SEL-2414 Transformer Monitor

Complete System for Control and Monitoring

Major Features and Benefits

The SEL-2414 Transformer Monitor provides an exceptional combination of monitoring, control, and communications in a compact package.

➤ **Thermal Monitoring and Metering Capabilities.** Safeguard transformers from overheating by tracking thermal conditions. Track the minimum and maximum transformer top oil temperature, hot-spot temperature, and as many as 10 RTDs or thermocouples.

➤ **High Reliability, Rugged Design, and Low Price.** Apply the SEL-2414 in harsh physical and electrical environments. The SEL-2414 withstands vibration, electrical surges, fast transients, extreme operating temperatures from -40° to +85°C, and meets stringent utility standards. Compare our superior specification compliance, higher reliability, lower price, and worldwide, ten-year warranty to other transformer monitor alternatives.

➤ **Flexible I/O for Transformer Status, Alarms, and More.** Input/output options include digital inputs for status such as oil level and sudden pressure; RTD and thermocouple inputs for measurements such as ambient, top-oil, and hot-spot temperatures; digital outputs for control and alarms; analog inputs and outputs; and ac current and voltage inputs. Easily program monitoring and control functions with powerful logic, math, timers, counters, and edge-trigger functions. These features allow easy integration with new and retrofit transformer monitor applications. Monitor critical substation assets with comprehensive transformer thermal and through-fault monitoring.

➤ **Advanced Asset Monitoring.** Monitor critical substation assets with comprehensive transformer thermal and through-fault monitoring. Calculate top oil, hot-spot, insulation aging acceleration factor, and loss of life while generating hourly and daily data about your transformer. Capture the maximum/minimum values of all transformer model quantities. Capture through-fault current data that could lead to increased transformer wear.

➤ **Critical Reporting and Logging.** Store as many as 512 Sequential Events Recorder (SER) reports of digital input transitions, time-tagged to the nearest millisecond. Analyze SER reports, analog trending, and oscillographic event reports for rapid commissioning, testing, and post-event diagnostics. Send the SER data to a communications processor or computer for system analysis.
Communications and Integration. Automate fan bank control with flexible communication options that provide easy integration with SCADA. Choose from single and dual Ethernet, Modbus® TCP, DNP3 LAN/WAN, IEC 61850, Modbus Serial, EIA-232, EIA-485, Telnet, and File Transfer protocols.

AC Metering Capabilities. The SEL-2414 provides extensive ac metering and monitoring capabilities. Voltage, current, power, energy, power factor, frequency; demand/peak demand metering; and maximum/minimum metering are measured and recorded. Values can be used in programmable calculations and triggers within the meter.

Simple Commissioning Tools. Front-panel HMI provides complete configuration access and displays settings, measurements, and calculated values. Easily set with ACCELERATOR QuickSet® SEL-5030 Software.

Product Summary

The SEL-2414 Transformer Monitor withstands harsh physical and electrical environments and is built and tested to meet mission-critical IEEE and IEC protective relay standards. Apply the SEL-2414 to satisfy standalone or distributed monitoring and control of transformers, or choose from the flexible communications options to connect to a substation distributed SCADA or automation system, or a SCADA master. Communications options include serial, fiber-optic, and Ethernet connections and ASCII, SEL Fast Message, MIRRORED BITS® communications, Modbus, and DNP3 protocols. Figure 1 shows the SEL-2414 functionality.

Figure 1  Functional Block Diagram
Monitoring and Control Features

Apply flexible I/O options to meet the many needs of new or retrofit transformer installations. The SEL-2414 includes four slots for plug-in I/O cards. Use digital inputs (DI) to monitor critical transformer alarms and status points. Use analog inputs (AI) to measure pressure, oil level, temperatures, tap positions, and process-level signals (e.g., 4–20 mA, 0–1 mA) from transducers. Operate cooling fans, equipment, alarms, or provide indication with relay-contact or solid-state digital outputs (DO) and analog outputs (AO). Measure ac currents and ac voltage to calculate three-phase power, demand, energy, save in oscillographic reports, and for automatic control processes.

