CHOOSING BETWEEN COMMUNICATIONS PROCESSORS, RTUS, AND PLCS AS SUBSTATION AUTOMATION CONTROLLERS

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SEL WHITE PAPER

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INTRODUCTION

Communications processors, RTUs, and PLCs are used as integration and automation controllers around the world. In order to appreciate the differences, it is appropriate to consider all aspects of integration and automation needs within the power system.

SYSTEM AUTOMATION AND SYSTEM INTEGRATION

System automation is the control of power system apparatus operations to take the place of the human functions of observation, decision, and action. Substation automation refers to using intelligent electronic device (IED) data within the substation and control commands from remote users to control the power system devices within the substation.

System integration is the act of communicating data to, from, or between IEDs in the Instrumentation and Control (I&C) system and remote users. Substation integration refers to combining data from the IEDs that are local to a substation so there is a single point of contact in the substation for all of the I&C data. Remote and local substation control is then mediated by this single point of contact. Since true substation automation relies on substation integration, the terms are often used interchangeably. There is often a need for multiple single points of contact to serve multiple user connections or provide redundancy. The single point of contact is an I&C device acting as a client/server, programmable logic platform, gateway, router, dial-out device, communication switch, time synchronization broadcaster, or a combination of these.

SUBSTATION CONTROLLER

Products from many industries are used to perform substation automation: RTUs, port switches, meters, bay modules, and protocol gateways from the SCADA industry; PLCs from the process control industry, relays and communications processors from the protection industry, and PCs from the office environment.

Substation controller and bay controller are terms commonly used to refer to devices that perform data acquisition and control of IEDs and contain local I/O. The communications processor is the only substation controller that can perform all of the substation automation tasks. The communications processor is also the only device that is designed to meet the same harsh environmental conditions as the relays themselves. SCADA and process control industry products are not designed to meet these environmental standards.

Table 1 presents the system integration and automation functions required in a substation. Comparison is made of substation controller devices often used in substation automation and the functions that each device commonly performs.

Table 1: Substation Automation Device Comparison

	Communications Processor	RTU	Bay Module	PLC	PC	Port Switch	Satellite Clock
Client/Server for Dynamic Data	✓	✓	✓	✓	✓		
Client/Server for Archived Data (File Transfer to IEDs)	✓				✓		
Data Concentrator	✓	✓	✓	✓	✓		
Message Broker	✓						
Programmable Logic Platform	✓	✓	✓	✓	✓		
Protocol Gateway	✓	✓	✓	✓	✓		
Router	✓				✓		
Dial-Out	✓				✓		
Communication Switch (Virtual Terminal and File Transfer to IEDs)	✓				✓	✓	
Time Synchronization Broadcast < 10 milliseconds accuracy	✓						✓
Local I/O	✓	✓	✓	✓			
Emulate Protocol Messaging	✓				✓		
Eavesdrop Communications	✓						
Autoconfiguration	✓						
Device-Level SER	✓	✓	✓	✓			
Station-Level SER	✓						
Tier-to-Tier	✓			✓	✓		
Peer-to-Peer	✓			✓	✓		
Substation-Hardened Design	✓					✓	✓

Client/Server for Dynamic Data

The communications industry uses the term client/server for a device that acts as a master, or client, retrieving data from some devices and then acts as a slave, or server, sending this data to other devices. The client/server for dynamic data collects and forwards data frequently based on the master poll rate or by exception. These data include protection data, metering data, automation data, control data, and supervisory data.

Client/Server for Archived Data

A substation archive client/server collects and archives historical data from several devices. These data include system profiles, event reports, sequential events recorder (SER) reports, power quality reports, and protection quality reports; they provide a clear picture of system performance. The user retrieves data when it is convenient to do so.

Data Concentrator

A data concentrator creates a substation database by collecting and concentrating dynamic data from several devices. In this fashion, essential subsets of data from many IEDs are forwarded to a master through one data transfer. The data concentrator database passes data from one IED to another when they are not connected peer-to-peer.

Message Broker

A message broker collects and stores entire messages from several sources. Rather than extract and concentrate only a subset of the data, the message broker collects the entire message including header, content, and error check terminator. The message broker then acts as an agent for the message by negotiating where and when to send the message. In this fashion, an entire message can be exchanged between two devices that cannot be directly or transparently connected.

Programmable Logic Platform

A programmable logic platform executes custom automation logic equations. The SEL communications processor and SEL relays work together to perform innovative automation using functionality that SEL develops in the products. RTUs and PLCs have little or no default automation capability. Therefore, RTUs and PLCs support more flexible programmability so the end user can create necessary automation from the ground up.

