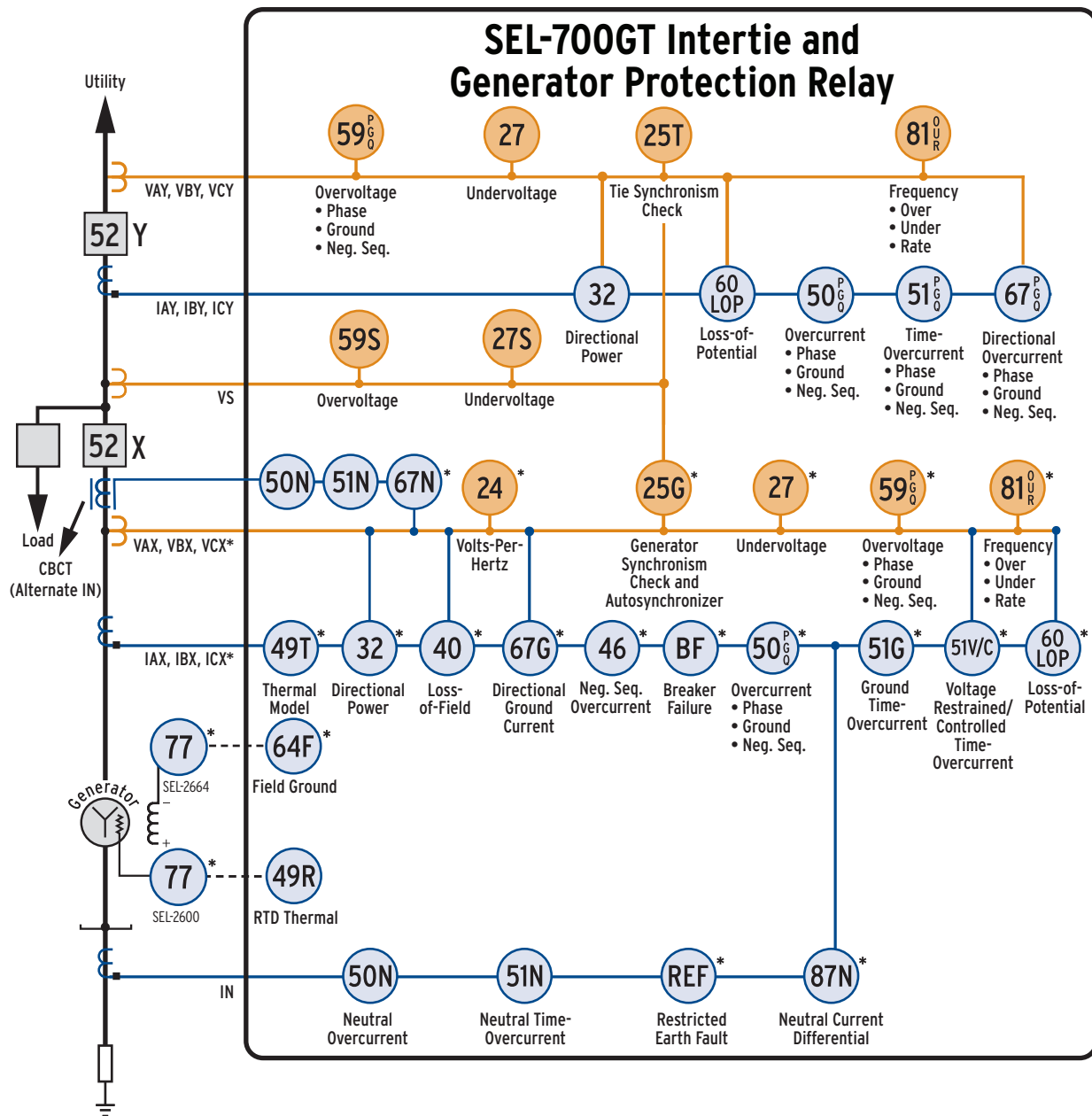


- Sequential Events Recorder
- Event Reports
- SEL ASCII, Ethernet\*, Modbus TCP\*, SNTP\*, IEC 61850\*, DNP3 LAN/WAN\*, DNP3 Serial\*, Modbus RTU, Telnet, FTP, and DeviceNet™ Communications\*
- Front-Panel LED Programmable Targets
- Two Inputs and Three Outputs Standard
- I/O Expansion\*—Additional Contact Inputs, Contact Outputs, Analog Inputs, Analog Outputs, and RTD Inputs
- Single or Dual Ethernet Copper or Fiber-Optic Communications Port\*

- Battery-Backed Clock, IRIG-B Time Synchronization
- Instantaneous Metering, Demand Metering
- Programmable Pushbuttons and LED Indicators
- Off-Frequency Operation Time Accumulators
- Advanced SELogic Control Equations
- 32 Programmable Display Messages
- MIRRORING BITS Communications
- Synchrophasor (IEEE C37.118)
- Breaker Wear Monitor
- Event Messenger Compatible

\*Optional

Figure 1 SEL-700G0, SEL-700G1 Generator Protection Relay



- Sequential Events Recorder
- Event Reports
- SEL ASCII, Ethernet\*, Modbus TCP\*, SNTP\*, IEC 61850\*, DNP3 LAN/WAN\*, DNP3 Serial\*, Modbus RTU, Telnet, FTP, and DeviceNet™ Communications\*
- Front-Panel LED Programmable Targets
- Two Inputs and Three Outputs Standard
- I/O Expansion\*—Additional Contact Inputs, Contact Outputs, Analog Inputs, Analog Outputs, and RTD Inputs
- Single or Dual Ethernet Copper or Fiber-Optic Communications Port\*

- Battery-Backed Clock, IRIG-B Time Synchronization
- Instantaneous Metering, Demand Metering
- Programmable Pushbuttons and LED Indicators
- Off-Frequency Operation Time Accumulators
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- 32 Programmable Display Messages
- MIRRORING BITS Communications
- Synchrophasor (IEEE C37.118)
- Breaker Wear Monitor
- Event Messenger Compatible

\*Optional

Figure 2 SEL-700GT Intertie and Generator Protection Relay

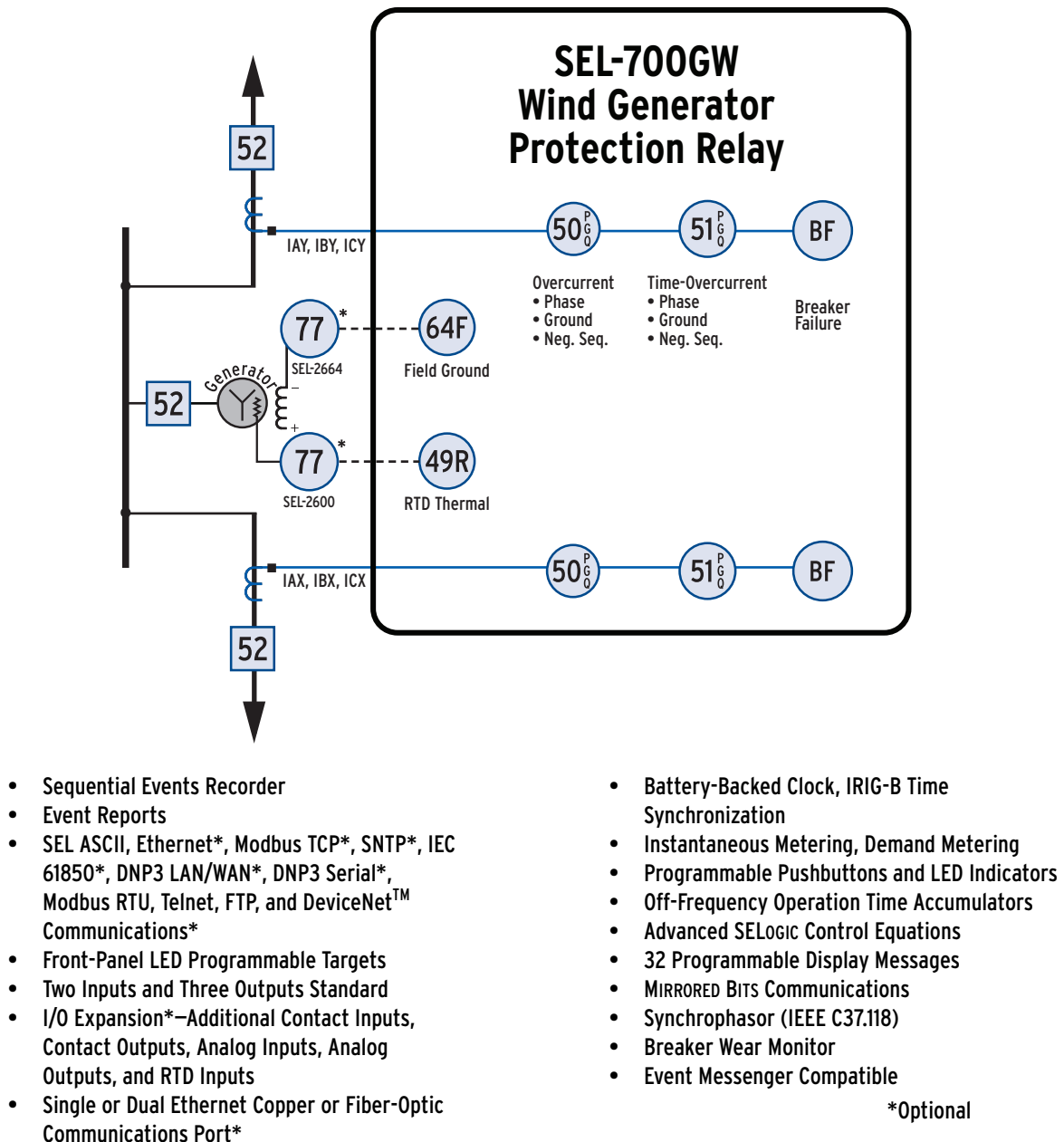


Figure 3 SEL-700GW Wind Generator Protection Relay

## Protection Features

### AC Analog Inputs

The SEL-700G has between 6 and 14 analog inputs, depending on the model and options selected. All analog inputs are recorded for event reporting and oscillography.

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

**Table 1 Current (ACI) and Voltage (AVI) Card Selection for 700G Models**

| Model  | Description                                                                             | Slot Z Card (MOT Digits)     | Slot Z Inputs                    | Slot E Card (MOT Digits) | Slot E Inputs                    |
|--------|-----------------------------------------------------------------------------------------|------------------------------|----------------------------------|--------------------------|----------------------------------|
| 700G0  | Basic generator protection                                                              | 4 ACI/3 AVI (81, 82, 85, 86) | IAX, IBX, ICX, IN, VAX, VBX, VCX | none (OX)                |                                  |
| 700G0+ | Basic generator protection plus (see <i>Table 2</i> for additional protection elements) | 4 ACI/3 AVI (81, 82, 85, 86) | IAX, IBX, ICX, IN, VAX, VBX, VCX | 2 AVI (74)               | VS, VN                           |
| 700G1  | Full generator protection                                                               | 4 ACI/3 AVI (81, 82, 85, 86) | IAX, IBX, ICX, IN, VAX, VBX, VCX | 3 ACIE (73, 77)          | IAY, IBY, ICY                    |
| 700G1+ | Full generator protection plus (see <i>Table 2</i> for additional protection elements)  | 4 ACI/3 AVI (81, 82, 85, 86) | IAX, IBX, ICX, IN, VAX, VBX, VCX | 3 ACI/2 AVI (72, 76)     | IAY, IBY, ICY, VS, VN            |
| 700GT  | Intertie protection                                                                     | 1 ACI (84, 88)               | IN                               | 3 ACI/4 AVI (71, 75)     | IAY, IBY, ICY, VS, VAY, VBY, VCY |
| 700GT+ | Intertie and generator protection                                                       | 4 ACI/3 AVI (81, 82, 85, 86) | IAX, IBX, ICX, IN, VAX, VBX, VCX | 3 ACI/4 AVI (71, 75)     | IAY, IBY, ICY, VS, VAY, VBY, VCY |
| 700GW  | Basic wind generator protection                                                         | 3 ACIZ (83, 87)              | IAX, IBX, ICX                    | 3 ACIE (73, 77)          | IAY, IBY, ICY                    |

The SEL-700G offers an extensive variety of protection features, depending on the model and options selected. *Table 2* shows the protection features available in the different models.

**Table 2 Protection Elements in SEL-700G Models (Sheet 1 of 2)**

| PROTECTION ELEMENTS |                          | Basic Generator Protection | Basic With       |             |                      | Intertie Protection | Intertie and Generator Protection | Wind Generator Protection |
|---------------------|--------------------------|----------------------------|------------------|-------------|----------------------|---------------------|-----------------------------------|---------------------------|
|                     |                          |                            | 21C, 25, 64G, 78 | 21C, 78, 87 | 21C, 25, 64G, 78, 87 |                     |                                   |                           |
|                     |                          | 700G0                      | 700G0+           | 700G1       | 700G1+               | 700GT               | 700GT+                            | 700GW                     |
| 87                  | Phase Differential       |                            |                  | X           | X                    |                     |                                   |                           |
| 87N                 | Ground Differential      | X                          | X                | X           | X                    |                     | X                                 |                           |
| REF                 | Restricted Earth Fault   | X                          | X                | X           | X                    |                     | X                                 |                           |
| 64G                 | 100% Stator Ground       |                            | X                |             | X                    |                     |                                   |                           |
| 64F                 | Field Ground             | X                          | X                | X           | X                    |                     | X                                 | X                         |
| 40                  | Loss of Field            | X                          | X                | X           | X                    |                     | X                                 |                           |
| 49T                 | Thermal Overload         | X                          | X                | X           | X                    |                     | X                                 |                           |
| 49RTD               | RTDs                     | X                          | X                | X           | X                    | X                   | X                                 | X                         |
| 46                  | Current Unbalance        | X                          | X                | X           | X                    |                     | X                                 |                           |
| 24                  | Volts/Hz                 | X                          | X                | X           | X                    |                     | X                                 |                           |
| 78                  | Out of Step              |                            | X                | X           | X                    |                     |                                   |                           |
| INAD                | Inadvertent Energization | X                          | X                | X           | X                    |                     | X                                 |                           |
| 21C                 | Compensator Distance     |                            | X                | X           | X                    |                     |                                   |                           |
| 51C                 | Voltage-Controlled TOC   | X                          | X                | X           | X                    |                     | X                                 |                           |
| 51V                 | Voltage-Restrained TOC   | X                          | X                | X           | X                    |                     | X                                 |                           |
| 51PX                | Phase Time-Overcurrent   |                            |                  |             |                      |                     |                                   | X                         |
| 51PY                | Phase Time-Overcurrent   |                            |                  |             |                      | X <sup>a</sup>      | X <sup>a</sup>                    | X                         |

**Table 2 Protection Elements in SEL-700G Models (Sheet 2 of 2)**

| PROTECTION ELEMENTS |                                   | Basic<br>Generator<br>Protection | Basic With          |                |                         | Intertie<br>Protection | Intertie and<br>Generator<br>Protection | Wind<br>Generator<br>Protection |
|---------------------|-----------------------------------|----------------------------------|---------------------|----------------|-------------------------|------------------------|-----------------------------------------|---------------------------------|
|                     |                                   |                                  | 21C, 25,<br>64G, 78 | 21C, 78,<br>87 | 21C, 25,<br>64G, 78, 87 |                        |                                         |                                 |
|                     |                                   | 700G0                            | 700G0+              | 700G1          | 700G1+                  | 700GT                  | 700GT+                                  | 700GW                           |
| 51QX                | Neg.-Seq. Time-Overcurrent        |                                  |                     |                |                         |                        |                                         | X                               |
| 51QY                | Neg.-Seq. Time-Overcurrent        |                                  |                     |                |                         | X <sup>a</sup>         | X <sup>a</sup>                          | X                               |
| 51GX                | Ground Time-Overcurrent           | X <sup>a</sup>                   | X <sup>a</sup>      | X <sup>a</sup> | X <sup>a</sup>          |                        | X <sup>a</sup>                          | X                               |
| 51GY                | Ground Time-Overcurrent           |                                  |                     |                |                         | X <sup>a</sup>         | X <sup>a</sup>                          | X                               |
| 51N                 | Neutral Time-Overcurrent          | X <sup>a</sup>                   | X <sup>a</sup>      | X <sup>a</sup> | X <sup>a</sup>          | X                      | X <sup>a</sup>                          |                                 |
| 50PX                | Phase Overcurrent                 | X                                | X                   | X              | X                       |                        | X                                       | X                               |
| 50PY                | Phase Overcurrent                 |                                  |                     | X              | X                       | X                      | X                                       | X                               |
| 67PY                | Directional Phase Overcurrent     |                                  |                     |                |                         | X                      | X                                       |                                 |
| 50QX                | Neg.-Seq. Overcurrent             | X                                | X                   | X              | X                       |                        | X                                       | X                               |
| 50QY                | Neg.-Seq. Overcurrent             |                                  |                     | X              | X                       | X                      | X                                       | X                               |
| 67QY                | Directional Neg.-Seq. Overcurrent |                                  |                     |                |                         | X                      | X                                       |                                 |
| 50GX                | Ground Overcurrent                | X                                | X                   | X              | X                       |                        | X                                       | X                               |
| 67GX                | Directional Ground Overcurrent    | X                                | X                   | X              | X                       |                        | X                                       |                                 |
| 50GY                | Ground Overcurrent                |                                  |                     | X              | X                       | X                      | X                                       | X                               |
| 67GY                | Directional Ground Overcurrent    |                                  |                     |                |                         | X                      | X                                       |                                 |
| 50N                 | Neutral Overcurrent               | X <sup>b</sup>                   | X <sup>b</sup>      | X <sup>b</sup> | X <sup>b</sup>          | X                      | X <sup>b</sup>                          |                                 |
| 67N                 | Directional Neutral Overcurrent   | X                                | X                   | X              | X                       |                        | X                                       |                                 |
| 27X                 | Undervoltage                      | X                                | X                   | X              | X                       |                        | X                                       |                                 |
| 27Y                 | Undervoltage                      |                                  |                     |                |                         | X                      | X                                       |                                 |
| 27S                 | Synchronism Undervoltage          |                                  | X                   |                | X                       | X                      | X                                       |                                 |
| 59X                 | Overvoltage (P, Q, G)             | X                                | X                   | X              | X                       |                        | X                                       |                                 |
| 59Y                 | Overvoltage (P, Q, G)             |                                  |                     |                |                         | X                      | X                                       |                                 |
| 59S                 | Synchronism Overvoltage           |                                  | X                   |                | X                       | X                      | X                                       |                                 |
| 32X                 | Directional Power                 | X                                | X                   | X              | X                       |                        | X                                       |                                 |
| 32Y                 | Directional Power                 |                                  |                     |                |                         | X                      | X                                       |                                 |
| 81X                 | Over/Underfrequency               | X                                | X                   | X              | X                       |                        | X                                       |                                 |
| 81Y                 | Over/Underfrequency               |                                  |                     |                |                         | X                      | X                                       |                                 |
| 81RX                | Rate-of-Change of Frequency       | X                                | X                   | X              | X                       |                        | X                                       |                                 |
| 81RY                | Rate-of-Change of Frequency       |                                  |                     |                |                         | X                      | X                                       |                                 |
| BFX                 | Breaker Failure                   | X                                | X                   | X              | X                       |                        | X                                       | X                               |
| BFY                 | Breaker Failure                   |                                  |                     |                |                         | X                      | X                                       | X                               |
| 60LOPX              | Loss of Potential                 | X                                | X                   | X              | X                       |                        | X                                       |                                 |
| 60LOPY              | Loss of Potential                 |                                  |                     |                |                         | X                      | X                                       |                                 |
| 25 GEN              | Synchronism Check                 |                                  | X                   |                | X                       |                        | X                                       |                                 |
| 25 TIE              | Synchronism Check                 |                                  |                     |                |                         | X                      | X                                       |                                 |
|                     | Autosynchronizer                  |                                  | X                   |                | X                       |                        | X                                       |                                 |

<sup>a</sup> These inverse time-overcurrent elements have directional control.<sup>b</sup> The 50N element uses the 67NnP and 67NnT Relay Word bits for the SEL-700G0, SEL-700G0+, SEL-700G1, SEL-700G1+, and SEL-700GT+ models.