Figure 2 Transformer Monitor and Control System
I/O (Status and Alarms)

Use digital inputs to monitor critical alarms such as oil levels, pressures, gas accumulation; they may also be used for status points such as fans on/off and breakers open/closed, as shown in Figure 3.

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Analyze Transformer Sequence-of-Events

Record sequence-of-events related to transformer events or operations with the Sequential Events Recorder (SER) function. With this function, you can analyze assertions and deassertions of digital inputs and outputs; as many as 512 state changes to the millisecond for as many as 96 different digital points. The function also captures when the device powers up and a settings change occurs.

![Figure 4 Example SER Report](image)

Combine SER data from individual SEL-2414 Transformer Monitors into a system-wide log. Synchronize the system with IRIG-B time code and the report data will align perfectly.

![Figure 5 Combine SER Data From Multiple SEL-2414 Transformer Monitors for a System-Wide Log and Display](image)

SER System Log

Computer

![Figure 6 Example SER Collection Architecture](image)
Analyze Transformer Event Waveforms

Record analog and digital waveforms at 32 samples/cycle for as many as 64 power system cycles, approximately 1 s. Use the event report to move the oscillographic data to your PC. You can plot your event report data with the SEL-5601 ACSELERATOR Analytic Assistant® Software or with Microsoft® Excel®.

Event reports contain ac currents, ac voltages, and digital inputs and outputs. The report automatically adjusts content to the I/O cards you use. Reports are stored in nonvolatile memory to protect your data even if power is lost. Event reports are optimized for recording power disturbances and relating them to your process.

Set the report to capture either 15 or 64 power system cycles of data around the trigger event. For a 60 Hz system, the event report lengths are 0.25 seconds and 1.07 seconds. For a 50 Hz system, the report lengths are 0.30 seconds and 1.28 seconds.

Trend Transformer Temperatures and Other Analog Inputs

Record measured ambient, transformer top-oil, transformer hot-spot and other analog data (measured or calculated) for trending with the Analog Signal Profile function. This profile (trending) function can track as many as 32 analog channels. The function records the magnitude and time of acquisition of each analog channel. Use the profile report to move trend records to your PC and quickly plot the data with Microsoft Excel or any other spreadsheet application.

Transformer Thermal Monitoring

Transformer thermal modeling per IEEE C57.91-1995 for mineral-oil immersed transformers is a standard feature in the SEL-2414. Specify the SEL-2414 to provide this capability for monitoring and protection of a single three-phase transformer, a three-phase transformer with tertiary windings (three-winding mode with separate CT ratios), or three independent single-phase units. Use the thermal element to activate a control action or issue a warning or alarm when your transformer overheats or is in danger of excessive insulation aging or loss-of-life.
Use the thermal event report to capture current hourly and daily data about your transformer. Operating temperature calculations are based on load currents, type of cooling system, and actual temperature inputs (ambient and top-oil). Use as many as four thermal sensor inputs: a single ambient temperature transducer and one transducer for top-oil temperature from each of three single-phase transformers. Temperature data are obtained via an internal RTD/thermocouple card or from an external SEL-2600A RTD Module. While the SEL-2414 can receive temperature data at any rate, the thermal element uses the temperature data once per minute.

The thermal element operates in one of three modes, depending upon the presence or lack of measured temperature inputs: 1) measured ambient and top-oil temperature inputs, 2) measured ambient temperature only, and 3) no measured temperature inputs. If the device receives measured ambient and top-oil temperatures, the thermal element calculates hot-spot temperature. When the device receives a measurement of ambient temperature without top-oil temperature, the thermal element calculates the top-oil temperature and hot-spot temperature. In the absence of any measured ambient or top-oil temperatures, the thermal element uses a default ambient temperature setting that you select and calculates the top-oil and hot-spot temperatures. The device uses hot-spot temperature as a basis for calculating the insulation aging acceleration factor (FAA) and loss-of-life quantities. Use the thermal element to indicate alarm conditions and/or activate control actions when one or more of the following exceed settable limits:

- Top-oil temperature
- Winding hot-spot temperature
- Insulation aging acceleration factor (FAA)
- Daily loss-of-life
- Total loss-of-life

Generate a thermal monitor report that indicates the present thermal status of the transformer. Historical thermal event reports and profile data are stored in the device in hourly format for the previous 24 hours and in daily format for the previous 31 days.