Protocol Gateway

A gateway converts conversations from one protocol, or communication language, to another. Often RTUs or PLCs are used for the sole purpose of acting as a gateway between substation data and a legacy SCADA or EMS protocol.

Router

Router is another term from the communications industry that refers to a device that routes data in transit between source and destination. The router intelligently transmits messages received on one communications port out another communications port. The destination port for the message is dynamically determined via the content of the message. This is used to efficiently route SER and other messages through multiple substation controllers without affecting substation automation.

Dial-Out

A dial-out device initiates conversations or triggers paging from the substation to a remote user. Uses for dial-out include ensuring connection security, eliminating the need for a dedicated communications connection, and performing unsolicited indication of a disturbance with fault location.

Communications Switch

A communications switch is the single point of contact for remote users to dial in and make a direct connection to all substation IEDs individually. A single communications connection from inside or outside the substation is switched between several IEDs. The user initiates a dynamic conversation with a specific IED and the port switch merely “passes through” the conversation.

Time Synchronization Broadcast

In order to synchronize IED clocks, a device in the substation needs to generate, or acquire from an external source, a time value and then broadcast it to the IEDs. Millisecond accuracy and repetitive synchronization are necessary.

Local I/O

Substation controllers often make use of the I/O within connected IEDs. They also support local I/O terminated at the substation controller for automation and alarm functions.

Eavesdrop Communications

Eavesdrop communications refers to monitoring a conversation between two devices in the I&C system, and capturing and storing the transferred data. This is useful for extracting information without influencing the flow of data between devices that may not have an available communications interface for integration.

Emulate Protocol Messaging with Settings, not Code

When choosing the best new and in-service devices to create a successful I&C system, it is often necessary to select from multiple vendors and also multiple vintages or generations of products. Many of these devices employ proprietary communications and interfaces. Most substation controllers must have embedded software written specifically to communicate via proprietary interfaces. The SEL communications processors can communicate most relay protocols, or communications languages, without developing vendor-specific protocol software for each type of relay installed. Instead, through database settings, pertinent subsets of these protocols are communicated to the relay from the SEL communications processor for data acquisition and control.

Autoconfiguration

Some substation controllers simplify implementation through autoconfiguration. This process automatically determines the proper baud rate to communicate with the connected IED as well as start-up parameters, device type, and capabilities.

Device-Level SER

A device-level SER application creates and stores event data with a time stamp. Predefined input contacts and logic elements are monitored as the source of event records. The SER associates a time of occurrence with each event and stores these data in a buffer. It forwards these data in order of event occurrence in an unsolicited fashion and/or in response to a request.

Station-Level SER

A station-level SER application creates and stores event data with a time stamp for local inputs. It also collects and stores SER messages from other IEDs in the station in an unsolicited fashion and/or in response to a request. The local SER messages and the SER messages from the other IEDs are stored in a buffer and organized in order of occurrence. The station SER data are also forwarded in order of event occurrence in an unsolicited fashion and/or in response to a request.

Tier-to-Tier / Peer-to-Peer

Some substation controllers accommodate substations of varying size as well as redundant designs by supporting peer-to-peer and tier-to-tier functionality. Peer-to-peer refers to the direct transfer of data between devices functioning in a similar capacity. Tier-to-tier refers to devices that can transfer data while connected in such a way that one is the client and the other the server.

Substation Hardened

The inverse of the failure rate of a device, or mean time between failure (MTBF), compares the reliability of devices. Most devices that were traditionally used for automation in the past, such as RTUs and PLCs, were designed to be operated in controlled environments like control rooms and generation facilities. The average MTBF of RTUs and PLCs is 11 and 17 years respectively. This low MTBF reflects a design philosophy based on frequent replacement and maintenance. Protection devices are designed to be more reliable, fail less frequently, be in service longer, and cost less to maintain than PLCs and RTUs. The device MTBF can be used to predict how available an automation system will be and how frequently the maintenance staff will be replacing failed devices.

Table 2 lists unavailabilities of common I&C system devices that were calculated using MTBF values and averages from publicly available sources, such as vendor publications, and studies performed in the workplace.