## Overcurrent Protection

The SEL-700G provides complete overcurrent protection with as many as two sets of three-phase CTs and one neutral CT input. Phase overcurrent protection is provided for both three-phase inputs. The following overcurrent elements are provided.

### Instantaneous Overcurrent Elements

The following instantaneous overcurrent elements are provided in the SEL-700G relay as shown in *Table 2*. All instantaneous overcurrent elements provide torque control and definite-time delay settings.

- As many as six instantaneous phase overcurrent elements (50P) with peak detection algorithms to enhance element sensitivity during high-fault current conditions where severe CT saturation may occur.
- As many as four instantaneous negative-sequence overcurrent (50Q) elements.
- As many as four residual-ground instantaneous overcurrent (50G) elements. These elements use calculated residual (3I0) current levels.
- As many as two neutral instantaneous overcurrent elements (50N).

### Directional Instantaneous Overcurrent Elements

The following directional overcurrent elements are available in the SEL-700G with directional control (see *Table 2*).

- As many as three directional phase overcurrent elements (67P).
- As many as two directional negative-sequence overcurrent elements (67Q).
- As many as four directional residual-ground overcurrent elements (67G).
- As many as two directional neutral-ground overcurrent elements (67N).

### Time-Overcurrent Elements

The SEL-700G provides the time-overcurrent elements listed in *Table 2*. These time-overcurrent elements support the IEC and US (IEEE) time-overcurrent characteristics. Electromechanical disc reset capabilities are provided for all time-overcurrent elements.

- As many as two phase time-overcurrent (51P) elements are provided. These phase elements operate on the maximum of phase currents. One 51P element has directional control.
- As many as two negative-sequence time-overcurrent (51Q) elements are provided. These elements operate on the calculated negative-sequence current for each set of three-phase inputs. One 51Q element has directional control.

- As many as two residual time-overcurrent (51G) elements are provided. These elements use calculated residual (3I0) current levels. Both 51G elements have directional control.
- One neutral time-overcurrent (51N) element is provided with directional control.

## Differential Protection (87)

When specified, the SEL-700G detects stator faults using a secure, sensitive current differential function. This function has a sensitive percentage-restrained differential element and an unrestrained element. The differential function provides the unique capability of power transformer and CT connection compensation. This allows you to conveniently include the unit step-up transformer in the generator differential zone using wye-connected CTs for both input sets. The relay allows you to choose harmonic blocking, harmonic restraint, or both, providing a reliable differential protection during transformer inrush conditions. Even-numbered harmonics (second and fourth) provide security during energization, while fifth harmonic blocking provides security for over-excitation conditions. Set second-, fourth-, and fifth-harmonic thresholds independently. The dual-slope percentage restraint characteristic improves element security for through-fault conditions. The high-security mode provides additional security against CT saturation during external events including external transformer energization, external faults, etc.

## Restricted Earth Fault (REF) Protection

Apply the REF protection feature for sensitive detection of internal ground faults on grounded wye-connected windings. The neutral current CT provides the operating current. Polarizing current is derived from the residual current calculated for the protected winding. A sensitive directional element determines whether the fault is internal or external. Zero-sequence current thresholds and selectable CT saturation logic supervise tripping.

## Ground Differential Protection (87N)

SEL-700G relays with generator protection are equipped with a ground differential function that provides selective ground fault detection for solidly grounded and low-impedance grounded generators. This function helps protect generators on multimachine buses, because the element does not respond to ground faults on the parallel generators.

## Generator Synchronism Check (25G)

You can specify the SEL-700G relay with a built-in generator synchronism-check function (25G). The synchronism-check function is extremely accurate and provides supervision for acceptable voltage window and

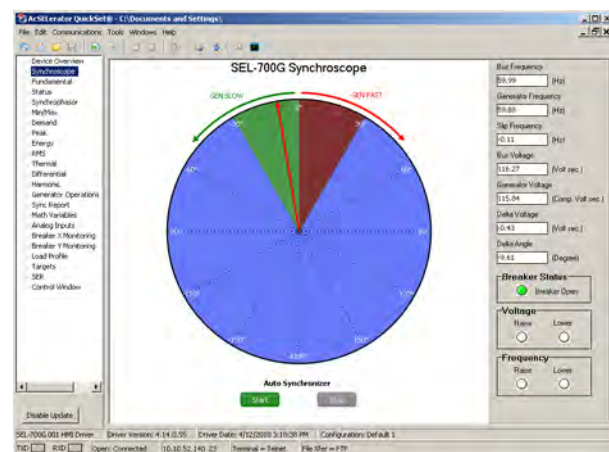
maximum percentage difference, maximum and minimum allowable slip frequency, target closing angle, and breaker closing delay. The synchronism-check report gives complete information on the three latest paralleling operations, including the generator and system voltages and frequencies, slip frequency, and phase angle when the close was initiated. The relay also keeps a running average of the breaker close time.

### Intertie Synchronism Check (25T)

The intertie model of the SEL-700G has the tie synchronism-check function (25T), which provides the closing window for the bus-tie breaker when connecting to the utility system.

### Autosynchronizer

Selected SEL-700G models have the built-in autosynchronizer function, which provides output contact interfaces for the generator field voltage regulator and the prime mover speed control governor. Frequency, voltage, and phase are automatically synchronized and the generator is connected to the power system with this function. The relay also provides generator autosynchronism reports to record the automatic synchronizing event. The generator synchronization process can be viewed on a PC-based synchroscope (see example in *Figure 4*) with ACSELERATOR QuickSet.



**Figure 4 QuickSet Synchroscope**

### 100 Percent Stator Ground Detection (64G)

The SEL-700G detects stator ground faults on high-impedance grounded generators using a conventional neutral-overvoltage element and a third-harmonic voltage differential detection scheme for 100 percent stator winding coverage. The neutral overvoltage element detects winding ground faults in approximately 85 percent of the winding. Faults closer to the generator neutral do not result in high neutral voltage but are detected using third harmonic neutral and terminal volt-

ages. The combination of the two measuring methods provides ground fault protection for the full winding.

Use the SEL-2664S Stator Ground Protection Relay for 100 percent stator ground protection using a multisine signal injection method for a superior solution that is independent of third-harmonic voltage magnitude. This relay works with the generator in or out of service and during generator ramp up without any blind spots.

### Field Ground Protection (64F)

The SEL-700G, with the SEL-2664 Field Ground Module, detects field ground faults by measuring field insulation-to-ground resistance using the switched dc voltage injection method. Two-level protection for alarm and trip functions is provided.

### Directional Power Detection (32)

Sensitive directional power elements in the SEL-700G provide antimotoring and/or low forward power tripping. As many as eight elements (four each for the X side and Y side) for detecting real (Watts) or reactive (VARs) directional power flows, having independent time-delays and sensitivities are provided. Directly trip the generator under loss-of-prime mover conditions to prevent prime movers from motoring, or use low forward power indication as a tripping interlock when an orderly shutdown is required.

### Over-Excitation Protection (24)

The SEL-700G provides one definite-time for alarm and one composite inverse-time volts/hertz element. The composite inverse-time characteristic may be enabled with a two-step definite-time characteristic, a definite/inverse-time characteristic, or a simple inverse-time characteristic. A custom curve option is also available.

### Loss-of-Field Protection (40)

Two offset positive-sequence mho elements detect loss-of-field conditions. Settable time-delays help reject power swings that pass through the machine impedance characteristic. By using the included directional supervision, one of the mho elements can be set to coordinate with the generator minimum excitation limiter and its steady-state stability limit.

### Out-of-Step Protection (78)

SEL-700G relays use a single or a double-blinder scheme, depending on user selection, to detect an out-of-step condition. In addition to the blinders, the scheme uses a mho circle that restricts the coverage of the out-of-step function to the desired extent. Furthermore, both schemes contain current supervision and torque control to supervise the operation of the out-of-step element.

### Negative-Sequence Overcurrent Protection (46)

Negative-sequence current heats the rotor at a higher rate than positive-sequence or ground current. The negative-sequence definite-time element provides alarm for early stages of an unbalanced condition. The inverse time-overcurrent element provides tripping for sustained unbalance conditions to prevent machine damage. The inverse-time negative-sequence element provides industry standard  $(I_2)^2 \cdot t$  protection curves.

### System Backup Protection (21C, 51V, 51C)

The SEL-700G offers you the choice of three methods for performing system backup protection. Compensator distance elements (21C), a voltage-restrained phase time-overcurrent element (51V), and a voltage-controlled phase time-overcurrent (51C) element are all available; you simply enable the element you wish to use.

### Over- and Undervoltage Protection (27, 59)

Phase, phase-to-phase, and positive-sequence undervoltage (27), overvoltage (59), residual overvoltage (59G) and negative-sequence overvoltage (59Q) elements help you create protection and control schemes, such as undervoltage load shedding, or standby generation start/stop commands.

- Phase, and phase-to-phase undervoltage elements operate with the minimum of the measured voltage magnitudes; these elements operate when any single measurement falls below the set thresholds.
- Phase and phase-to-phase overvoltage elements operate with the maximum of the measured voltage magnitudes.
- The positive-sequence undervoltage elements operate when the calculated positive-sequence voltage V1 drops below the set thresholds.
- The positive-sequence overvoltage elements operate when the calculated positive-sequence voltage V1 exceeds the set thresholds.
- The negative-sequence overvoltage elements operate when the calculated negative-sequence voltage V2 exceeds set thresholds.
- The residual-ground voltage element operates when the zero-sequence voltage 3V0 exceeds the setpoint.

All voltage elements provide definite-time delay settings.

### Loss-of-Potential Logic (60LOP)

Relay functions that use phase voltages or symmetrical component voltages rely on valid inputs to make the correct decisions. The LOP logic detects open voltage transformer fuses or other conditions that cause a loss of relay secondary voltage input. The SEL-700G with voltage inputs, includes loss-of-potential logic that

detects one, two, or three potentially blown fuses. This patented logic is unique as it does not require settings and is universally applicable. The LOP feature allows for the blocking of protection elements to add security during fuse failure.

### Breaker Failure Protection (BF)

The SEL-700G offers breaker failure protection for up to two three-pole breakers. Use the breaker failure detection to issue re-trip commands to the failed breaker, or to trip adjacent breakers using the relay's contact output logic or communications-based tripping schemes.

### Inadvertent Energization Detection

Occasionally, the unit breaker for an out-of-service generator is closed inadvertently. The SEL-700G detects this condition using voltage, current, and other supervisory conditions you select through an SELOGIC control equation.

### Frequency Protection (81)

Six levels of over- or underfrequency elements detect abnormal frequency operating conditions. Use the independently time-delayed output of these elements to trip or alarm. Phase undervoltage supervision prevents undesired frequency element operation during start-up, shutdown, and faults, and while the field is de-energized. SEL-700G frequency elements have high accuracy (less than 0.01 Hz).

### Rate-of-Change-of-Frequency Protection (81R)

Four independent rate-of-change-of-frequency elements are provided with individual time delays for use when frequency changes occur, for example, when there is a sudden imbalance between generation and load. They call for control action or switching action such as network decoupling or load shedding. Each element includes logic to detect either increasing or decreasing frequency and above or below nominal frequency.

### Off-Frequency Accumulators

The SEL-700G tracks the total time-of-operation in up to six off-nominal frequency bands. If the off-nominal time of operation exceeds one of the independent time set points, the relay can trip or alarm.

### Thermal Overload Protection (49T)

The SEL-700G thermal element provides generator overload protection based on the thermal model described in IEC standard 60255-8. The model can be biased by ambient temperature if the RTD option is used.

The relay operates a thermal model with a trip value defined by the relay settings and a present heat estimate that varies with time and changing generator current.

### RTD Thermal Protection

When the SEL-700G is equipped with either an optional 10 RTD input expansion card or an external SEL-2600 RTD Module with up to 12 RTD inputs, as many as 12 thermal elements in the relay can be programmed for two levels of thermal protection per element. Each RTD input provides an alarm and trip thermal pickup setting in degrees C, provides open and shorted RTD detection, and is compatible with the following three-wire RTD types:

- PT100 (100 ohm platinum)
- Ni100 (100 ohm nickel)
- Ni120 (120 ohm nickel)
- Cu10 (10 ohm copper)

Additionally, the winding RTDs and the ambient temperature RTD can be configured and used to bias the generator thermal model and thermal protection.

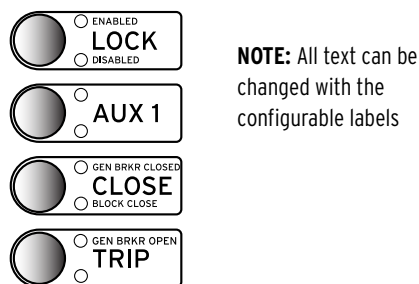
### Additional Ordering Options

You can order the following options for any SEL-700G model (see the Model Option Table for details).

- Single or dual, copper or fiber-optic Ethernet port(s), Modbus TCP, DNP3 serial and DNP3 LAN/WAN, FTP, Telnet
- IEC 61850
- DeviceNet™
- EIA-232 or EIA-485 communications
- Additional EIA-232 or EIA-485 port
- Analog I/O (4 AI/4 AO)
- Digital I/O (4 DI/4 DO, 8 DI, 8 DO, 3 DI/4 DO/1 AO, 4 DI/3DO [2 Form C, 1 Form B])
- Voltage/current input options. See *Table 1*.
- 10 RTDs
- Conformal coating for chemically harsh and high moisture environments

## Operator Controls

Operator controls eliminate traditional panel control switches. Four conveniently sized operator controls are located on the relay front panel (see *Figure 5*). The SER can be set to track operator controls. Change operator control functions using SELOGIC control equations.



**Figure 5** Operator Controls (Shown for the SEL-700G0, SEL-700G1 Models)

The following operator control descriptions are for factory-set logic for the model shown.

**Lock:** The LOCK operator control blocks selected functions. Press it for at least three seconds to engage or disengage the lock function. While locked in position, the following operator controls cannot change state if pressed: TRIP and CLOSE.

**Aux:** The AUX operator control and LEDs are user programmable.

**Close and Trip:** Use the CLOSE and TRIP operator controls to close and open the connected circuit breaker. They can be programmed with intentional time delays to support operational requirements for breaker-mounted relays. This allows the operator to press the CLOSE or TRIP pushbutton, then move to an alternate location before the breaker command is executed.

## Relay and Logic Settings Software

ACSELERATOR QuickSet Software simplifies settings and provides analysis support for the SEL-700G. With ACSELERATOR QuickSet you have several ways to create and manage relay settings:

- Develop settings off-line with an intelligent settings editor that only allows valid settings.
- Create SELOGIC control equations with a drag-and-drop text editor.

- Configure proper settings using online help.
- Organize settings with the relay database manager
- Load and retrieve settings using a simple PC communications link.

With ACSELERATOR QuickSet you can verify settings and analyze events; and analyze power system events with the integrated waveform and harmonic analysis tools.

The following features of ACSELERATOR QuickSet can monitor, commission, and test the SEL-700G:

- The PC interface remotely retrieves power system data.
- The Human-Machine Interface (HMI) monitors meter data, Relay Word bits, and output contacts status during testing. The control window allows resetting of metering quantities, and other control functions.
- The synchroscope screen provides a visual display of the autosynchronizer function.

## Metering and Monitoring

The SEL-700G, depending on the model selected, provides extensive metering capabilities. See *Specifications on page 30* for metering and power measurement accuracies. As shown in *Table 3*, metered quantities include voltages and currents; sequence voltages and

currents; power, frequency, and energy; and maximum/minimum logging of selected quantities. The relay reports all metered quantities in primary quantities (current in A primary and voltage in V primary).

**Table 3 SEL-700G Metered Values**

| Quantities                                                                                                | Description                                                                                                         |
|-----------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| Currents: $IAn$ , $IBn$ , $ICn$ , $IGn$ , $IN$                                                            | Phase currents, calculated residual currents ( $IG = 3I0 = IA + IB + IC$ ) and neutral current, for $n = X$ and $Y$ |
| Voltages: $VAn$ , $VBn$ , $VCn$ , $VN$                                                                    | Wye-connected voltage inputs for $n = X$ and $Y$                                                                    |
| Voltages: $VABn$ , $VBCn$ , $VCAn$                                                                        | Delta-connected voltage inputs for $n = X$ and $Y$                                                                  |
| Voltage $VS$                                                                                              | Synchronism-check voltage input                                                                                     |
| Power $kWAn$ , $Bn$ , $Cn$ , $3Pn$<br>$kVARAn$ , $Bn$ , $Cn$ , $3Pn$<br>$kVAAn$ , $Bn$ , $Cn$ , $3Pn$     | Single and three-phase kilowatts, kilovars, and kilovolt-amps for $n = X$ and $Y$                                   |
| Energy $MWhAn$ , $Bn$ , $Cn$ , $3Pn$<br>$MVARhAn$ , $Bn$ , $Cn$ , $3Pn$<br>$MVAhAn$ , $Bn$ , $Cn$ , $3Pn$ | Single and three-phase real, reactive and apparent energy for $n = X$ and $Y$                                       |
| Power Factor $PFAn$ , $Bn$ , $Cn$ , $3Pn$                                                                 | Single and three-phase power factor for $n = X$ and $Y$                                                             |
| Sequence $I1n$ , $3I2n$ , $3I0n$ , $V1n$ , $3V2n$ , $3V0n$                                                | Positive, negative and zero-sequence currents and voltages for $n = X$ and $Y$                                      |
| Frequency $FREQn$ , $FREQS$ (Hz)                                                                          | Instantaneous power system frequency for $n = X$ and $Y$ and for synchronism-check voltage input $VS$               |
| V/Hz                                                                                                      | Calculated volts/hertz in percent, using highest measured voltage and measured frequency                            |
| $VPX3$ , $VN3$                                                                                            | Phase and neutral third harmonic voltage for stator ground protection                                               |
| Gen TCU %                                                                                                 | Generator thermal capacity used (%)                                                                                 |
| Rf kilohms                                                                                                | Field winding insulation resistance to ground (kilohms)                                                             |
| $RTDn$ ( $n = 1$ to $12$ )                                                                                | RTD temperature measurement (degrees C)                                                                             |

### Types of Metering

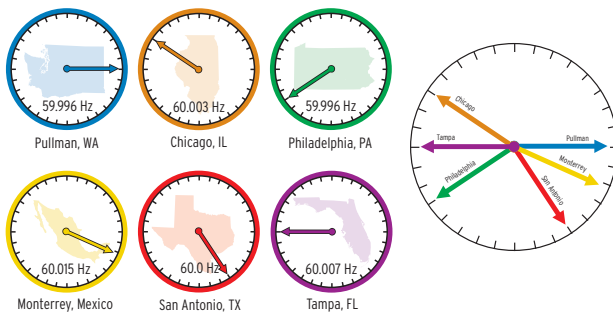
|                                  |                |                |
|----------------------------------|----------------|----------------|
| Instantaneous                    | Differential   | Max/Min        |
| Harmonics (Differential element) | Math variables | Synchrophasors |
| Demand and Peak Demand           | Energy         | RMS            |
| Analog inputs                    | Thermal        |                |

## Synchronized Phasor Measurement

Combine the SEL-700G with an SEL IRIG-B time source to measure the system angle in real time with a timing accuracy of  $\pm 10 \mu\text{s}$ . Measure instantaneous voltage and current phase angles in real time to improve system operation with synchrophasor information. Replace state measurement, study validation, or track system stability. Use SEL-5077 SYNCHROWAVE® Server Software or SEL-5078 SYNCHROWAVE® Console Software to view system angle at multiple locations for precise system analysis and system-state measurement (see Figure 6).