The thermal model can be used even if a current card is not installed. Current magnitude data can be received by IEC 61850 or other communications protocols.

**Through-Fault Event Monitor**

A through fault is an overcurrent event external to the differential protection zone. Though a through fault is not an in-zone event, the currents required to feed this external fault can cause great stress on the apparatus inside the differential protection zone. Through-fault currents can cause transformer winding displacement leading to mechanical damage and increased transformer thermal wear because of mechanical stress of insulation components in the transformer. The SEL-2414 through-fault event monitor gathers current level, duration, and date/time for each through fault. The monitor also calculates a \( I^2t \) and cumulatively stores these data per-phase.

The SEL-2414 through-fault report also provides percent of total through-fault accumulated according to the *IEEE Guide for Liquid-Immersed Transformer Through-Fault-Current Duration, C57.109-1993*. Use through-fault event data to schedule proactive transformer bank maintenance and help justify through-fault mitigation efforts. Apply the accumulated \( I^2t \) alarm capability of the device to indicate excess through-fault current over time.

**Simplify Your Transformer Commissioning**

The SEL-2414 front panel simplifies commissioning and troubleshooting:

- View field data and calculated values
- Diagnose data flow problems in seconds instead of hours
- Dramatically reduce troubleshooting time
- Eliminate the need for out-of-service time
Front-Panel Visualization and Control

Build your own custom displays. Rotating displays show device measurements and settings information based on user-configured display points.

Access device configuration, detailed I/O status, alarms, and measured values with easy-to-use controls for operator interface.

Program LEDs to indicate control state

Program 4 pushbuttons to perform direct user controls

Make your own labels by hand or with included Microsoft® Word template

Figure 10  Simplify Your Commissioning
Configuration and Commissioning Software

The included ACSELERATOR QuickSet software program simplifies device configuration in addition to providing commissioning and analysis support for the SEL-2414.

➤ Access settings creation help online.
➤ Organize settings with the device database manager.
➤ Load and retrieve settings using a simple PC communications link.
➤ Analyze event records with the integrated waveform and harmonic analysis tool.

➤ Use the PC interface to remotely retrieve reports and other system data.
➤ Monitor analog data, device I/O, and logic point status during commissioning tests.
➤ Remotely operate and monitor using the device overview as a virtual front panel.

Settings–Develop Settings Offline With an Intelligent Settings Editor That Only Allows Valid Settings.

Settings–Create SELOGIC Control Equations With a Drag and Drop Editor and/or Text Editor.

HMI–Device Overview.
The SEL-2414 provides extensive metering capabilities. See Specifications for metering and power measurement accuracies. As shown in Table 1, metering includes current and voltage based metering and analog input, math variable, and remote analog metering. Fundamental, maximum and minimum, and demand metering typically includes phase voltages and currents; sequence voltages and currents; and power, frequency, and energy.

<table>
<thead>
<tr>
<th>Table 1 Metering Types</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard</strong></td>
</tr>
<tr>
<td>Fundamental</td>
</tr>
<tr>
<td>Energy</td>
</tr>
<tr>
<td>Maximum and Minimum</td>
</tr>
<tr>
<td>Demand and Peak Demand</td>
</tr>
<tr>
<td>Analog Input</td>
</tr>
<tr>
<td>Math Variable</td>
</tr>
<tr>
<td>Remote Analog</td>
</tr>
<tr>
<td>Analog Signal Profiling</td>
</tr>
<tr>
<td><strong>Optional</strong></td>
</tr>
<tr>
<td>Temperature and thermal</td>
</tr>
<tr>
<td>Maximum and Minimum Temperatures</td>
</tr>
</tbody>
</table>

### Additional Ordering Options

The following options can be ordered for any SEL-2414 model (see the SEL-2414 Model Option Table for details):

| Digital I/Oa | 8 DI (PN 9760), 8 DO (PN9761), 4 DI/4 DO (PN 9764), 4 DI/3 DO with 2 Form C and 1 Form B (PN 9773) |
| Analog I/O   | 8 AI (PN9762), 4 AI/4 AO (PN 9763) |
| Temperatures | 10 RTDs (PN 9772) |
| CTs and PTs  | 3 ACI/3 AVI (PN 9771), 4CT (PN 9770), 3 AVI (PN 9769) |
| Port 1       | Single/Dual 10/100BASE-T copper (RJ45 connector) Single/Dual 100BASE FX (LC connector) |
| Port 2       | Fiber-Optic Port (62.5 µm core fiber, ST connectors, SEL-2812 compatible) |
| Port 4       | EIA-232 or EIA-485 (PN 9751) |
| Protocols    | Serial: DNP3; Ethernet: Modbus TCP, DNP3 LAN/WAN, FTP, Telnet, IEC 61850 |
| Mounting     | Surface Mounting kit for in-cabinet installation (PN 915900204) |
| Environment  | Conformal coating for chemically harsh and high-moisture environments |

a Unless otherwise specified, all digital outputs are Form A.
Automation

Flexible Control Logic and Integration Features

The SEL-2414 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, one fiber-optic port, and one EIA-232 or EIA-485 port option card. The device does not require special communications software. Use any system that emulates a standard terminal system for engineering access to the device. Establish communication by connecting computers, modems, protocol converters, printers, an SEL communications processor, SCADA serial port, and an RTU for local or remote communication. 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-2414. Included communications protocols are listed below.

Standard Protocols

- Modbus RTU
- SEL ASCII
- SEL Compressed ASCII
- SEL Fast Meter
- SEL Fast Operate
- SEL Fast SER
- SEL Fast Message
- SEL MIRRORED BITS

SEL-2414 logic improves integration in the following ways.

Replaces Traditional Panel Control Switches

Eliminate traditional panel control switches with operator control pushbuttons or the 32 local bits, available through the menu system. Program the four conveniently sized operator pushbuttons to control fan banks and fan lockout. 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 breaker trip/close.

Replaces Traditional Indicating Panel Lights

Replace traditional indicating panel lights with 32 programmable displays. Define custom messages (e.g., Fan On, Fan Off) to report transformer or device conditions on the front-panel display. Use advanced SELOGIC control equations to control which messages the device displays. Figure 11 shows an example.

Replaces Traditional Temperature Gauges

Replace traditional temperature gauges that show the temperature, and the maximum and minimum temperature since last reset. The SEL-2414 Max/Min metering records and time stamps the maximum and minimum temperatures and transformer thermal model quantities.

Replaces Traditional Latching Relays

Replace as many as 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 device loses power.

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 control scheme logic.

Eliminates RTU-to-Device Wiring

Eliminate RTU-to-Device 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 and close.

Define custom messages to report station or device conditions with user-configured display points.

Figure 11 Define Custom Messages to Report Station or Device Conditions
**Communications Architectures**

**Figure 12** Typical Ethernet and EIA-485 Communications Architectures

**Figure 13** Typical EIA-232 and Fiber-Optic Communications Architecture
Front- and Rear-Panel Diagrams

Figure 14  Front Panel With Default Configurable Labels

Figure 15  Rear-Panel Connections and Labels
Dimensions

Figure 16  SEL-2414 Panel-Mount

Figure 17  SEL-2414 Surface-Mount Dimensions

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

UL, cUL:  UL 508, CSA C22.2 No. 142
CSA:  CSA C22.2 No. 61010-1
CE Mark:  EMC Directive
Low-Voltage Directive
Hazardous Locations:  Complies with UL 1604, CSA 22.2
Approvals:  No. 213, and EN 60079-15.