## Load Profile

The SEL-700G features a programmable Load Profile (LDP) recorder that records as many as 17 metering quantities into nonvolatile memory at fixed time intervals. The LDP saves several days to several weeks of the most recent data depending on the LDP settings.



**Figure 6** View of System Angle at Multiple Locations

## Event Reporting

Event Reports and the SER simplify post-fault analysis and improve understanding of simple and complex protective scheme operations. In response to a user-selected trigger, the voltage, current, frequency, and element status information contained in each event report confirms relay, scheme, and system performance for every fault. Decide how much detail is necessary when you request an event report (e.g., 1/4-cycle or 1/32-cycle resolution, filtered or raw analog data).

The relay stores as many as 4 of the most recent 180-cycle, 17 of the most recent 64-cycle, or 72 of the most recent 15-cycle event reports in nonvolatile memory. The relay always appends relay settings to the bottom of each event report.

The following analog data formats are available:

- 1/4-cycle or 1/32-cycle resolution
- Unfiltered or filtered
- ASCII or Compressed ASCII

The types of event reports available are:

- Analog data (**EVE** command)
- Digital data (**EVE D** command)
- Differential (**EVE DIF** command)
- Stator ground (**EVE GND** command)
- Synchronism-check (**SYN** command)
- Generator Autosynchronism (**CGSR** command)
- Generator Operating Statistics (**GEN** command)
- SER (**SER** command)

The relay SER feature stores the latest 1024 entries. Use this feature to gain a broad perspective at a glance. An SER entry helps to monitor input/output change-of-state occurrences and element pickup/dropout. The IRIG-B time-code input synchronizes the SEL-700G time to within  $\pm 5 \text{ ms}$  of the time-source input. A convenient source for this time code is the SEL-2401 Satellite-Synchronized Clock or the SEL-2032, SEL-2030, or SEL-2020 Communications Processor (via Serial Port 2 or 3 on the SEL-700G).

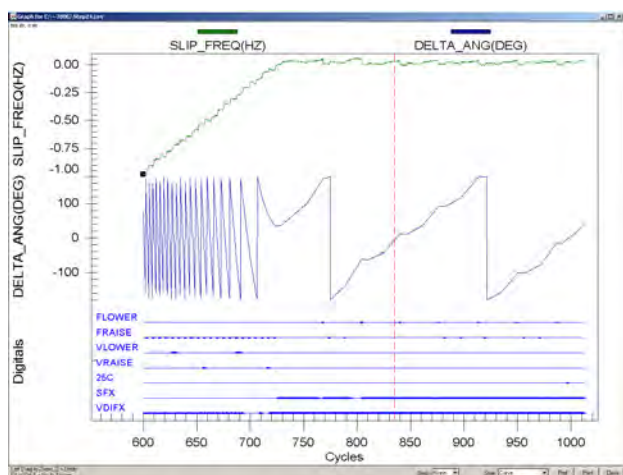
## Generator Operating Statistics Monitoring

The SEL-700G relay having generator elements, tracks the performance and utilization of the protected generator by tracking the following generator operating statistics.

- Total generator running hours
- Total generator stopped hours
- Generator full load hours
- Percent of time running
- Accumulated generator  $I_2^2 \cdot t$
- Average real and reactive power outputs
- Average power factor

## Generator Autosynchronism Report

The SEL-700G with the autosynchronism function generates a generator autosynchronism report with all the relevant analog and digital signals for a quick analysis of the event. The sample rate can be selected between 0.25, 1, and 5 cycles. The report captures 4800 time-stamped data points.



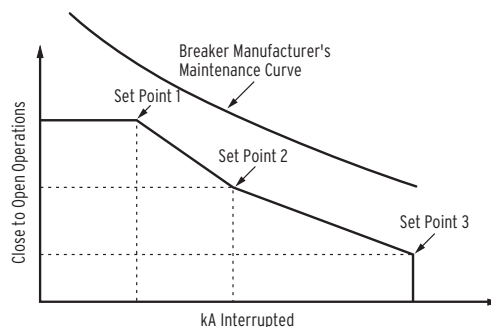
**Figure 7 Graphical Display of Generator Synchronizer Report**

### Circuit Breaker Monitor

Circuit breakers experience mechanical and electrical wear every time they operate. Intelligent scheduling of breaker maintenance takes into account manufacturer's published data of contact wear versus interruption levels

and operation count. With the breaker manufacturer's maintenance curve as input data, the SEL-700G breaker monitor feature compares this input data to the measured (unfiltered) ac current at the time of trip and the number of close-to-open operations. Every time the breaker trips, it integrates the measured current information.

When the result of this integration exceeds the breaker wear curve threshold (*Figure 8*) the relay alarms via output contact, communications port, or front-panel display. This kind of information allows timely and economical scheduling of breaker maintenance.



**Figure 8 Breaker Contact Wear Curve and Settings**

## Automation

### Flexible Control Logic and Integration

The SEL-700G is equipped with as many as four independently operated serial ports: one EIA-232 port on the front, one EIA-232 or EIA-485 port on the rear, and one fiber-optic port. Additionally, the SEL-700G has one EIA-232 or EIA-485 port option card. Optionally, the relay supports single or dual, copper or fiber-optic Ethernet ports. The relay does not require special

communications software. You can use any system that emulates a standard terminal system. Establish communication by connecting: computers; modems; protocol converters; printers; an SEL-2032, SEL-2030 or SEL-2020 Communications Processor; SCADA serial port; and RTUs for local or remote communication. Refer to *Table 4* for a list of communications protocols available in the SEL-700G.

**Table 4 Communications Protocols (Sheet 1 of 2)**

| Type                                 | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|--------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Simple ASCII                         | Plain language commands for human and simple machine communications. Use for metering, setting, self-test status, event reporting, and other functions.                                                                                                                                                                                                                                                                                                                                  |
| Compressed ASCII                     | Comma-delimited ASCII data reports. Allows external devices to obtain relay data in an appropriate format for direct import into spreadsheets and database programs. Data are checksum protected.                                                                                                                                                                                                                                                                                        |
| Extended Fast Meter and Fast Operate | Binary protocol for machine-to-machine communications. Quickly updates SEL communications processors, RTUs, and other substation devices with metering information, relay 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 control operator metering information is not lost while a technician is transferring an event report. |
| Fast SER Protocol                    | Provides SER events to an automated data collection system.                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Modbus                               | Serial- or Ethernet-based Modbus with point remapping. Includes access to metering data, protection elements, contact I/O, targets, SER, relay summary event reports, and setting groups.                                                                                                                                                                                                                                                                                                |
| DNP3                                 | Serial or Ethernet-based DNP3 protocols. Provides default and mappable DNP3 objects that include access to metering data, protection elements, Relay Word bits, contact I/O, targets, SER, relay summary event reports, and setting group selection.                                                                                                                                                                                                                                     |

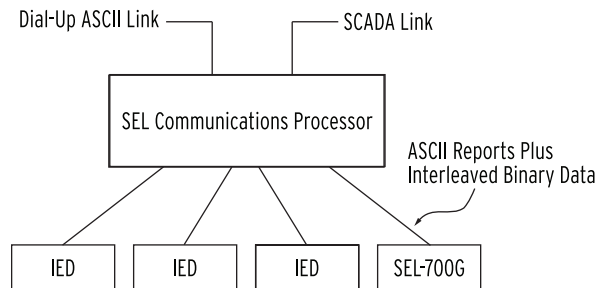
**Table 4 Communications Protocols (Sheet 2 of 2)**

| Type            | Description                                                                                                                                                                           |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| IEC 61850       | Ethernet-based international standard for interoperability between intelligent devices in a substation. Operates remote bits and I/O. Monitors Relay Word bits and analog quantities. |
| Synchrophasors  | IEEE C37.118-compliant synchrophasors for system state, response, and control capabilities.                                                                                           |
| Event Messenger | The SEL-3010 allows users to receive alerts sent directly to their cell phone. Alerts can be triggered through relay events and can include quantities measured by the relay.         |
| DeviceNet       | Allows for connection to a DeviceNet network for access to metering data, protection elements, contact I/O, targets, and setting groups.                                              |
| SNTP            | Ethernet-based protocol that provides time synchronization of the relay.                                                                                                              |

Apply an SEL communications processor as the hub of a star network, with point-to-point fiber or copper connection between the hub and the SEL-700G (Figure 9).

The communications processor supports external communications links including the public switched telephone network for engineering access to dial-out alerts and private line connections of the SCADA system.

SEL manufactures a variety of standard cables for connecting this and other relays to a variety of external devices. Consult your SEL representative for more information on cable availability.

**Figure 9 Example Communications System**

SEL-700G control logic improves integration in the following ways:

- **Replaces traditional panel control switches.** Eliminate traditional panel control switches with 32 local bits. Set, clear, or pulse local bits with the front-panel pushbuttons and display. Program the local bits into your control scheme with SELOGIC control equations. Use the local bits to perform functions such as a trip test or a breaker trip/close.
- **Eliminates RTU-to-relay wiring.** Eliminate RTU-to-relay wiring with 32 remote bits. Set, clear, or pulse remote bits using serial port commands. Program the remote bits into your control scheme with SELOGIC control equations. Use remote bits for SCADA-type

control operations such as trip, close, and settings group selection.

- **Replaces traditional latching relays.** Replace up to 32 traditional latching relays for such functions as “remote control enable” with latch bits. Program latch set and latch reset conditions with SELOGIC control equations. Set or reset the nonvolatile latch bits using optoisolated inputs, remote bits, local bits, or any programmable logic condition. The latch bits retain their state when the relay loses power.
- **Replaces traditional indicating panel lights.** Replace traditional indicating panel lights with 32 programmable displays. Define custom messages (e.g., Breaker Open, Breaker Closed) to report power system or relay conditions on the front-panel display. Use Advanced SELOGIC control equations to control which messages the relay displays.
- **Eliminates external timers.** Eliminate external timers for custom protection or control schemes with 32 general purpose SELOGIC control equation timers. Each timer has independent time-delay pickup and dropout settings. Program each timer input with any desired element (e.g., time qualify a current element). Assign the timer output to trip logic, transfer trip communications, or other control scheme logic.
- **Eliminates settings changes.** Selectable setting groups make the SEL-700G ideal for applications requiring frequent setting changes and for adapting the protection to changing system conditions.

The relay stores three setting groups. Select the active setting group by optoisolated input, command, or other programmable conditions. Use these setting groups to cover a wide range of protection and control contingencies.

Switching setting groups switches logic and relay element settings. Program groups for different operating conditions, such as station maintenance, seasonal operations, emergency contingencies, loading, source changes, and downstream relay setting changes.

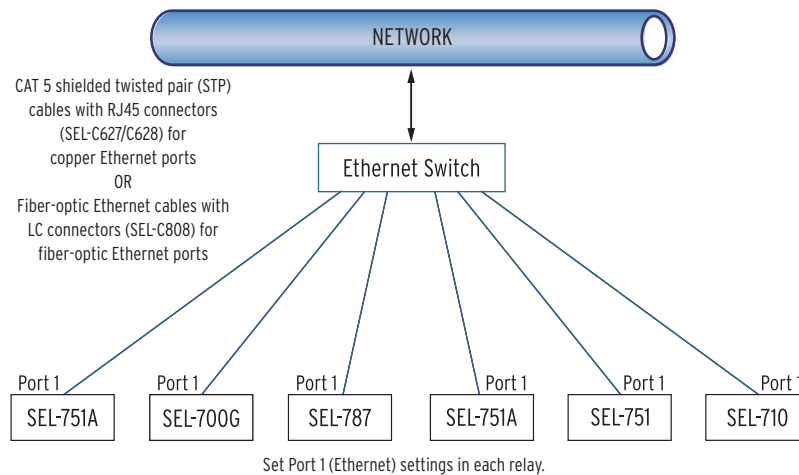
## Fast SER Protocol

SEL Fast SER Protocol provides SER events to an automated data collection system. SEL Fast SER Protocol is available on any rear serial port. Devices with embedded processing capability can use these messages to enable and accept unsolicited binary SER messages from SEL-700G relays.

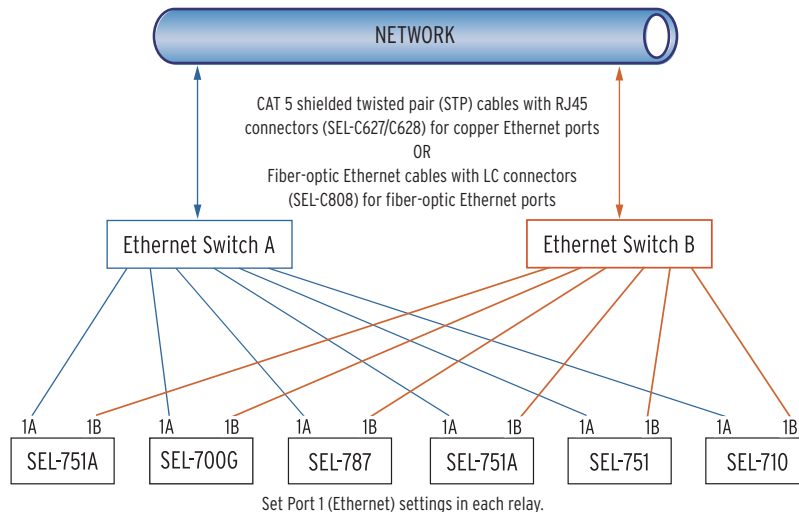
SEL relays and communications processors have two separate data streams that share the same serial port. The

normal serial interface consists of ASCII character commands and reports that are intelligible to people using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information, and then allow the ASCII data stream to continue. This mechanism allows a single communications channel to be used for ASCII communications (e.g., transmission of a long event report) interleaved with short bursts of binary data to support fast acquisition of metering or SER data.

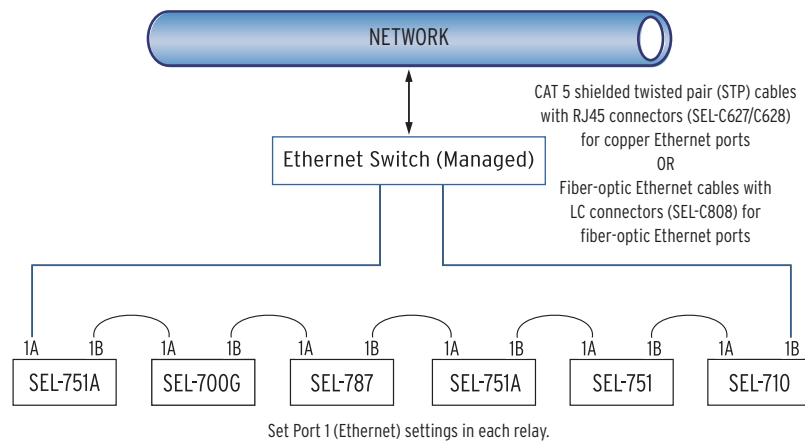
## Ethernet Network Architectures



**Figure 10 Simple Ethernet Network Configuration**



**Figure 11 Simple Ethernet Network Configuration With Dual Redundant Connections (Failover Mode)**



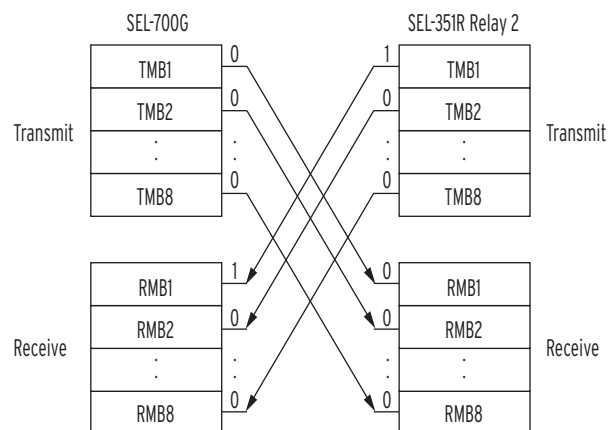
**Figure 12 Simple Ethernet Network Configuration With Ring Structure (Switched Mode)**

## Additional Features

### MIRRORED BITS Relay-to-Relay Communications

The SEL-patented MIRRORED BITS communications technology provides bidirectional relay-to-relay digital communications. MIRRORED BITS can operate independently on as many as two EIA-232 rear serial ports and one fiber-optic rear serial port on a single SEL-700G.

This bidirectional digital communication creates eight additional virtual outputs (transmitted MIRRORED BITS) and eight additional virtual inputs (received MIRRORED BITS) for each serial port operating in the MIRRORED BITS mode (see *Figure 13*). Use these MIRRORED BITS to transmit/receive information between upstream relays and a downstream relay to enhance coordination and achieve faster tripping for downstream faults. MIRRORED BITS technology also helps reduce total scheme operating time by eliminating the need to assert output contacts to transmit information.



**Figure 13 MIRRORED BITS Transmit and Receive Bits**

### Status and Trip Target LEDs

The SEL-700G includes 16 status and trip target LEDs on the front panel. When shipped from the factory, all LEDs are predefined and fixed in settings. You can reprogram these LEDs for specific applications. This combination of targets is explained and shown in *Figure 23*. Some front-panel relabeling of LEDs may be needed if you reprogram them for unique or specific applications—see *Configurable Labels*.

### Event Messenger Points

The SEL-700G, when used with the SEL-3010 Event Messenger, can allow for ASCII-to-voice translation of as many as 32 user-defined messages, along with analog data that have been measured or calculated by the relay. With this combination, you can receive voice messages on any phone for alerts to transition of any Relay Word bits in the relay.

Verbal notification of breaker openings, fuse failures, RTD alarms, etc. can now be sent directly to your cell phone through the use of your SEL-700G and SEL-3010 (must be connected to an analog telephone line). In addition, messages can include an analog value such as current, voltage, or power measurements made by the SEL-700G.