General

Operating Temperature Range

–40° to +85°C (–40° to +185°F), per IEC 60068-2-1 and 60068-2-2.
Note: LCD contrast impaired for temperatures below –20°C and above +70°C (–4°F and +158°F, respectively).

UL/CSA Conformal Coated:  –40° to +75°C (–40° to +167°F)

Operating Environment

Pollution Degree:  2
Overvoltage Category:  II
Relative Humidity:  5–95%, noncondensing
Maximum Altitude:  2000 m

Dimensions

See Figure 16 and Figure 17.

Weight

2.0 kg (4.4 lb)

Frequency

System Frequency:  50, 60 Hz

Inputs

AC Current Input Phase

<table>
<thead>
<tr>
<th>$I_{\text{nom}}$</th>
<th>$I_{\text{nom}} = 5 , \text{A}$</th>
<th>$I_{\text{nom}} = 1 , \text{A}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Range</td>
<td>0.1–96.0 A</td>
<td>0.02–19.20 A</td>
</tr>
<tr>
<td></td>
<td>(according to IEC 60255-5, 60664-1)</td>
<td></td>
</tr>
</tbody>
</table>
Note: This is a linearity specification and is not meant to imply continuous operation.

Continuous Thermal Rating:
- 15 A
- 3 A
  (according to IEC 60255-6, IEEE C37.90-1989)
- 500 A
- 100 A
  (according to IEC 60255-6)

1 Second Thermal:
- 500 A
- 100 A
  (according to IEC 60255-6)

Rated Frequency:
- 50/60 ±5 Hz
- 50/60 ±5 Hz

Burden (per phase):
- <0.050 VA
- <0.002 VA

Measurement Category: II

AC Current Input Neutral

<table>
<thead>
<tr>
<th>I_{nom}</th>
<th>\text{I}_{nom} = 5 \hspace{1em} A</th>
<th>\text{I}_{nom} = 1 \hspace{1em} A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Range:</td>
<td>0.05–10.00 A</td>
<td>0.01–2.00 A</td>
</tr>
</tbody>
</table>

Note: This is a linearity specification and is not meant to imply continuous operation.

Continuous Thermal Rating:
- 15 A
- 3 A
  (according to IEC 60255-6, IEEE C37.90-1989)
- 500 A
- 100 A
  (according to IEC 60255-6)

1 Second Thermal:
- 500 A
- 100 A
  (according to IEC 60255-6)

Rated Frequency:
- 50/60 ±5 Hz
- 50/60 ±5 Hz

Burden (per phase):
- <0.1 VA
- <0.01 VA

Measurement Category: II

AC Voltage Input (300 V)

Rated Operating Voltage (U_e):
- 100–250 Vac

Rated Insulation Voltage:
- 300 Vac

10-Second Thermal:
- 600 Vac

Rated Frequency:
- 50/60 ±5 Hz

Burden:
- <0.1 W

DC Transducer (Analog) Inputs

Input Impedance:
- Current Mode: 200 Ω
- Voltage Mode: >10 kΩ

Input Range (Maximum):
- Current Mode: ±20 mA
- Voltage Mode: ±10 V

Sampling Rate: At least 5 ms

Step Response: 1 s

Accuracy at 25°C:
- ADC: 16 bit
- With user calibration: 0.05% of full scale (current mode)
- 0.025% of full scale (voltage mode)
- Without calibration: Better than 0.5% of full scale at 25°C

Accuracy Variation With Temperature:
- ±0.015% per °C of full scale (±10 V)

CMRR (typical): 100 dBv

Noise Rejection: Up to 1 Vrms 50/60 Hz

RTD Input Card

Number of Channels: Ten 3-wire RTDs

Input Type: 100 Ω platinum (PT100)

Supports the following RTD types on each independent input:
- 100 Ω nickel (NI100)
- 120 Ω nickel (NI120)
- 10 Ω copper (CU10)

Measuring Range:
- RTDs: –50° to 250°C
- Thermocouples (TCs):
  - J: –200° to 1200°C
  - K: –200° to 1370°C
  - T: –200° to 400°C
  - E: –200° to 950°C

ADC Resolution: 24 bit

Accuracy:
- CU10: ±0.1°C typical at 25°C
- PT100, NI100, NI120: ±0.1°C typical at 25°C
- CU10, PT100, NI100, NI120: ±2°C worst case

Universal Temperature Input Card

Number of Channels: Ten (thermocouples or 3-wire RTDs)

Input Type: 100 Ω platinum (PT100)

Supports the following RTD or TC types on each independent input:
- 100 Ω nickel (NI100)
- 120 Ω nickel (NI120)
- 10 Ω copper (CU10)

Measuring Range:
- RTDs: –50° to 250°C
- Thermocouples (TCs):
  - J: –200° to 1200°C
  - K: –200° to 1370°C
  - T: –200° to 400°C
  - E: –200° to 950°C

ADC Resolution: 24 bit

Accuracy:
- CU10: ±1°C typical at 25°C
- PT100, NI100, NI120: ±1°C typical at 25°C
- CU10, PT100, NI100, NI120: ±2°C worst case
TCs
J, K, T, E: ±1°C with field calibration
±3°C without field calibration
Resolution: ±0.1°C
Update Rate: < 3 s
CMRR (typical): 100 dBv
Noise Rejection: Up to 1 V rms 50/60 Hz
Isolation
Number of Banks: Two Banks (5 channels each)
Max. Working
Common Mode: 250 Vdc
Cold Junction
Compensation: Automatic

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
Accuracy: ±3 milliseconds

Time-Code Input (SNTP)
High-Priority Server
Accuracy: ±5 ms
Accuracy: ±25 ms

Outputs
General
OUT103 is Form C Trip Output, all other outputs are Form A.
Dielectric Test Voltage: 2000 Vac
Impulse Withstand Voltage ($U_{imp}$): 4000 V
Mechanical Durability: 10M no load operations

DC Output Ratings
Electromechanical
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; 4 A @ 85°C
Continuous Carry (UL/CSA Derating with All Outputs Asserted): 5 A @ < 60°C; 2.5 A 60 to 70°C
Thermal: 50 A for 1 s
Contact Protection: 360 Vdc, 40 J MOV protection across open contacts
Operating Time (coil energization to contact closure, resistive load): Pickup or Dropout time ≤ 8 ms typical
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 Capacity (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
Fast Hybrid (high-speed high current interrupting)
Make: 30 A
Carry: 6 A continuous carry at 70°C
1 s Rating: 50 A
MOV Protection (maximum voltage): 250 Vac/330 Vdc

Skin-2414 Data Sheet
Analog Outputs
- Current Ranges (Max): ±20 mA
- Voltage Ranges (Max): ±10 V
- Output Impedance For Current Outputs: ≥100 kΩ
- Output Impedance For Voltage Outputs: ≤ 20 Ω
- Maximum Load: 0–750 Ω current mode
  >2kΩ voltage mode
- Accuracy: ±0.55% of full scale at 25°C
- Step Response: 100 ms

Communications
- Communications Ports
  Standard EIA-232 (2 ports)
  - Location (fixed): Front Panel
  - Rear Panel
  - Data Speed: 300–38400 bps
  - Optional Ethernet port:
    Single/Dual 10/100BASE-T copper (RJ45 connector)
    Single/Dual 100BASE FX Multimode (LC connector)
  - Optional multimode fiber-optic serial port:
    Class I LED product

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: 50–200 µm
  - Approximate Range: ~6.4 Km
  - Data Rate: 100 Mb
  - Typical Fiber Attenuation: –2 dB/Km
- Port 2 Serial
  - Wavelength: 850 nm
  - Optical Connector Type: ST
  - Fiber Type: Multimode
  - Link Budget: 8 dB
  - Typical TX Power: –16 dBm
  - RX Min. Sensitivity: –24 dBm
  - Fiber Size: 50–200 µm
  - Approximate Range: ~4 Km with 62.5 µm,
    ~1 Km with 200 µm
  - Data Rate: 5 Mb
  - Typical Fiber Attenuation: –4 dB/Km