## Configurable Labels

Use the configurable labels to relabel the operator controls and LEDs (shown in *Figure 23*) to suit the installation requirements. This feature includes preprinted labels (with factory default text), blank label media, and a Microsoft® Word template on CD-ROM. This allows quick, professional-looking labels for the SEL-700G. Labels

may also be customized without the use of a PC by writing the new label on the blank stock provided. The ability to customize the control and indication features allows specific utility or industry procedures to be implemented without the need for adhesive labels. All of the figures in this data sheet show the factory default labels of the SEL-700G, including the standard model shown in *Figure 23*.

## Guideform Specification

The microprocessor-based relay shall provide a combination of functions including protection, monitoring, control, and automation. Relay self-checking functions shall be included. Specific requirements follow.

### Protection and Control–SEL-700G0, SEL-700G1 Generator Protection Relays

The relay shall provide protection over the operating frequency range of 15–70 Hz. Protection and control functions shall include the following:

- Two-zone, positive-sequence impedance mho element for loss-of-field detection (40)
- 100% stator ground fault detection based on measurement of neutral overvoltage plus neutral and terminal third-harmonic voltage differential with settable sensitivity (64G)
- DC field ground protection (64F) based on switched dc voltage injection method (requires SEL-2664 Field Ground Module)
- Out-of-step protection based on single or double blinders (78)
- Overexcitation detection based on volts/hertz measurement. One definite-time and a composite definite/inverse-time element shall be provided together with a custom curve element (24)
- Negative-sequence overcurrent elements, including definite-time and inverse-time operating characteristics (46)
- As many as eight (four each for the X side and Y side) sensitive directional power elements with flexibility to provide antimotoring, over-power, or low-forward power indication (32)
- Two-zone compensator distance and voltage-restrained or voltage-controlled phase time-overcurrent element for backup protection (21/51V/51C)
- Phase, residual, neutral, and negative-sequence instantaneous and definite time-overcurrent; and inverse-time residual and neutral overcurrent elements (50P, G, N, Q/51N, G)
- Restricted earth fault (REF) protection element for the detection of ground faults in wye-connected windings
- Directional residual-ground overcurrent elements (67G)

- Directional neutral overcurrent elements (67N)
- Phase, phase-to-phase, positive-sequence, negative-sequence, and residual overvoltage elements (59P, PP, V1, Q, G), phase, phase-to-phase, and positive-sequence undervoltage (27P, PP, V1) elements, and synchronism-check voltage input over- and undervoltage (59S, 27S) elements
- Inadvertent energization protection (50/27)
- Unit breaker failure protection (BF)
- Supervision of voltage-based protection functions by loss-of-relaying-potential detection logic (60LOP)
- Over- and underfrequency elements (81) and rate-of-change-of-frequency elements (81R)
- Percentage restraint and unrestrained phase current differential elements (87) with fixed or variable percentage, using one or two settable slopes. Second-, fourth-, and fifth-harmonic elements, with the choice of either harmonic blocking or harmonic restraint to prevent restrained differential element operation during inrush or overexcitation conditions
- Ground differential element (87N)
- Full “round-the-clock” current compensation, in 30-degree increments, to accommodate virtually any type of transformer/generator and CT winding connection
- Synchronism-check (25) element and auto-synchronizer with speed control and voltage control outputs
- Thermal model element (49T) for overload protection and RTD-based thermal protection

### Protection and Control–SEL-700GT Intertie or Intertie and Generator Protection Relay

The relay shall provide protection over the operating frequency range of 15–70 Hz. Protection and control functions shall include the following:

#### Intertie

- Phase, residual, and negative-sequence instantaneous and definite-time overcurrent elements (50P, G, Q)
- Phase, residual, and negative-sequence directional overcurrent elements (67P, G, Q)

- Phase, residual, and negative-sequence inverse-time overcurrent elements (51P, G, Q)
- Breaker failure protection (BF)
- Phase, phase-to-phase, negative-sequence, and residual overvoltage elements (59P, PP, Q, G), phase and phase-to-phase undervoltage (27P, PP) elements, and synchronism-check over- and undervoltage (59S, 27S) elements
- Tie synchronism-checking element (25)
- Directional power elements (32)
- Over- and underfrequency elements (81) and rate-of-change-of-frequency elements (81R)
- Supervision of voltage-based protection functions by loss-of-relaying-potential detection logic (60LOP)
- RTD-based thermal protection

#### Generator

Same protection as SEL-700G0, -1 above without 87, 21, 64G, and 78 elements.

### Protection and Control–SEL-700GW Wind Generator Protection Relay

The relay shall provide protection over the operating frequency range of 15–70 Hz. Protection and control functions shall include the following:

- Two sets of phase, residual, and negative-sequence overcurrent elements (instantaneous and definite-time delay)
- Two sets of phase, residual, and negative-sequence inverse-time overcurrent elements (51P, G, Q)
- Two breaker failure protection (BF) elements
- DC field ground protection (64F) based on switched dc voltage injection method (requires SEL-2664 Field Ground Module)
- RTD-based thermal protection

#### Temperature Inputs

The relay shall have the following features when equipped with as many as 12 RTD inputs in an external module (SEL-2600 with ST<sup>®</sup> connectors option) or 10 RTD inputs with an internal card:

- Optical fiber transmission of RTD temperatures (using SEL-2600 series) to relay: range as far as 1000 m
- Separately field-selected RTD types: PT100, NI100, NI120, or CU10
- Noise immunity (50 Hz and higher) on RTD inputs up to 1.4 Vac<sub>peak</sub>
- One contact input (with SEL-2600 series)

### Automation

The relay shall provide the following logic and control functions:

- 32 local control logic points, 32 remote control logic points, 32 latching logic points, 32 counters, 32 math variables, 32 logic variables, and 32 timers
- SELOGIC control equations with Boolean and math equations capability for logic and control

### Communications/Integration

The relay shall provide the following communications options:

- ASCII, MIRRORED BITS<sup>®</sup>, Event Messenger, Modbus<sup>®</sup> RTU, DeviceNet<sup>™</sup>, Telnet, FTP, SNTP (Simple Network Time Protocol), Modbus<sup>®</sup> TCP, DNP LAN/WAN or serial, IEEE C37.118 (synchrophasor data), and IEC 61850 protocols
- One front-panel EIA-232 port and one rear-panel EIA-232 or EIA-485 port, one fiber-optic serial port, and an optional single or dual copper or fiber-optic Ethernet port
- Capability for an additional rear-panel EIA-232 or EIA-485 port
- Windows<sup>®</sup>-based PC software for settings, report retrieval, and synchroscope

### Synchronized Phasor Measurements

- The relay shall provide high-accuracy ( $\pm 10 \mu\text{s}$  or better) phasor measurements for voltages and currents if an IRIG-B signal is available.
- The relay shall provide a selectable synchrophasor data update rate of 1–50 or 60 times per second (depending on nominal frequency).

### Front-Panel Visualization

- The front panel shall be capable of displaying measured values, calculated values, I/O status, device status, and configuration parameters on a front-panel LCD display.
- The display shall have a rotating capability to display custom messages and data. Thirty-two display messages shall be provided.
- The front panel shall also have a minimum of six user-programmable LEDs and four user-programmable pushbutton controls with eight programmable LEDs.

## Monitoring and Reporting

**Load-Profile Monitoring.** Provides periodic snapshot (selectable rate from every 5 to 60 minutes) of as many as 17 selectable analog quantities.

**Metering.** The relay shall include metering capabilities (model dependent) for real-time current, voltage, power, energy quantities, volts/Hz, and differential quantities, as well as phase demand and peak demand current values. Harmonic content from the fundamental to the fifth harmonic for all ac current inputs shall be included. Thermal metering, synchrophasor data metering, differential metering, rms metering, demand metering, and minimum/maximum metering shall also be included.

**Event Summaries.** Fault type and trip data, including time of tripping.

**Event Reports.** 15-cycle length (as many as 72 reports), 64-cycle length (as many as 17 reports), or 180-cycle length (as many as 4 reports) with 4 or 32 raw or filtered samples/cycle resolution.

**Generator Autosynchronism Reports.** As many as 5 generator synchronism reports (0.25, 1, or 5 cycle resolution), each with as many as 4800 time-stamped samples.

**Sequential Events Recorder (SER).** As many as 1024 time-tagged, most recent input, output, and element transitions.

**Settings, Event Report, and SER Data.** Stored in non-volatile, Flash memory.

## Hardware

- Operating temperature range of  $-40^{\circ}$  to  $+85^{\circ}\text{C}$
- Power supply input operating voltage range of 24/48 Vdc, 125/250 Vdc, or 120/240 Vac

- Demodulated IRIG-B time-synchronization input capability
- Optional 10 internal RTD inputs or 12 external RTD inputs
- 5 A or 1 A, as many as 7 ac current inputs (IAX, IBX, ICX, IAY, IBY, ICY, and optional IN input)
- 300 V maximum, as many as 7 ac voltage inputs (VAX, VBX, VCX, VN, VS, VAY, VBY, VCY)
- Flexible, configurable I/O, including digital I/O and analog I/O
- Electromechanical or fast, high current interrupting (optional) digital outputs
- Optoisolated digital inputs
- Jumper-selectable current (up to  $\pm 20$  mA range) or voltage (up to  $\pm 10$  V range) analog inputs
- Jumper selectable current (up to  $\pm 20$  mA range) or voltage (up to  $\pm 10$  V range) analog outputs
- Relay front panel shall meet the requirements of NEMA 12/IP65
- Class I, Division 2 hazardous locations applications

## Service and Support

**Reliability.** The vendor shall supply the actual measured mean time between failures (MTBF) for the device upon request.

**Manufacturer.** The device shall be manufactured in the U.S.A.

**Conformal Coating.** The device shall have optional conformal coating to protect the circuit boards from harsh environments.

**Warranty.** The device shall include a ten-year, no-questions-asked warranty for all material and workmanship defects. In addition, the warranty shall cover accidental customer-induced damage.

## Dimensions

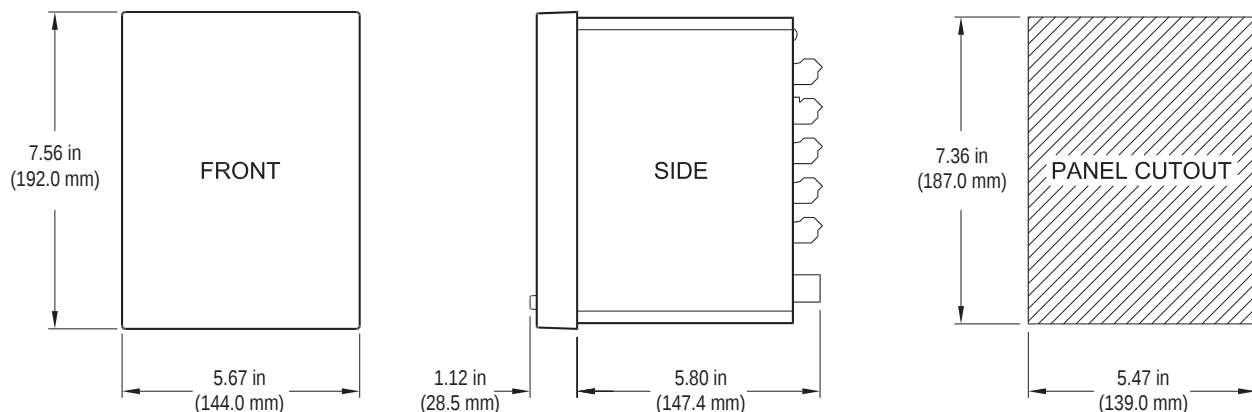
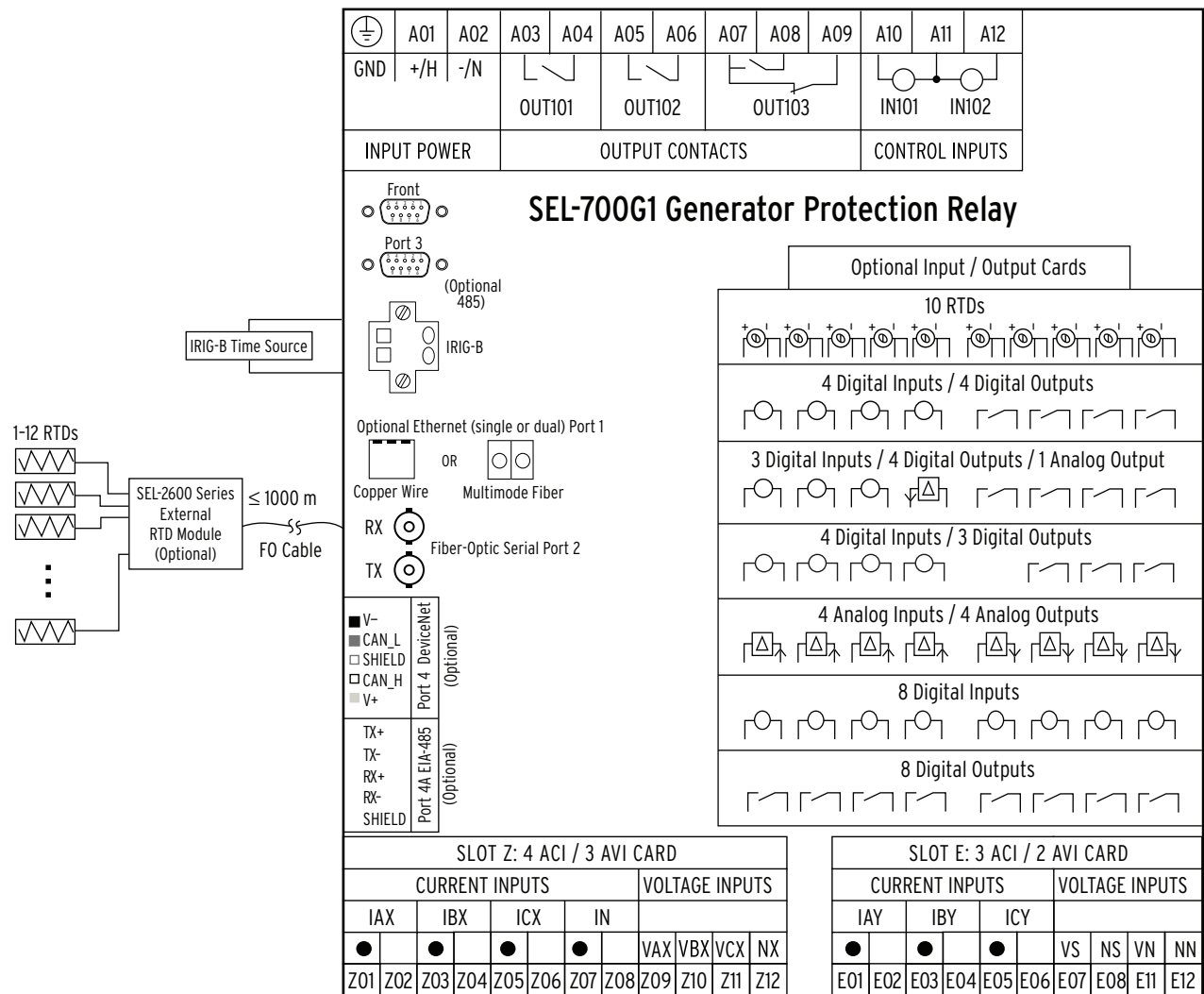


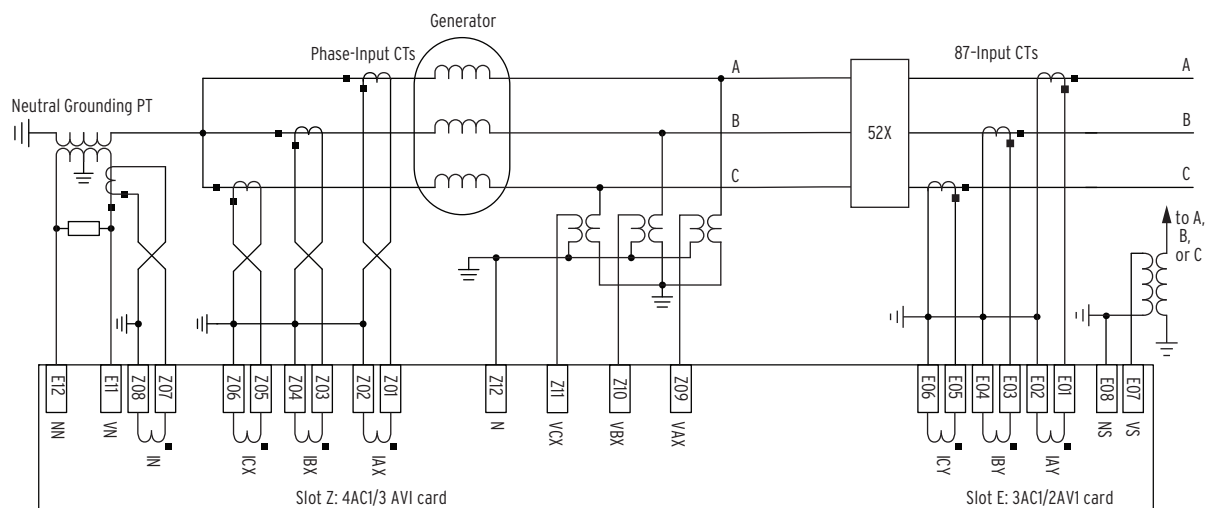
Figure 14 SEL-700G Dimensions for Rack- and Panel-Mount Models

# Hardware Overview

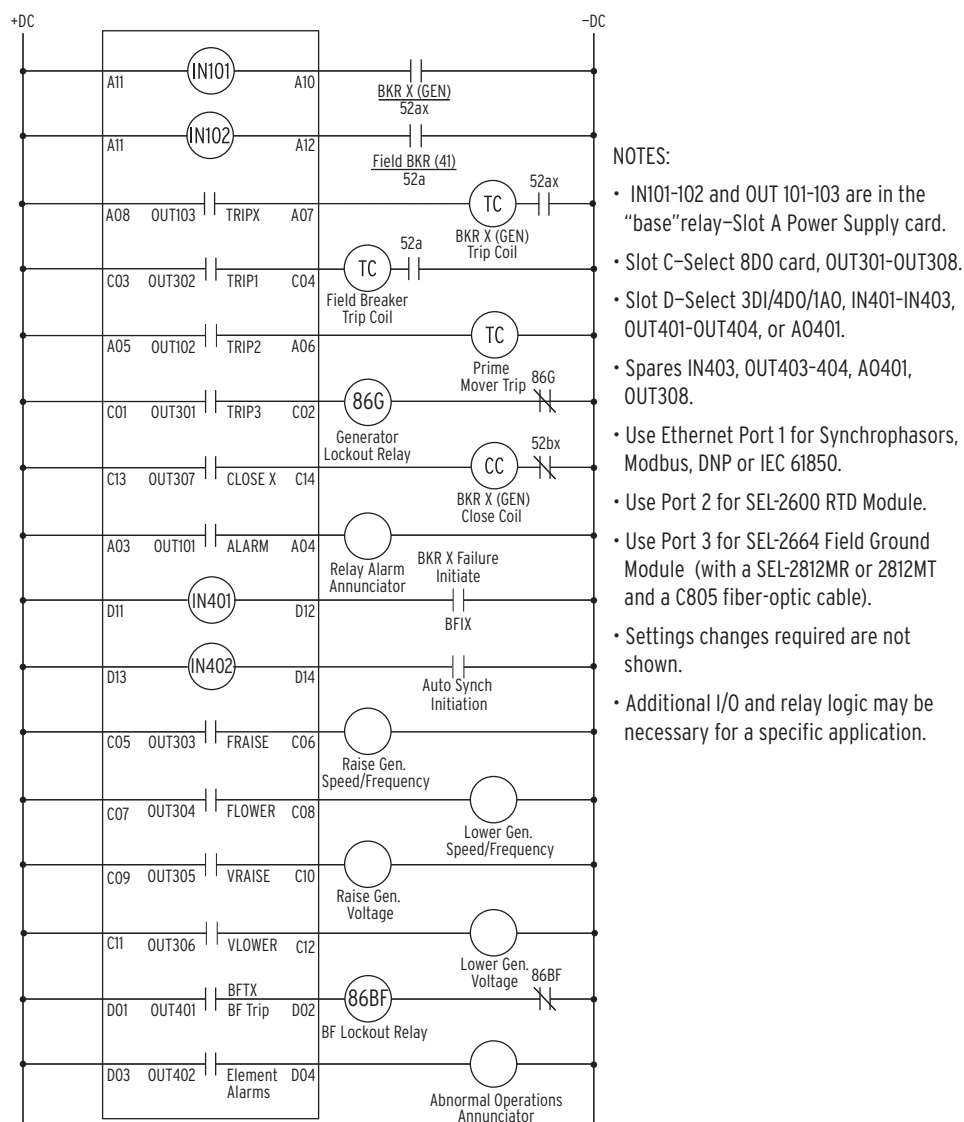


**Figure 15 Typical Connection Diagram**

## SEL-700G1 Generator Relay Applications—Example 1

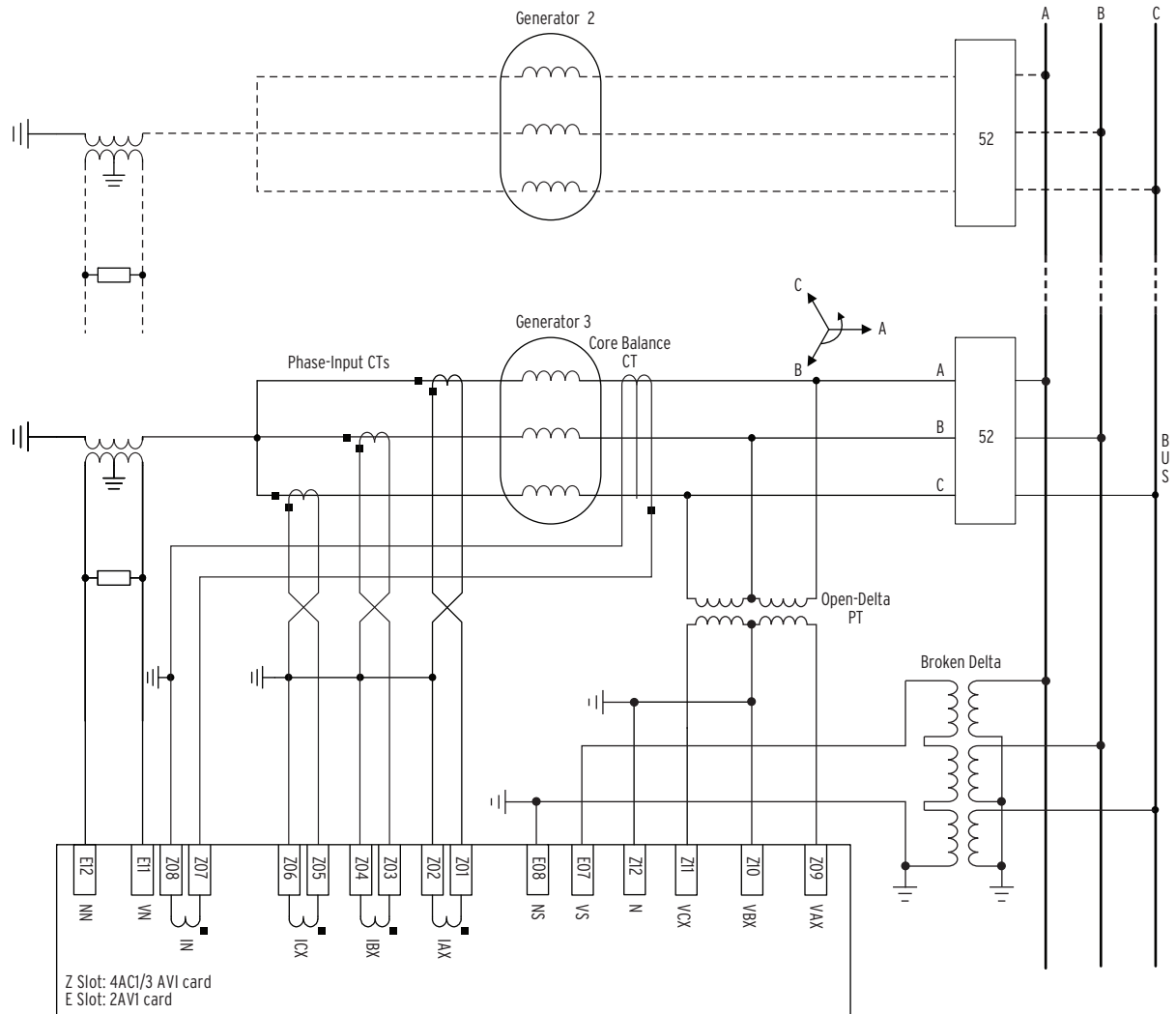


**Figure 16 SEL-700G1 Relay Typical AC Current and Four-Wire Wye Voltage Connection**



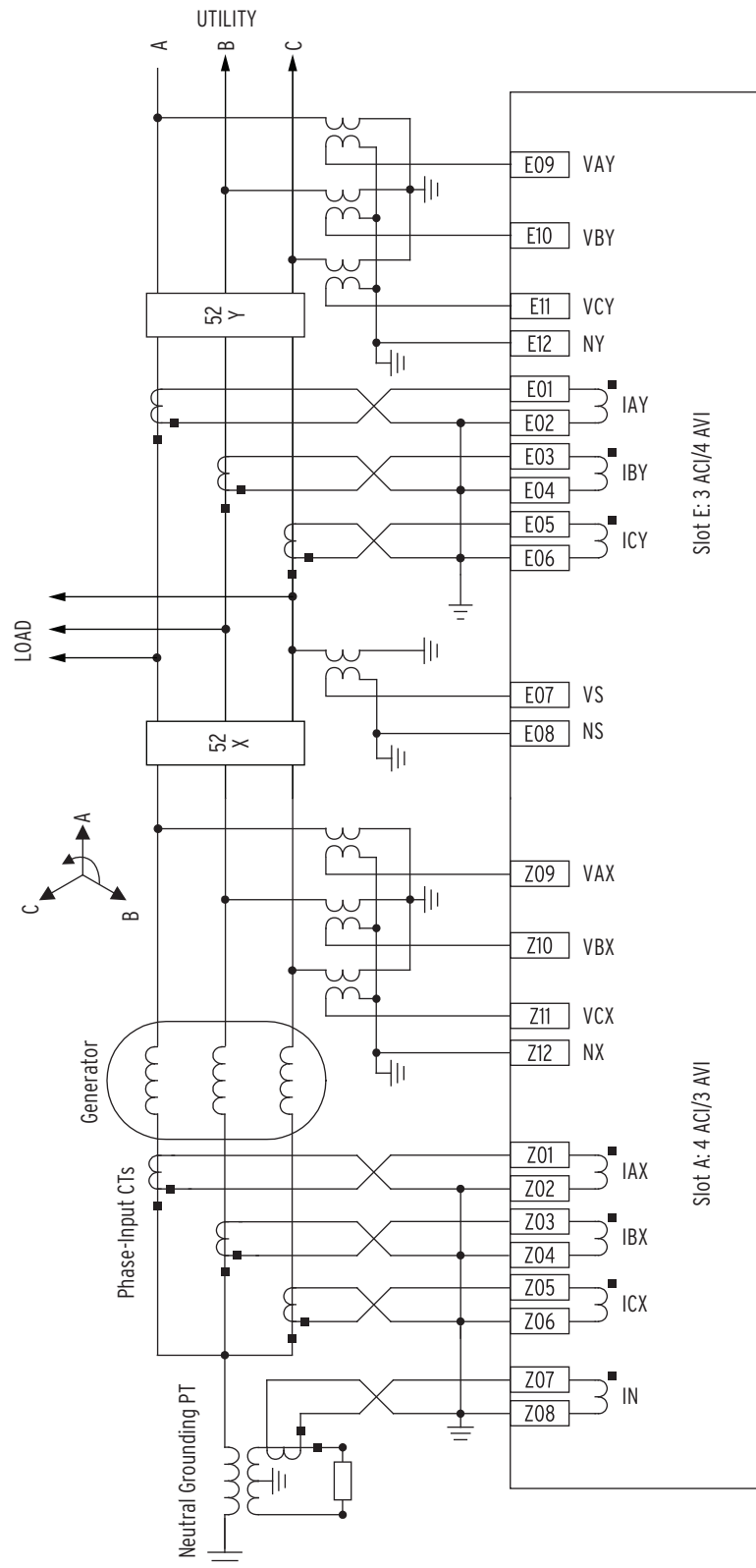
**Figure 17 SEL-700G1 Typical DC External Connections**

## SEL-700G1 Generator Relay Applications—Example 2

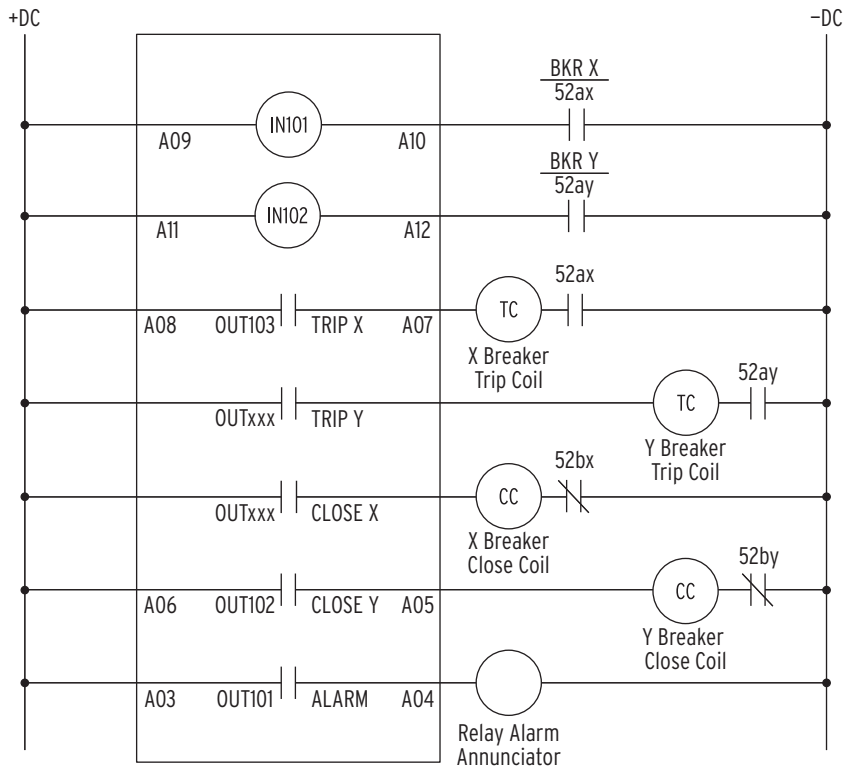


**Figure 18 SEL-700G1+ Relay AC Connection Example, Multiple High-Impedance Grounded Generators Connected to a Common Bus, With 67N and Other Protection**

# SEL-700GT Intertie Relay Applications



**Figure 19 SEL-700GT Relay Typical AC Current and Four-Wire Wye Voltage Connection**

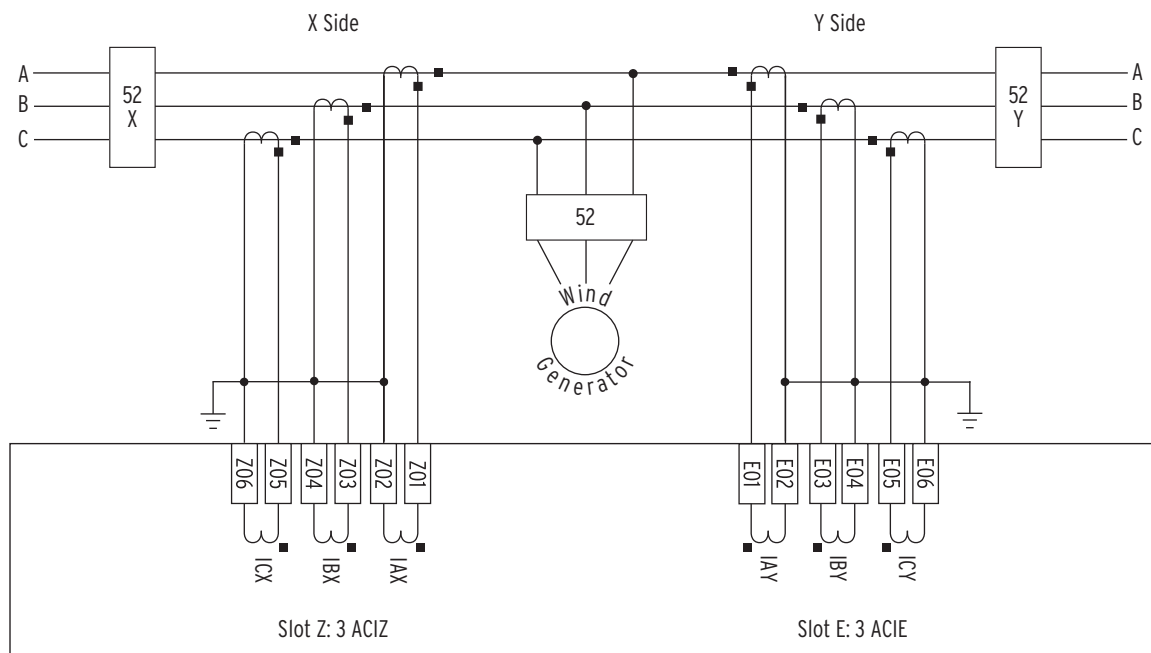


**Figure 20 SEL-700GT Typical DC External Connections**

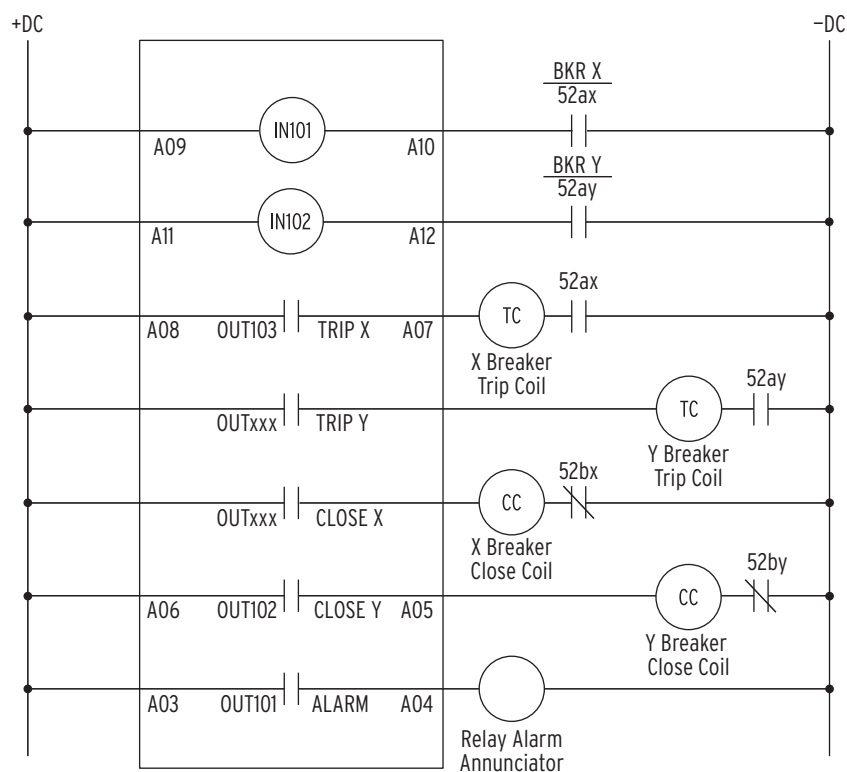
**NOTES:**

- OUTxxx requires an additional I/O card in Slot C or D.
- IN101-102 and OUT 101-103 are in the "base" relay.
- Additional I/O and relay logic may be necessary for a specific application.
- Settings changes are not shown.
- RTD Inputs—requires SEL-2600 RTD Module or RTD input card in Slot D.

## SEL-700GW Wind Generator Relay Applications



**Figure 21 SEL-700GW Dual Feeder AC Current Connections**



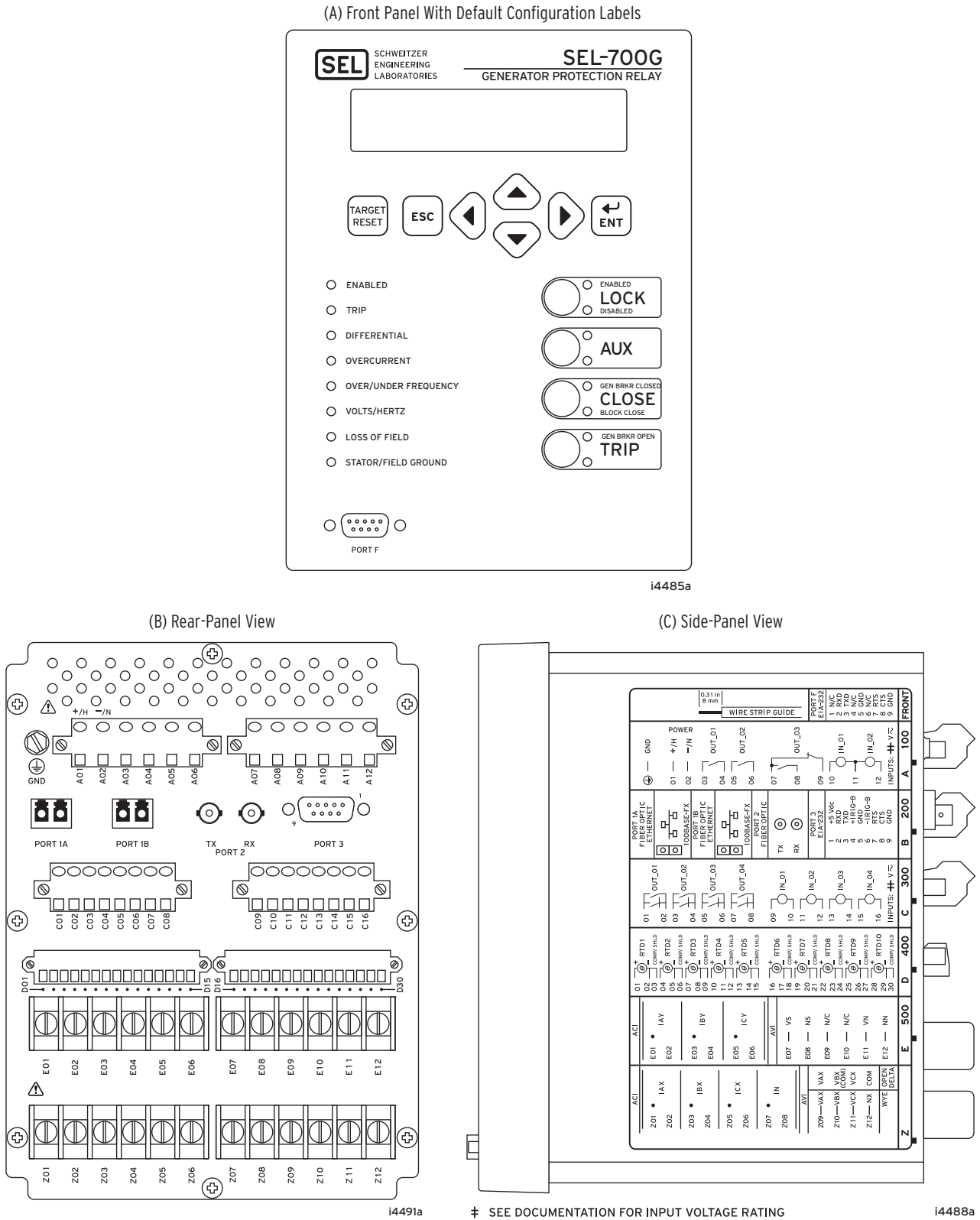
**Figure 22 SEL-700GW Typical DC External Connections**

### NOTES:

- OUTxxx requires an additional I/O card in Slot C or D.
- IN101-102 and OUT 101-103 are in the "base" relay.
- Additional I/O and relay logic may be necessary for a specific application.
- Settings changes are not shown.
- Field ground element (64F) requires SEL-2664 Field Ground Module.
- RTD Inputs—requires SEL-2600 RTD Module or RTD input card in Slot D.