Optional Communications Card
- Standard EIA-232 or EIA-485 (ordering option)
- Data Speed: 300–38400 bps

Communications Protocols
- Modbus® RTU slave or Modbus TCP
- DNP3 Level 2 Outstation (LAN/WAN and Serial)
- IEC 61850 Communications
- Ethernet FTP
- Telnet
- SEL MIRRORED BITS (MBA, MBB, MB8A, MB8B, MBTB)
- Ymodem file transfer on the front and rear port
- Xmodem file transfer on the front port
- SEL ASCII and Compressed ASCII
- SEL Fast Meter
- SEL Fast Operate
- SEL Fast SER
- SEL Fast Message unsolicited write
- SEL Fast Message read request
- SEL Event Messenger Points

Maximum Concurrent Connections
- Modbus Slave: 1
- DNP3 Level 2 Outstation: 3
- Ethernet FTP: 2
- Telnet: 2
  * Maximum in any combination of serial and/or LAN/WAN links.

Power Supply
- Rated Supply Voltage
  - Low-Voltage Model: 24/48 Vdc
  - High-Voltage Model: 110/250 Vdc
    110/230 Vac, 50/60 Hz
- Input Voltage Range
  - Low-Voltage Model: 18–60 Vdc
  - High-Voltage Model: 85–275 Vdc
    85–264 Vac
- Power Consumption
  - AC: <40 VA
  - DC: <15 W

Interruptions
- Low-Voltage Model: 10 ms @ 24 Vdc
  50 ms @ 48 Vdc
- High-Voltage Model: 50 ms @ 125 Vac/Vdc
  100 ms @ 250 Vac/Vdc

AC Metering Accuracies
- Current
  - Phase Current: ±0.5% typical, 25°C, 60 Hz, nominal current
  - Neutral Current: ±0.5% typical, 25°C, 60 Hz, nominal current
  - Negative Sequence (3I2): ±0.5% typical, 25°C, 60 Hz, nominal current (calculated)
  - Residual Ground Current: ±0.5% typical, 25°C, 60 Hz, nominal current (calculated)
- Voltage
  - Line-to-Neutral Voltage: ±0.08% typical, 25°C, 60 Hz, nominal voltage
  - Line-to-Line Voltage: ±0.08% typical, 25°C, 60 Hz, nominal voltage
  - Negative-Sequence (3V2): ±0.5% typical, 25°C, 60 Hz, nominal voltage (calculated)
**Power**

Three-Phase Real Power (kW): ±1% typical, 25°C, 60 Hz, nominal voltage and current with 0.10 to 1.00 power factor

Three-Phase Reactive Power (kVAR): ±1% typical, 25°C, 60 Hz, nominal voltage and current with 0.00 to 0.90 power factor

Three-Phase Apparent Power (kVA): ±1% typical, 25°C, 60 Hz, nominal voltage and current

**Power Factor**

Three-Phase (wye connected): ±1% typical, 25°C, 60 Hz, nominal voltage and current (between 0.97 and 1)

**Sampling and Processing Specifications**

**Without Voltage Card or Current Card**

<table>
<thead>
<tr>
<th>Analog Inputs</th>
<th>Digital Inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling Rate: Every 4 ms</td>
<td>Sampling Rate: 2 kHz</td>
</tr>
<tr>
<td>Digital Inputs</td>
<td>Contact Outputs</td>
</tr>
<tr>
<td>Refresh Rate: 2 kHz</td>
<td>Logic Update: Every 4 ms</td>
</tr>
<tr>
<td>Analog Outputs</td>
<td>Refesh Rate: Every 4 ms</td>
</tr>
<tr>
<td>New Value: Every 100 ms</td>
<td>Timer Accuracy: ±0.5% of settings and ±4 ms</td>
</tr>
</tbody>
</table>

**With Either Voltage Card, Current Card, or Both Voltage and Current Cards**

<table>
<thead>
<tr>
<th>Analog Inputs</th>
<th>Digital Inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling Rate: 4 times/cycle</td>
<td>Sampling Rate: 32 times/cycle</td>
</tr>
<tr>
<td>Digital Inputs</td>
<td>Contact Outputs</td>
</tr>
<tr>
<td>Refresh Rate: 32 times/cycle</td>
<td>Logic Update: 4 times/cycle</td>
</tr>
<tr>
<td>Analog Outputs</td>
<td>Refesh Rate: 4 times/cycle</td>
</tr>
<tr>
<td>New Value: Every 100 ms</td>
<td>Timer Accuracy: ±0.5% of settings and ±1/4 cycle</td>
</tr>
</tbody>
</table>

**Processing Specifications**

- AC Voltage and Current Inputs: 16 samples per power system cycle
- Frequency Tracking Range: 44–66 Hz
- Digital Filtering: Cycle cosine after low-pass analog filtering. Net filtering (analog plus digital) rejects dc and all harmonics greater than the fundamental.
- Control Processing: 4 times per power system cycle or 4 ms if no current or voltage card (except for math variables and analog signals used in logic, which are processed every 100 ms)

**Type Tests**

**Environmental Tests**

<table>
<thead>
<tr>
<th>IP Code:</th>
<th>IEC 60529:2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibration:</td>
<td>IEC 60255-21-1:1988, Class 1</td>
</tr>
<tr>
<td>Cold:</td>
<td>IEC 60068-2-1:1993, Class 2</td>
</tr>
<tr>
<td>Damp Heat, Cyclic:</td>
<td>IEC 60255-21-2:1988, Class 1</td>
</tr>
<tr>
<td>Dry Heat:</td>
<td>IEC 60068-2-1:2007</td>
</tr>
</tbody>
</table>

**Dielectric Strength and Impulse Tests**

<table>
<thead>
<tr>
<th>Dielectric Strength:</th>
<th>IEC 60255-5:2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiated RF Immunity:</td>
<td>IEEE C37.90-2005</td>
</tr>
</tbody>
</table>

**RFI and Interference Tests**

| Radiated RF Immunity: | IEEE C37.90-2004, 35 V/m |
| Electrostatic Discharge Immunity: | IEEE C37.90-2004, 35 V/m |
| Radiated RF Immunity: | IEEE C37.90-2004, 35 V/m |
| Fast Transient, Burst Immunity: | IEEE C37.90-2004, 35 V/m |

**IP Code:**

- IEC 60529:2001
- IP34
- IEC 60255-21-2:1988, Class 1
- IEC 60068-2-1:2007
- 25–35°C, 6 cycles, 95% relative humidity
- IEC 60068-2-2:2007
- 85°C, 16 hours

**Dielectric Strength:**

- IEC 60255-5:2000
- IEEE C37.90-2005
- 2.5 kVac on analog inputs, contact I/O
- 3.1 kVdc on power supply and analog outputs

**Impulse:**

- IEC 60255-5:2000
- 0.5 J, 5.0 kV

**Dielectric Strength:**

- IEC 60255-5:2000
- IEEE C37.90-2005
- 2.5 kVac on analog inputs, contact I/O
- 3.1 kVdc on power supply and analog outputs

**Impulse:**

- IEC 60255-5:2000
- 0.5 J, 5.0 kV
IEC 61000-4-5:2005
2 kV line-to-line
4 kV line-to-earth

2.5 kV common-mode
1.0 kV differential-mode
IEEE C37.90.1-2002,
2.5 kV oscillatory, 4 kV fast transient

Conducted RF Immunity: IEC 60255-22-6:2001, 10 Vrms
IEC 61000-4-6:2006, 10 Vrms

Magnetic Field Immunity:
IEC 61000-4-8:2009
1000 A/m for 3 seconds
100 A/m for 1 minute

EMC Emissions
Conducted Emissions: IEC 60255-25:2000, Class A
Radiated Emissions: IEC 60255-25:2000, Class A