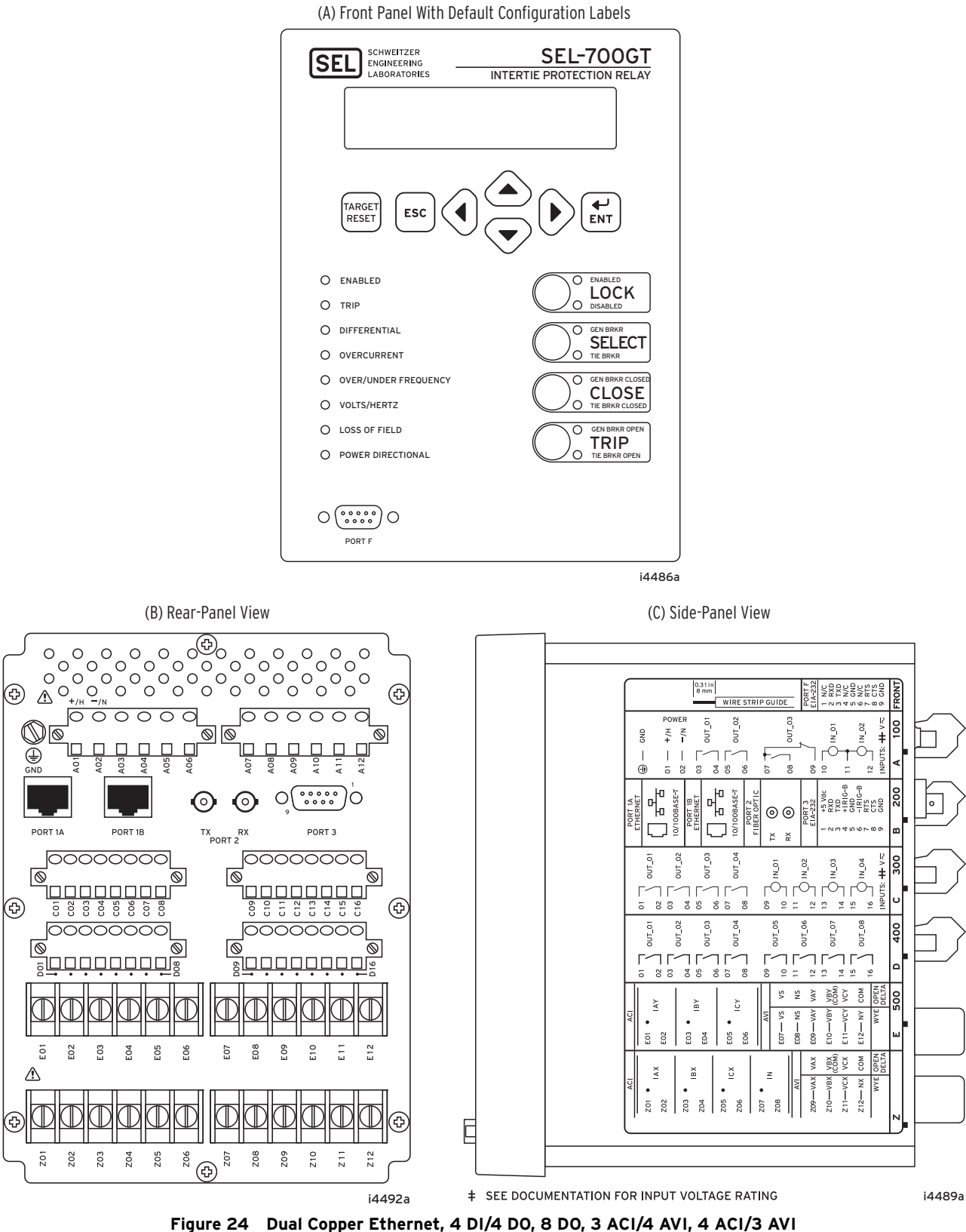
# SEL-700G1 Generator Relay Panel Diagrams

0700G11ACA9X76850830



# SEL-700GT Intertie Relay Panel Diagrams

0700GT1A2X75850630



# SEL-700GW Wind Generator Relay Panel Diagrams

0700GW1A1A6X77870310

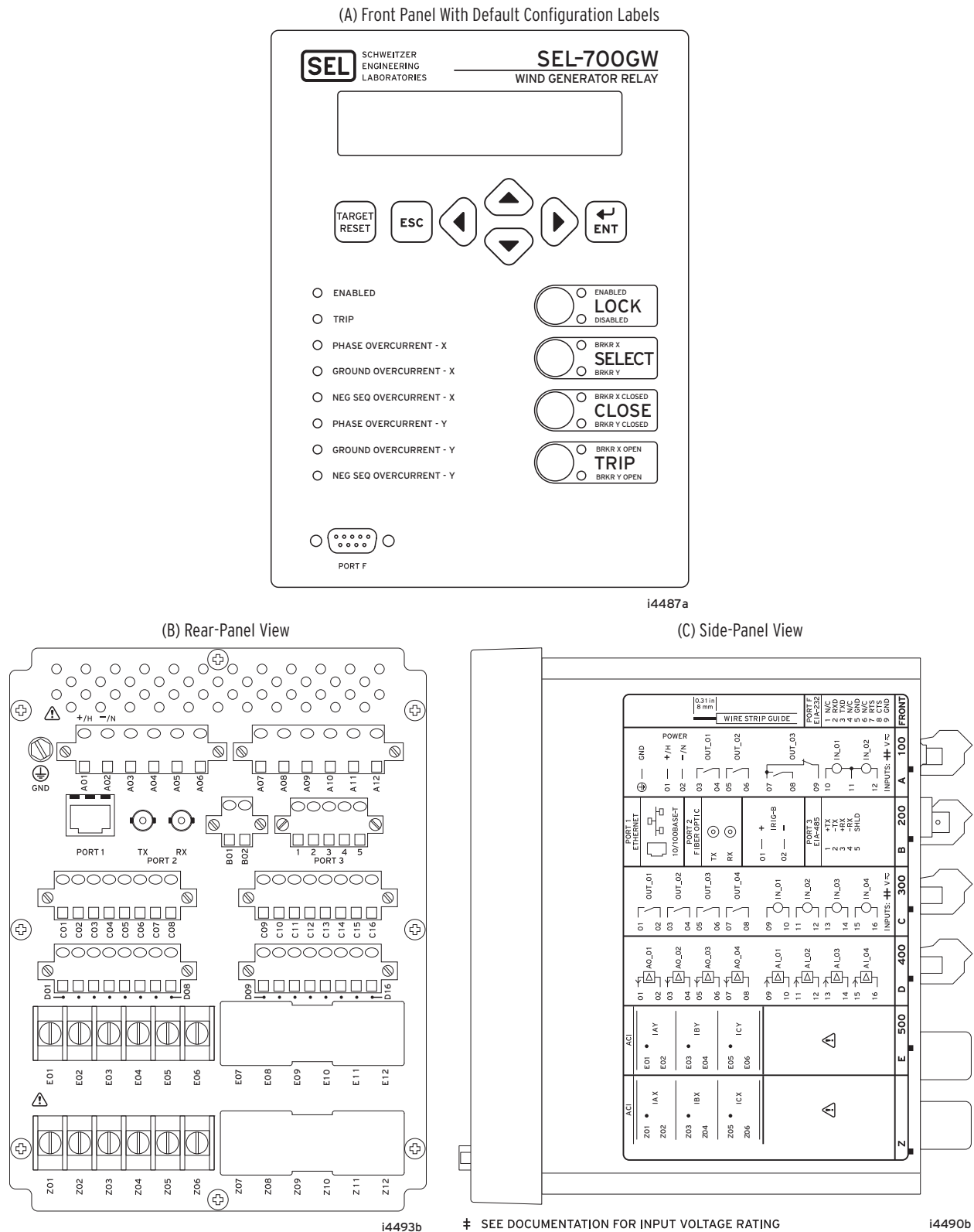


Figure 25 Copper Ethernet, 4 DI/4 DO, 4 AI/4 AO, 3 ACIE, 3 ACIZ

# Specifications

## Compliance

|                                |                                                                                                                     |
|--------------------------------|---------------------------------------------------------------------------------------------------------------------|
| ISO 9001:2008 Certified        |                                                                                                                     |
| UL, cUL:                       | Protective Relay Category NRGU, NRGU7 per UL 508, C22.2 No. 14                                                      |
| CE:                            | CE Mark-EMC Directive<br>Low Voltage Directive<br>IEC 61010-1:2001<br>IEC 60947-1<br>IEC 60947-4-1<br>IEC 60947-5-1 |
| Hazardous Locations Approvals: | Complies with UL 1604, ISA 12.12.01, CSA 22.2 No. 213, and EN 60079-15 (Class I, Division 2)                        |

## General

### AC Current Input

Phase and Neutral Currents

$I_{NOM} = 1 \text{ A}$  or 5 A secondary depending on model.

#### $I_{NOM} = 5 \text{ A}$

|                     |                                  |
|---------------------|----------------------------------|
| Continuous Rating:  | 15 A, linear to 96 A symmetrical |
| 1 Second Thermal:   | 500 A                            |
| Burden (per Phase): | <0.1 VA @ 5 A                    |

#### $I_{NOM} = 1 \text{ A}$

|                       |                                    |
|-----------------------|------------------------------------|
| Continuous Rating:    | 3 A, linear to 19.20 A symmetrical |
| 1 Second Thermal:     | 100 A                              |
| Burden (per Phase):   | <0.01 VA @ 1 A                     |
| Measurement Category: | II                                 |

### AC Voltage Inputs

|                             |                                                                                     |
|-----------------------------|-------------------------------------------------------------------------------------|
| VNOM (L-L secondary) Range: | 100–250 V (if DELTA_Y := DELTA)<br>100–440 V (if DELTA_Y := WYE)                    |
| Rated Continuous Voltage:   | 300 Vac                                                                             |
| 10 Second Thermal:          | 600 Vac                                                                             |
| Burden:                     | <0.1 VA                                                                             |
| Input Impedance:            | 4 M $\Omega$ differential (phase-phase)<br>7 M $\Omega$ common mode (phase-chassis) |

### Power Supply

125/250 Vdc or 120/240 Vac

|                       |                                             |
|-----------------------|---------------------------------------------|
| Rated Supply Voltage: | 110–240 Vac, 50/60 Hz<br>110–250 Vdc        |
| Input Voltage Range:  | 85–264 Vac<br>85–275 Vdc                    |
| Power Consumption:    | <40 VA (ac)<br><20 W (dc)                   |
| Interruptions:        | 50 ms @ 125 Vac/Vdc<br>100 ms @ 250 Vac/Vdc |

24/48 Vdc

|                       |                                  |
|-----------------------|----------------------------------|
| Rated Supply Voltage: | 24–48 Vdc                        |
| Input Voltage Range:  | 19.2–60 Vdc                      |
| Power Consumption:    | <20 W (dc)                       |
| Interruptions:        | 10 ms @ 24 Vdc<br>50 ms @ 48 Vdc |

### Output Contacts

General

**OUT103** is a Form C Trip Output, all other outputs are Form A, except for the SELECT 4 DI/3 DO card, which supports two Form C and one Form B outputs.

|                        |                                              |
|------------------------|----------------------------------------------|
| Mechanical Durability: | 100,000 no load operations                   |
| Pickup/Dropout Time:   | ≤8 ms (coil energization to contact closure) |

### DC Output Ratings

|                            |                                                   |
|----------------------------|---------------------------------------------------|
| Rated Operational Voltage: | 250 Vdc                                           |
| Rated Voltage Range:       | 19.2–275 Vdc                                      |
| Rated Insulation Voltage:  | 300 Vdc                                           |
| Make:                      | 30 A @ 250 Vdc per IEEE C37.90                    |
| Continuous Carry:          | 6 A @ 70°C<br>4 A @ 85°C                          |
| Thermal:                   | 50 A for 1 s                                      |
| Contact Protection:        | 360 Vdc, 40 J MOV protection across open contacts |

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

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

Cyclic (2.5 cycles/second) per IEC 60255-0-20:1974:

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

### AC Output Ratings

|                                                             |                                                  |
|-------------------------------------------------------------|--------------------------------------------------|
| Maximum Operational Voltage ( $U_o$ ) Rating:               | 240 Vac                                          |
| Insulation Voltage ( $U_i$ ) Rating:                        | 300 Vac                                          |
| Utilization Category:                                       | AC-15 (control of electromagnetic loads > 72 VA) |
| Contact Rating Designation:                                 | B300 (B = 5 A, 300 = rated insulation voltage)   |
| Voltage Protection Across Open Contacts:                    | 270 Vac, 40 J                                    |
| Rated Operational Current ( $I_o$ ):                        | 3 A @ 120 Vac<br>1.5 A @ 240 Vac                 |
| Conventional Enclosed Thermal Current ( $I_{the}$ ) Rating: | 5 A                                              |
| Rated Frequency:                                            | 50/60 $\pm$ 5 Hz                                 |
| Electrical Durability Make VA Rating:                       | 3600 VA, $\cos\phi = 0.3$                        |
| Electrical Durability Break VA Rating:                      | 360 VA, $\cos\phi = 0.3$                         |

UL/CSA Digital Output Contact Temperature Derating for Operating at Elevated Temperatures

| Digital Output Cards Installed | Operating Ambient          | Maximum Value of Current ( $I_{the}$ ) | Duty Factor |
|--------------------------------|----------------------------|----------------------------------------|-------------|
| 1–3                            | less than or equal to 60°C | 5.0 A                                  | Continuous  |
| 1–3                            | between 60°C and 70°C      | 2.5 A                                  | Continuous  |

Fast Hybrid (high-speed high current interrupting)

|                                   |                                                              |
|-----------------------------------|--------------------------------------------------------------|
| Make:                             | 30 A                                                         |
| Carry:                            | 6 A continuous carry at 70°C<br>4 A continuous carry at 85°C |
| 1 s Rating:                       | 50 A                                                         |
| Open State Leakage Current:       | <100 $\mu$ A                                                 |
| MOV Protection (Maximum Voltage): | 250 Vac/330 Vdc                                              |
| Pickup Time:                      | <50 $\mu$ s, resistive load                                  |
| Dropout Time:                     | 8 ms, resistive load                                         |

Break Capacity (10000 operations):

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

Cyclic Capacity (4 cycles in 1 second, followed by 2 minutes idle for thermal dissipation):

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

**NOTE:** Per IEC 60255-23:1994, using the simplified method of assessment.

**NOTE:** Make rating per IEEE C37.90-1989.

### Optoisolated Control Inputs

When Used With DC Control Signals

|        |                                           |
|--------|-------------------------------------------|
| 250 V: | ON for 200–312.5 Vdc<br>OFF below 150 Vdc |
| 220 V: | ON for 176–275 Vdc<br>OFF below 132 Vdc   |
| 125 V: | ON for 100–156.2 Vdc<br>OFF below 75 Vdc  |
| 110 V: | ON for 88–137.5 Vdc<br>OFF below 66 Vdc   |
| 48 V:  | ON for 38.4–60 Vdc<br>OFF below 28.8 Vdc  |
| 24 V:  | ON for 15–30 Vdc<br>OFF for <5 Vdc        |

When Used With AC Control Signals

|        |                                             |
|--------|---------------------------------------------|
| 250 V: | ON for 170.6–312.5 Vac<br>OFF below 106 Vac |
| 220 V: | ON for 150.2–275 Vac<br>OFF below 93.3 Vac  |
| 125 V: | ON for 85–156.2 Vac<br>OFF below 53 Vac     |
| 110 V: | ON for 75.1–137.5 Vac<br>OFF below 46.6 Vac |
| 48 V:  | ON for 32.8–60 Vac<br>OFF below 20.3 Vac    |
| 24 V:  | ON for 14–30 Vac<br>OFF below 5 Vac         |

|                                     |                                                              |
|-------------------------------------|--------------------------------------------------------------|
| Current draw at nominal dc voltage: | 2 mA (at 220–250 V)<br>4 mA (at 48–125 V)<br>10 mA (at 24 V) |
|-------------------------------------|--------------------------------------------------------------|

|                                                |        |
|------------------------------------------------|--------|
| Rated Impulse Withstand Voltage ( $U_{imp}$ ): | 4000 V |
|------------------------------------------------|--------|

### Analog Output (Optional)

|                               | 1A0                                      | 4A0     |
|-------------------------------|------------------------------------------|---------|
| Current:                      | 4–20 mA                                  | ±20 mA  |
| Voltage:                      | —                                        | ±10 V   |
| Load at 1 mA:                 | —                                        | 0–15 kΩ |
| Load at 20 mA:                | 0–300 Ω                                  | 0–750 Ω |
| Load at 10 V:                 | —                                        | >2000 Ω |
| Refresh Rate:                 | 100 ms                                   | 100 ms  |
| % Error, Full Scale, at 25°C: | <±1%                                     | <±0.55% |
| Select From:                  | Analog quantities available in the relay |         |

### Analog Input (Optional)

|                                      |                                                                            |
|--------------------------------------|----------------------------------------------------------------------------|
| Maximum Input Range:                 | ±20 mA<br>±10 V<br>Operational range set by user                           |
| Input Impedance:                     | 200 Ω (current mode)<br>>10 kΩ (voltage mode)                              |
| Accuracy at 25°C:                    |                                                                            |
| With user calibration:               | 0.050% of full scale (current mode)<br>0.025% of full scale (voltage mode) |
| Without user calibration:            | Better than 0.5% of full scale at 25°C                                     |
| Accuracy Variation With Temperature: | ±0.015% per °C of full scale<br>(±20 mA or ±10 V)                          |

### Frequency and Phase Rotation

|                     |           |
|---------------------|-----------|
| System Frequency:   | 50, 60 Hz |
| Phase Rotation:     | ABC, ACB  |
| Frequency Tracking: | 15–70 Hz  |

### Time-Code Input

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

Synchronization Accuracy

|                                               |                               |
|-----------------------------------------------|-------------------------------|
| Internal Clock:                               | ±1 μs                         |
| Synchrophasor Reports(e.g., MET PM):          | ±10 μs                        |
| All Other Reports:                            | ±5 ms                         |
| Simple Network Time Protocol (SNTP) Accuracy: | ±5 ms                         |
| Unsynchronized Clock Drift Relay Powered:     | 2 minutes per year, typically |

### Communications Ports

Standard EIA-232 (2 ports)

|             |                           |
|-------------|---------------------------|
| Location:   | Front Panel<br>Rear Panel |
| Data Speed: | 300–38400 bps             |

EIA-485 Port (Optional)

|             |               |
|-------------|---------------|
| Location:   | Rear Panel    |
| Data Speed: | 300–19200 bps |

Ethernet Port (Optional)

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

Standard Multimode Fiber-Optic Port

|             |               |
|-------------|---------------|
| Location:   | Front Panel   |
| Data Speed: | 300–38400 bps |

### Fiber-Optic Ports Characteristics

Port 1 (or 1A, 1B) Ethernet

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

## Port 2 Serial

|                            |                  |
|----------------------------|------------------|
| Wavelength:                | 820 nm           |
| Optical Connector Type:    | ST               |
| Fiber Type:                | Multimode        |
| Link Budget:               | 8 dB             |
| Typical TX Power:          | -16 dBm          |
| RX Min. Sensitivity:       | -24 dBm          |
| Fiber Size:                | 62.5/125 $\mu$ m |
| Approximate Range:         | ~1 km            |
| Data Rate:                 | 5 Mb             |
| Typical Fiber Attenuation: | -4 dB/km         |

## Optional Communications Cards

|           |                                        |
|-----------|----------------------------------------|
| Option 1: | EIA-232 or EIA-485 communications card |
| Option 2: | DeviceNet communications card          |

## Communications Protocols

SEL, Modbus, DNP, FTP, TCP/IP, Telnet, SNTP, IEC 61850, MIRRORING BITS, EVMSG, C37.118 (synchrophasors), and DeviceNet.

## Operating Temperature

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

**NOTE:** Not applicable to UL applications

**NOTE:** LCD contrast is impaired for temperatures below -20°C and above +70°C

|                                       |                       |
|---------------------------------------|-----------------------|
| DeviceNet Communications Card Rating: | +60°C (140°F) maximum |
|---------------------------------------|-----------------------|

## Operating Environment

|                       |                      |
|-----------------------|----------------------|
| Pollution Degree:     | 2                    |
| Overvoltage Category: | II                   |
| Atmospheric Pressure: | 80–110 kPa           |
| Relative Humidity:    | 5–95%, noncondensing |
| Maximum Altitude:     | 2000 m               |

## Dimensions

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

## Weight

2.0 kg (4.4 lbs)

## Relay Mounting Screw (#8-32) Tightening Torque

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

## Terminal Connections

|                      |                    |
|----------------------|--------------------|
| Terminal Block       |                    |
| Screw Size:          | #6                 |
| Ring Terminal Width: | 0.310 inch maximum |

## Terminal Block Tightening Torque

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

## Compression Plug Tightening Torque

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

## Compression Plug Mounting Ear Screw Tightening Torque

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

## Type Tests

## Environmental Tests

|                          |                                                                                                                                                                                                                            |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Enclosure Protection:    | IEC 60529:2001<br>IP65 enclosed in panel<br>IP20 for terminals<br>IP54 rated terminal dust protection assembly (SEL Part #915900170).<br>10°C temperature derating applies to the temperature specifications of the relay. |
| Vibration Resistance:    | IEC 60255-21-1:1988,<br>Class 2 Endurance<br>Class 2 Response<br>IEC 60255-21-3:1993, Class 2                                                                                                                              |
| Shock Resistance:        | IEC 60255-21-2:1988,<br>Class 1 Shock Withstand, Bump<br>Class 2 Shock Response                                                                                                                                            |
| Cold:                    | IEC 60068-2-1:2007<br>-40°C, 16 hours                                                                                                                                                                                      |
| Damp Heat, Steady State: | IEC 60068-2-78:2001<br>40°C, 93% relative humidity, 4 days                                                                                                                                                                 |
| Damp Heat, Cyclic:       | IEC 60068-2-30:2005<br>25–55°C, 6 cycles, 95% relative humidity                                                                                                                                                            |
| Dry Heat:                | IEC 60068-2-2:2007<br>85°C, 16 hours                                                                                                                                                                                       |

## Dielectric Strength and Impulse Tests

|                     |                                                                                                                                                                                        |
|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Dielectric (HiPot): | IEC 60255-5:2000<br>IEEE C37.90-2005<br>2.5 kVac on current inputs, voltage inputs, contact I/O<br>2.0 kVac on analog inputs<br>1.0 kVac on analog output<br>2.83 kVdc on power supply |
| Impulse:            | IEC 60255-5:2000<br>0.5 J, 4.7 kV on power supply, contact I/O, ac current and voltage inputs<br>0.5 J, 530 V on analog outputs                                                        |

## RFI and Interference Tests

|                                      |                                                                                                                                                                             |
|--------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| EMC Immunity                         |                                                                                                                                                                             |
| Electrostatic Discharge Immunity:    | IEC 60255-22-2:2008<br>IEC 61000-4-2:2008<br>Severity Level 4<br>8 kV contact discharge<br>15 kV air discharge                                                              |
| Radiated RF Immunity:                | IEC 60255-22-3:2007<br>IEC 61000-4-3:2002, 10 V/m<br>IEEE C37.90.2-1995, 35 V/m                                                                                             |
| Fast Transient, Burst Immunity:      | IEC 60255-22-4:2008<br>IEC 61000-4-4:2004<br>4 kV @ 2.5 kHz<br>2 kV @ 5.0 kHz for comm. ports                                                                               |
| Surge Immunity:                      | IEC 60255-22-5:2008<br>IEC 61000-4-5:2005<br>2 kV line-to-line<br>4 kV line-to-earth                                                                                        |
| Surge Withstand Capability Immunity: | IEC 60255-22-1:1988<br>2.5 kV common mode<br>1.0 kV differential mode<br>1 kV common mode on comm. ports<br>IEEE C37.90.1-2002<br>2.5 kV oscillatory<br>4 kV fast transient |
| Conducted RF Immunity:               | IEC 60255-22-6:2001<br>IEC 61000-4-6:2006, 10 Vrms                                                                                                                          |
| Magnetic Field Immunity:             | IEC 61000-4-8:2001<br>1000 A/m for 3 seconds<br>100 A/m for 1 minute                                                                                                        |

**EMC Emissions**

|                      |                        |
|----------------------|------------------------|
| Conducted Emissions: | EN 55011:1998, Class A |
| Radiated Emissions:  | EN 55011:1998, Class A |

**Electromagnetic Compatibility**

|                   |               |
|-------------------|---------------|
| Product Specific: | EN 50263:1999 |
|-------------------|---------------|

**Processing Specifications and Oscilloscope**

|                                    |                                                                                                                                                                                                                                                                                                                         |
|------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| AC Voltage and Current Inputs:     | 32 samples per power system cycle                                                                                                                                                                                                                                                                                       |
| Analog Inputs:                     | 4 samples per power system cycle                                                                                                                                                                                                                                                                                        |
| Frequency Tracking Range:          | 15–70 Hz                                                                                                                                                                                                                                                                                                                |
| Digital Filtering:                 | One-cycle cosine after low-pass analog filtering. Net filtering (analog plus digital) rejects dc and all harmonics greater than the fundamental.                                                                                                                                                                        |
| Protection and Control Processing: | Processing interval is 4 times per power system cycle (except for math variables and analog quantities, which are processed every 100 ms). The protection elements 40, 51, and 78 are processed twice per cycle. Analog quantities for rms data are determined through use of data averaged over the previous 8 cycles. |

**Oscilloscope**

|                        |                                                                 |
|------------------------|-----------------------------------------------------------------|
| Length:                | 15, 64, 180 cycles                                              |
| Sampling Rate:         | 32 samples per cycle unfiltered<br>4 samples per cycle filtered |
| Trigger:               | Programmable with Boolean expression                            |
| Format:                | ASCII and Compressed ASCII                                      |
| Time-Stamp Resolution: | 1 ms                                                            |
| Time-Stamp Accuracy:   | ±5 ms                                                           |

**Sequential Events Recorder**

|                                                    |       |
|----------------------------------------------------|-------|
| Time-Stamp Resolution:                             | 1 ms  |
| Time-Stamp Accuracy (with respect to time source): | ±5 ms |

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

|                                    |                                                                                                                                        |
|------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| Pickup Setting Range, A secondary: |                                                                                                                                        |
| 5 A models:                        | 0.50–96.00 A, 0.01 A steps                                                                                                             |
| 1 A models:                        | 0.10–19.20 A, 0.01 A steps                                                                                                             |
| Accuracy:                          | ±5% of setting plus ±0.02 • I <sub>NOM</sub> A secondary (Steady State pickup)                                                         |
| Time Delay:                        | 0.00–400.00 seconds, 0.01 seconds steps, ±0.5% plus ±0.25 cyc<br>0.10–400.00 seconds, 0.01 seconds steps, ±0.5% plus ±0.25 cyc for 50Q |
| Pickup/Dropout Time:               | <1.5 cyc                                                                                                                               |

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

|                                    |                                                                                           |
|------------------------------------|-------------------------------------------------------------------------------------------|
| Pickup Setting Range, A secondary: |                                                                                           |
| 5 A models:                        | 0.50–16.00 A, 0.01 A steps                                                                |
| 1 A models:                        | 0.10–3.20 A, 0.01 A steps                                                                 |
| Accuracy:                          | ±5% of setting plus ±0.02 • I <sub>NOM</sub> A secondary (Steady State pickup)            |
| Time Dial:                         |                                                                                           |
| US:                                | 0.50–15.00, 0.01 steps                                                                    |
| IEC:                               | 0.05–1.00, 0.01 steps                                                                     |
| Accuracy:                          | ±1.5 cycles plus ±4% between 2 and 30 multiples of pickup (within rated range of current) |

**Differential (87)**

|                                |                              |
|--------------------------------|------------------------------|
| Unrestrained Pickup Range:     | 1.0–20.0 in per unit of TAP  |
| Restrained Pickup Range:       | 0.10–1.00 in per unit of TAP |
| Pickup Accuracy (A secondary): |                              |
| 5 A Model:                     | ±5% plus ±0.10 A             |
| 1 A Model:                     | ±5% plus ±0.02 A             |
| TAP Range (A secondary):       |                              |
| 5 A Model:                     | 0.5–31.0 A                   |
| 1 A Model:                     | 0.1–6.2 A                    |

**Unrestrained Element**

|              |                                  |
|--------------|----------------------------------|
| Pickup Time: | 0.8/1.0/1.9 cycles (Min/Typ/Max) |
|--------------|----------------------------------|

**Restrained Element (With Harmonic Blocking)**

|              |                                  |
|--------------|----------------------------------|
| Pickup Time: | 1.5/1.6/2.2 cycles (Min/Typ/Max) |
|--------------|----------------------------------|

**Restrained Element (With Harmonic Restraint)**

|              |                                     |
|--------------|-------------------------------------|
| Pickup Time: | 2.62/2.72/2.86 cycles (Min/Typ/Max) |
|--------------|-------------------------------------|

**Harmonics**

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

**Restricted Earth Fault (REF)**

|                                                               |                                                                                         |
|---------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| Pickup Range (per unit of INOM of neutral current input, IN): | 0.05–3.00 per unit, 0.01 per-unit steps                                                 |
| Pickup Accuracy (A secondary):                                |                                                                                         |
| 5 A Model:                                                    | ±5% plus ±0.10 A                                                                        |
| 1 A Model:                                                    | ±5% plus ±0.02 A                                                                        |
| Timing Accuracy:                                              |                                                                                         |
| Directional Output:                                           | 1.5 ±0.25 cyc                                                                           |
| ANSI Extremely Inverse TOC Curve (U4 With 0.5 Time Dial):     | ±5 cycles plus ±5% between 2 and 30 multiples of pickup (within rated range of current) |

**Undervoltage (27P, 27PP, 27V1, 27S)**

|                      |                                                                                                                 |
|----------------------|-----------------------------------------------------------------------------------------------------------------|
| Pickup Range:        | Off, 2.0–300.0 V (2.0–520.0 V for phase-to-phase wye connected; 2.0–170.0 V positive-sequence, delta connected) |
| Accuracy:            | ±5% of setting plus ±2 V                                                                                        |
| Pickup/Dropout Time: | <1.5 cycle                                                                                                      |
| Time Delay:          | 0.00–120.00 seconds, 0.01 second steps                                                                          |
| Accuracy:            | ±0.5% plus ±0.25 cycle                                                                                          |

**Overvoltage (59P, 59PP, 59V1, 59S, 59Q, 59G)**

|                          |                                                                                                                 |
|--------------------------|-----------------------------------------------------------------------------------------------------------------|
| Pickup Range:            | Off, 2.0–300.0 V (2.0–520.0 V for phase-to-phase wye connected; 2.0–170.0 V positive sequence, delta connected) |
| Pickup Range (59G, 59Q): | Off, 2.0–200.0 V                                                                                                |
| Accuracy:                | ±5% of setting plus ±2 V                                                                                        |
| Pickup/Dropout Time:     | <1.5 cycle                                                                                                      |
| Time Delay:              | 0.00–120.00 seconds, 0.01 second steps                                                                          |
| Accuracy:                | ±0.5% plus ±0.25 cycle                                                                                          |

**Volts/Hertz (24)****Definite-Time Element**

|                               |                            |
|-------------------------------|----------------------------|
| Pickup Range:                 | 100–200%                   |
| Steady-State Pickup Accuracy: | ±1% of setpoint            |
| Pickup Time:                  | 25 ms @ 60 Hz (Max)        |
| Time-Delay Range:             | 0.04–400.00 s              |
| Time-Delay Accuracy:          | ±0.1% plus ±4.2 ms @ 60 Hz |
| Reset Time Range:             | 0.00–400.00 s              |

**Inverse-Time Element**

|                               |                                                                                                      |
|-------------------------------|------------------------------------------------------------------------------------------------------|
| Pickup Range:                 | 100–200%                                                                                             |
| Steady-State Pickup Accuracy: | ±1% of setpoint                                                                                      |
| Pickup Time:                  | 25 ms @ 60 Hz (Max)                                                                                  |
| Curve:                        | 0.5, 1.0, or 2.0                                                                                     |
| Factor:                       | 0.1–10.0 s                                                                                           |
| Timing Accuracy:              | ±4% plus ±25 ms @ 60 Hz, for V/Hz above 1.2 multiple of pickup setting, and for operating times >4 s |
| Reset Time Range:             | 0.00–400.00 s                                                                                        |

**Composite-Time Element**

Combination of Definite-Time and Inverse-Time specifications

**User-Definable Curve Element**

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

**Directional Power (32)****Instantaneous/Definite Time, 3 Phase Elements**

|                                      |                                                                                                                                                                                                                                                                                                                              |
|--------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Type:                                | +W, –W, +VAR, –VAR                                                                                                                                                                                                                                                                                                           |
| Pickup Settings Range, VA secondary: |                                                                                                                                                                                                                                                                                                                              |
| 5 A Model:                           | 1.0–6500.0 VA, 0.1 VA steps                                                                                                                                                                                                                                                                                                  |
| 1 A Model:                           | 0.2–1300.0 VA, 0.1 VA steps                                                                                                                                                                                                                                                                                                  |
| Accuracy:                            | ±0.10 A • (L-L voltage secondary) and ±5% of setting at unity power factor for power elements and zero power factor for reactive power element (5 A nominal)<br>±0.02 A • (L-L voltage secondary) and ±5% of setting at unity power factor for power elements and zero power factor for reactive power element (1 A nominal) |
| Pickup/Dropout Time:                 | <10 cycles                                                                                                                                                                                                                                                                                                                   |
| Time Delay:                          | 0.00–240.00 seconds, 0.01 second steps                                                                                                                                                                                                                                                                                       |
| Accuracy:                            | ±0.5% plus ±0.25 cycle                                                                                                                                                                                                                                                                                                       |

**Frequency (81)**

|                      |                                        |
|----------------------|----------------------------------------|
| Setting Range:       | Off, 15.0–70.0 Hz                      |
| Accuracy:            | ±0.01 Hz (V1 >60 V)                    |
| Pickup/Dropout Time: | <4 cycles                              |
| Time Delay:          | 0.00–240.00 seconds, 0.01 second steps |
| Accuracy:            | ±0.5% plus ±0.25 cycle                 |

**RTD Protection**

|                               |                                                 |
|-------------------------------|-------------------------------------------------|
| Setting Range:                | Off, 1–250°C                                    |
| Accuracy:                     | ±2°C                                            |
| RTD Open-Circuit Detection:   | >250°C                                          |
| RTD Short-Circuit Detection:  | <–50°C                                          |
| RTD Types:                    | PT100, NI100, NI120, CU10                       |
| RTD Lead Resistance:          | 25 ohm max. per lead                            |
| Update Rate:                  | <3 s                                            |
| Noise Immunity on RTD Inputs: | To 1.4 Vac (peak) at 50 Hz or greater frequency |
| RTD Trip/Alarm Time Delay:    | Approx. 6 s                                     |

**Distance Element (21)**

Two zones of Compensator Distance elements with Load Encroachment block

|                                  |                                                              |
|----------------------------------|--------------------------------------------------------------|
| Reach Pickup Range:              | 5 A model: 0.1–100.0 ohms<br>1 A model: 0.5–500.0 ohms       |
| Offset Range:                    | 5 A model: 0.0–10.0 ohms<br>1 A model: 0.0–50.0 ohms         |
| Steady-State Impedance Accuracy: | 5 A model: ±5% plus ±0.1 ohm<br>1 A model: ±5% plus ±0.5 ohm |
| Definite-Time Delay:             | 0.00–400.00 s                                                |
| Accuracy:                        | ±0.1% plus ±0.25 cycle                                       |
| Minimum Phase Current:           | 5 A model: 0.5 A<br>1 A model: 0.1 A                         |
| Maximum Torque Angle Range:      | 90–45°, 1° step                                              |

**Loss-of-Field Element (40)****Two Mho Zones**

|                                         |                                                                                                             |
|-----------------------------------------|-------------------------------------------------------------------------------------------------------------|
| Zone 1 Offset:                          | 5 A model: –50.0–0.0 ohms<br>1 A model: –250.0–0.0 ohms                                                     |
| Zone 2 Offset:                          | 5 A model: –50.0–50.0 ohms<br>1 A model: –250.0–250.0 ohms                                                  |
| Zone 1 and Zone 2 Diameter:             | 5 A model: 0.1–100.0 ohms<br>1 A model: 0.5–500.0 ohms                                                      |
| Steady-State Impedance Accuracy:        | 5 A model: ± 0.1 ohm plus ±5% of (offset + diameter)<br>1 A model: ±0.5 ohm plus ±5% of (offset + diameter) |
| Minimum Pos.-Seq. Signals:              | 5 A model: 0.25 V (V1), 0.25 A (I1)<br>1 A model: 0.25 V (V1), 0.05 A (I1)                                  |
| Directional Element Angle:              | –20.0°–0.0°                                                                                                 |
| Pickup Time:                            | 3 cycles (Max)                                                                                              |
| Zone 1 and Zone 2 Definite-Time Delays: | 0.00–400.00 s                                                                                               |
| Accuracy:                               | ±0.1% plus ± ½ cycle                                                                                        |

**Voltage-Restrained Phase Time-Overcurrent Element (51V)**

|                                 |                                                                                                       |
|---------------------------------|-------------------------------------------------------------------------------------------------------|
| Phase Pickup (A secondary):     | 5 A Model: 2.0–16.0 A<br>1 A Model: 0.4–3.2 A                                                         |
| Steady-State Pickup Accuracy:   | 5 A Model: ±5% plus ±0.10 A<br>1 A Model: ±5% plus ±0.02 A                                            |
| Time Dials:                     | US: 0.50–15.00, 0.01 steps<br>IEC: 0.05–1.00, 0.01 steps                                              |
| Accuracy:                       | ±4% plus ±1.5 cycles for current between 2 and 20 multiples of pickup (within rated range of current) |
| Linear Voltage Restraint Range: | 0.125–1.000 per unit of VNOM                                                                          |

**Voltage-Controlled Phase Time-Overcurrent Element (51C)**

|                               |                                                                                                                  |
|-------------------------------|------------------------------------------------------------------------------------------------------------------|
| Phase Pickup (A secondary):   | 5 A Model: 0.5–16.0 A<br>1 A Model: 0.1–3.2 A                                                                    |
| Steady State Pickup Accuracy: | 5 A Model: $\pm 5\%$ plus $\pm 0.10$ A<br>1 A Model: $\pm 5\%$ plus $\pm 0.02$ A                                 |
| Time Dials:                   | US: 0.50–15.00, 0.01 steps<br>IEC: 0.05–1.00, 0.01 steps                                                         |
| Accuracy:                     | $\pm 4\%$ plus $\pm 1.5$ cycles for current between 2 and 20 multiples of pickup (within rated range of current) |

**100 Percent Stator Ground Protection (64G)**

|                                                                                         |                                   |
|-----------------------------------------------------------------------------------------|-----------------------------------|
| Neutral Fundamental Overvoltage (64G1):                                                 | OFF, 0.1–150.0 V                  |
| Steady-State Pickup Accuracy:                                                           | $\pm 5\%$ plus $\pm 0.1$ V        |
| Pickup Time:                                                                            | 1.5 cycles (Max)                  |
| Definite-Time Delay:                                                                    | 0.00–400.00 s                     |
| Accuracy:                                                                               | $\pm 0.1\%$ plus $\pm 0.25$ cycle |
| Third-Harmonic Voltage Differential or Third-Harmonic Neutral Undervoltage Pickup 64G2: | 0.1–20.0 V                        |
| Steady-State Pickup Accuracy:                                                           | $\pm 5\%$ plus $\pm 0.1$ V        |
| Third-Harmonic Voltage Differential Ratio Setting Range:                                | 0.0 to 5.0                        |
| Pickup Time:                                                                            | 3 cycles (Max)                    |
| Definite-Time Delay:                                                                    | 0.00–400.00 s                     |
| Accuracy:                                                                               | $\pm 0.1\%$ plus $\pm 0.25$ cycle |

**Field Ground Protection (64F)****(Requires SEL-2664 Field Ground Module)**

|                                       |                                                                                                                                                                                                                     |
|---------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Field Ground Protection Element:      | 0.5–200.0 kilohms, 0.1 kilohm step                                                                                                                                                                                  |
| Pickup Accuracy:                      | $\pm 5\%$ plus $\pm 500$ ohms for $48 \pm \text{VF} \pm 825 \text{ Vdc}$<br>$\pm 5\%$ plus $\pm 20$ kilohms for $825 < \text{VF} \pm 1500 \text{ Vdc}$<br>(VF is the generator field winding excitation dc voltage) |
| Pickup Time:                          | 2 s if the injection frequency in the SEL-2664 is selected at 1 Hz<br>8 s if the injection frequency in the SEL-2664 is selected at 0.25 Hz                                                                         |
| Definite-Time Delay:                  | 0.0–99.0 s                                                                                                                                                                                                          |
| Maximum Definite-Time Delay Accuracy: | $\pm 0.5\%$ plus $\pm 5$ ms                                                                                                                                                                                         |

**Out-of-Step Element (78)**

|                |                                                        |
|----------------|--------------------------------------------------------|
| Forward Reach: | 5 A model: 0.1–100.0 ohms<br>1 A model: 0.5–500.0 ohms |
| Reverse Reach: | 5 A model: 0.1–100.0 ohms<br>1 A model: 0.5–500.0 ohms |
| Single Blinder |                                                        |
| Right Blinder: | 5 A model: 0.1–50.0 ohms<br>1 A model: 0.5–250.0 ohms  |
| Left Blinder:  | 5 A model: 0.1–50.0 ohms<br>1 A model: 0.5–250.0 ohms  |

**Double Blinder**

|                                  |                                                                                                            |
|----------------------------------|------------------------------------------------------------------------------------------------------------|
| Outer Resistance Blinder:        | 5 A model: 0.2–100.0 ohms<br>1 A model: 1.0–500.0 ohms                                                     |
| Inner Resistance Blinder:        | 5 A model: 0.1–50.0 ohms<br>1 A model: 0.5–250.0 ohms                                                      |
| Steady-State Impedance Accuracy: | 5 A model: $\pm 0.1$ ohm plus $\pm 5\%$ of diameter<br>1 A model: $\pm 0.5$ ohm plus $\pm 5\%$ of diameter |
| Pos.-Seq. Current Supervision:   | 5 A model: 0.25–30.00 A<br>1 A model: 0.05–6.00 A                                                          |
| Pickup Time:                     | 3 cycles (Max)                                                                                             |
| Definite Time Delay:             | 0.00–1.00 s, 0.01 s step                                                                                   |
| Trip Delay Range:                | 0.00–1.00 s, 0.01 s step                                                                                   |
| Trip Duration Range:             | 0.00–5.00 s, 0.01 s step                                                                                   |
| Definite-Time Timers:            | $\pm 0.1\%$ plus $\pm \frac{1}{2}$ cycle                                                                   |

**Ground Differential Elements (87N)**

|                               |                                                                                                                                                                                     |
|-------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ground Differential Pickup:   | 5 A Model: $0.10 \cdot \text{CTR} / \text{CTRN} - 15.00 \text{ A}$<br>1 A Model: $0.02 \cdot \text{CTR} / \text{CTRN} - 3.00 \text{ A}$<br>(Ratio CTR/CTRN must be within 1.0–40.0) |
| Steady-State Pickup Accuracy: | 5 A Model: $\pm 5\%$ plus $\pm 0.10 \text{ A}$<br>1 A Model: $\pm 5\%$ plus $\pm 0.02 \text{ A}$                                                                                    |
| Pickup Time:                  | 1.5 cycles (Max)                                                                                                                                                                    |
| Time Delay Range:             | 0.00–5.00 s                                                                                                                                                                         |
| Time Delay Accuracy:          | $\pm 0.5\%$ plus $\pm \frac{1}{4}$ cycle                                                                                                                                            |

**Negative-Sequence Overcurrent Elements (46)**

|                                                        |                                                                                                    |
|--------------------------------------------------------|----------------------------------------------------------------------------------------------------|
| Definite-Time and Inverse-Time Neg.-Seq. $I^2$ Pickup: | 2%–100% of generator rated secondary current                                                       |
| Generator Rated Secondary Current:                     | 5 A Model: 1.0–10.0 A secondary<br>1 A Model: 0.2–2.0 A secondary                                  |
| Steady-State Pickup Accuracy:                          | 5 A Model: $\pm 0.025 \text{ A}$ plus $\pm 3\%$<br>1 A Model: $\pm 0.005 \text{ A}$ plus $\pm 3\%$ |
| Pickup Time:                                           | 50 ms at 60 Hz (max)                                                                               |
| Definite-Time Delay Setting Range:                     | 0.02–999.90 s                                                                                      |
| Maximum Definite-Time Delay Accuracy:                  | $\pm 0.1\%$ plus $\pm 4.2$ ms at 60 Hz                                                             |
| Inverse-Time Element Time Dial:                        | K = 1 to 100 s                                                                                     |
| Linear Reset Time:                                     | 240 s fixed                                                                                        |
| Inverse-Time Timing Accuracy:                          | $\pm 4\%$ plus $\pm 50$ ms at 60 Hz for $ I_2 $ above 1.05 multiples of pickup                     |

**Rate-of-Change of Frequency (81R)**

|                                                       |                                             |
|-------------------------------------------------------|---------------------------------------------|
| Pickup Setting Range:                                 | Off, 0.10–15.00 Hz/s                        |
| Accuracy:                                             | $\pm 100$ mHz/s plus $\pm 3.33\%$ of pickup |
| Trend Setting:                                        | INC, DEC, ABS                               |
| Pickup/Dropout Time:                                  | 3–30 cycles, depending on pickup setting    |
| Pickup/ Dropout Delay Range:                          | 0.10–60.00/0.00–60.00 s, 0.1 s increments   |
| Voltage Supervision (Positive Sequence) Pickup Range: | Off, 12.5–300.0 V, 0.1 V increments         |

**Synchronism Check (25Y) for Tie Breaker**

|                                        |                                                            |
|----------------------------------------|------------------------------------------------------------|
| Synchronism-Check Voltage Source:      | VAX, VBY, VCY, VABY, VBCY, VCAY or angle from VAY or VABY) |
| Voltage Window High Setting Range:     | 0.00–300.00 V                                              |
| Voltage Window Low Setting Range:      | 0.00–300.00 V                                              |
| Steady-State Voltage Accuracy:         | ±5% plus ±2.0 V (over the range of 12.5–300 V)             |
| Maximum Percentage Voltage Difference: | 1.0–15.0%                                                  |
| Maximum Slip Frequency:                | –0.05 Hz–0.50 Hz                                           |
| Steady-State Slip Accuracy:            | ±0.02 Hz                                                   |
| Close Acceptance Angle 1, 2:           | 0–80°                                                      |
| Breaker Close Delay:                   | 0.001–1.000 s                                              |
| Steady-State Angle Accuracy:           | ±2°                                                        |

**Synchronism Check (25X) for Generator Breaker**

|                                        |                                                            |
|----------------------------------------|------------------------------------------------------------|
| Synchronism-Check Voltage Source:      | VAX, VBX, VCX, VABX, VBCX, VCAX or angle from VAX or VABX) |
| Voltage Window High Setting Range:     | 0.00–300.00 V                                              |
| Voltage Window Low Setting Range:      | 0.00–300.00 V                                              |
| Steady-State Voltage Accuracy:         | ±5% plus ±2.0 V (over the range of 12.5–300 V)             |
| Maximum Percentage Voltage Difference: | 1.0–15.0%                                                  |
| Minimum Slip Frequency:                | –1.00 Hz–0.99 Hz                                           |
| Maximum Slip Frequency:                | –0.99 Hz–1.00 Hz                                           |
| Steady-State Slip Accuracy:            | ±0.02 Hz                                                   |
| Close Acceptance Angle 1, 2:           | 0–80°                                                      |
| Target Close Angle:                    | –15–15°                                                    |
| Breaker Close Delay:                   | 0.001–1.000 s                                              |
| Close Failure Angle:                   | 3–120°                                                     |
| Steady-State Angle Accuracy:           | ±2°                                                        |

**Generator Thermal Model (49T)**

|                                     |                                                                                                                     |
|-------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| Thermal Overload Trip Pickup Level: | 30–250% of Full Load Current (Full Load Current $I_{NOM}$ range: 0.2–2.0* $I_{NOM}$ , where $I_{NOM}$ = 1 A or 5 A) |
| TCU Alarm Pickup Level:             | 50–99% Thermal Capacity Used                                                                                        |
| Time-Constant Range (2):            | 1–1000 minutes                                                                                                      |
| Time Accuracy Pickup/ Dropout Time: | ±(5% + 25 ms) at multiple-of-pickup ≥2, 50/60 Hz (pre-load = 0)                                                     |

**Autosynchronizing****Frequency Matching**

|                                    |                                                        |
|------------------------------------|--------------------------------------------------------|
| Speed (Frequency) Control Outputs: |                                                        |
| Raise:                             | Digital Output, adjustable pulse duration and interval |
| Lower:                             | Digital Output, adjustable pulse duration and interval |
| Frequency Synchronism Timer:       | 5–3600 s, 1 s increments                               |
| Frequency Adjustment Rate:         | 0.01–10.00 Hz/s, 0.01 Hz/s increment                   |

|                           |                                |
|---------------------------|--------------------------------|
| Frequency Pulse Interval: | 1–120 s, 1 s increment         |
| Frequency Pulse Minimum:  | 0.10–60.00 s, 0.01 s increment |
| Frequency Pulse Maximum:  | 0.10–60.00 s, 0.01 s increment |
| Kick Pulse Interval:      | 1–120 s, 1 s increments        |
| Kick Pulse Minimum:       | 0.02–2.00 s, 0.01 s increments |
| Kick Pulse Maximum:       | 0.02–2.00 s, 0.01 s increments |

**Voltage Matching**

|                                           |                                                        |
|-------------------------------------------|--------------------------------------------------------|
| Voltage Control Outputs:                  |                                                        |
| Raise:                                    | Digital Output, adjustable pulse duration and interval |
| Lower:                                    | Digital Output, adjustable pulse duration and interval |
| Voltage Synchronized Timer:               | 5–3600 s, 1 s increments                               |
| Voltage Adjustment Rate (Control System): | 0.01–30.00 V/s, 0.01 V/s increment                     |
| Voltage Pulse Interval:                   | 1–120 s, 1 s increment                                 |
| Voltage Control Pulse Minimum:            | 0.10–60.00 s, 0.01 s increment                         |
| Voltage Control Pulse Maximum:            | 0.10–60.00 s, 0.01 s increment                         |
| Timing Accuracy:                          | ±0.5% plus ±¼ cyc                                      |

**Metering Accuracy**

|                                                                                                                                                                               |                                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Accuracies are specified at 20°C, nominal frequency, ac currents within (0.2–20.0) • $I_{NOM}$ A secondary, and ac voltages within 50–250 V secondary unless otherwise noted. |                                                                          |
| Phase Currents:                                                                                                                                                               | ±1% of reading, ±1° (±2.5° at 0.2–0.5 A for relays with $I_{NOM}$ = 1 A) |
| 3-Phase Average Current:                                                                                                                                                      | ±1% of reading                                                           |
| Differential Quantities:                                                                                                                                                      | ±5% of reading plus ±0.1 A (5 A nominal), ±0.02 A (1 A nominal)          |
| Current Harmonics:                                                                                                                                                            | ±5% of reading plus ±0.1 A (5 A nominal), ±0.02 A (1 A nominal)          |
| IG (Residual Current):                                                                                                                                                        | ±2% of reading, ±2° (±5.0° at 0.2–0.5 A for relays with $I_{NOM}$ = 1 A) |
| IN (Neutral Current):                                                                                                                                                         | ±1% of reading, ±1° (±2.5° at 0.2–0.5 A for relays with $I_{NOM}$ = 1 A) |
| 3I2 Negative-Sequence Current:                                                                                                                                                | ±2% of reading                                                           |
| System Frequency:                                                                                                                                                             | ±0.01 Hz of reading for frequencies within 20–70 Hz ( $V_1$ > 60 V)      |
| Line-to-Line Voltages:                                                                                                                                                        | ±1% of reading, ±1° for voltages within 24–264 V                         |
| 3-Phase Average Line-to-Line Voltage:                                                                                                                                         | ±1% of reading for voltages within 24–264 V                              |
| Line-to-Ground Voltages:                                                                                                                                                      | ±1% of reading, ±1° for voltages within 24–264 V                         |
| 3-Phase Average Line-to-Ground Voltages:                                                                                                                                      | ±1% of reading for voltages within 24–264 V                              |
| Voltage Harmonics:                                                                                                                                                            | ±5% of reading plus ±0.5 V                                               |
| 3V2 Negative-Sequence Voltage:                                                                                                                                                | ±2% of reading for voltages within 24–264 V                              |
| Real 3-Phase Power (kW):                                                                                                                                                      | ±3% of reading for 0.10 < pf < 1.00                                      |
| Reactive 3-Phase Power (kVAR):                                                                                                                                                | ±3% of reading for 0.00 < pf < 0.90                                      |
| Apparent 3-Phase Power (kVA):                                                                                                                                                 | ±3% of reading                                                           |
| Power Factor:                                                                                                                                                                 | ±2% of reading                                                           |
| RTD Temperatures:                                                                                                                                                             | ±2°C                                                                     |

## Synchrophasor Accuracy

### Maximum Message Rate

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

### Accuracy for Voltages

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

Conditions:

- At maximum message rate
- When phasor has the same frequency as the positive-sequence tracking quantity (see *Table H.9*)
- Frequency-based phasor compensation is enabled (PHCOMP := Y)
- The narrow bandwidth filter is selected (PMAPP := N)

Range:

|                                         |                                                        |
|-----------------------------------------|--------------------------------------------------------|
| Frequency:                              | $\pm 5.0$ Hz of nominal (50 or 60 Hz)                  |
| Magnitude:                              | 30 V–250 V                                             |
| Phase Angle:                            | $-179.99^\circ$ to $180^\circ$                         |
| Out-of-Band Interfering Frequency (Fs): | $10 \text{ Hz} \leq F_s \leq (2 \cdot F_{\text{NOM}})$ |

### Accuracy for Currents

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

Conditions:

- At maximum message rate
- When phasor has the same frequency as the positive-sequence tracking quantity (see *Table H.9*)
- Frequency-based phasor compensation is enabled (PHCOMP := Y)
- The narrow bandwidth filter is selected (PMAPP := N)

Range:

|                                         |                                                                                           |
|-----------------------------------------|-------------------------------------------------------------------------------------------|
| Frequency:                              | $\pm 5.0$ Hz of nominal (50 or 60 Hz)                                                     |
| Magnitude:                              | $(0.4\text{--}2) \cdot I_{\text{NOM}}$ ( $I_{\text{NOM}} = 1 \text{ A or } 5 \text{ A}$ ) |
| Phase Angle:                            | $-179.99$ to $180^\circ$                                                                  |
| Out-of-Band Interfering Frequency (Fs): | $10 \text{ Hz} \leq F_s \leq (2 \cdot F_{\text{NOM}})$                                    |

## Notes

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