Table 2: Approximate Availabilities of Devices

Device	Availability	Annual Downtime
Personal Computer	99.787 %	1122 minutes
Leased Telephone Line	99.900 %	526 minutes
Medium Remote Terminal Unit	99.952 %	252 minutes
Industrial Personal Computer	99.961 %	202 minutes
Programmable Logic Controller	99.968 %	168 minutes
Circuit Breaker	99.970 %	158 minutes
Transducer	99.992 %	42 minutes
Protective Relay (Industry Average)	99.995 %	29 minutes
DC Power System	99.995 %	26 minutes
Modem	99.997 %	16 minutes

Substation Communications Processor (SEL)	99.997 %	16 minutes
Protective Relay (SEL)	99.997 %	14 minutes
Simple Fiber-Optic Transceiver	99.999 %	5 minutes
Current Transformer (per phase)	99.999 %	5 minutes
Voltage Transformer (per phase)	99.999 %	5 minutes

Fault tree analysis is a tool that compares the reliability of systems. These values are used to compare availability, downtime, and maintainability of systems. Comparison of different I&C designs, for a 54-breaker substation, yields the results shown in Table 3.

Table 3: Reliability Comparison for Station With 54 Breakers

Substation Design	Nonredundant		Redundant	
	Unavailability	Availability	Unavailability	Availability
RTU Centric	$15{,}490 \times 10^{-6}$	98.45 %	240×10^{-6}	99.98 %
PLC Centric	$16{,}410 \times 10^{-6}$	98.35 %	269×10^{-6}	99.97 %
Multidropped Microprocessor Relays	$7{,}158 \times 10^{-6}$	99.28 %	$3{,}427 \times 10^{-6}$	99.66 %
Communications Processor Star to Microprocessor Relays	$4{,}150 \times 10^{-6}$	99.59 %	11×10^{-6}	99.999 %

Unavailability can be expressed in a simpler way, demonstrating the expected amount of time throughout the year that a system will be unable to perform its function. This value, "annual downtime," demonstrates the expected risk of different designs. Should a fault occur during the period of unavailability, the system will not be available for protection or control. Table 4 lists annual downtime calculations of several substation designs.

Maintainability analysis is a tool that estimates the cost of servicing systems to perform repair or replacement maintenance. This tool does not estimate the cost of preventative maintenance that may be recommended by the equipment manufacturer. The inverse of the MTBF for a device predicts the number of times per year the device may fail. The annual failure rate times the total number of devices predicts the total failures per year. The total of failures per maintenance period is the total annual failure rate times the number of years in the maintenance period being evaluated. The cost of each failure is the cost of repairing or replacing nonwarranty equipment plus the labor. Total failure maintenance cost is the sum of device failure costs for each type of device in the system.

Comparison of different I&C designs, for a 54-breaker substation, yields the results shown in Table 4.

Table 4: Maintainability Comparison for Station with 54 Breakers

Substation Design	Non-Redundant		Redundant	
	Five-Year Failure Maintenance budget	Annual Downtime	Five-Year Failure Maintenance Budget	Annual Downtime
RTU Centric	109 hrs	8,142 min	217 hrs	126 min
PLC Centric	121 hrs	8,625 min	243 hrs	141 min
Multidropped Microprocessor Relays	71 hrs	3,762 min	176 hrs	1,801 min
Communications Processor Star to Microprocessor Relays	67 hrs	2,181 min	110 hrs	6 min

INSTRUMENTATION AND CONTROL I/O PHILOSOPHY

Innovative integration developments within multifunction microprocessor-based relays and other IEDs have created new ways of collecting and reacting to data and using these data to create usable information. Power providers are facing demands to increase productivity and reduce costs that translate into the need to collect and act on reliable, available, decision-making information. When integrated together, relays and IEDs become a powerful, economical, and streamlined I&C system, capable of supporting all aspects of electric power protection, automation, control, monitoring, and analysis. In an SEL system, IEDs are connected to SEL communications processors using the star topology. This star topology is the basic building block used around the world for integrating SEL and non-SEL IEDs. Several of these building blocks together form large complete substation integration systems. The SEL system provides existing and expanded SCADA data collection and control, protection, automation, and monitoring functionality to new and retrofit stations. Therefore the system I/O possibilities are endless because you can connect two or more SEL communications processors together, allowing them to share I/O. Each one has local I/O, and you can connect SEL relays and other IEDs to the SEL communications processors providing further I/O. SEL communications processors can communicate with more than 80 other vendor IEDs (list available), demonstrating their ability to communicate with non-SEL devices.

SCADA, EMS, and other masters scan the SEL communications processor for analog data (including AMPS, MW, MVAR, kV, tap positions, and phase angles, etc.) and for alarms and status indication data (including circuit breaker, recloser and MOD status, alarm indication, back-feed indication, etc.). These masters communicate commanded control to the SEL communications processors to operate substation equipment (opening and closing circuit breakers, reclosers, MODs, and other switches; raising and lowering tap changers). The SEL system provides both initial and future SCADA requirements. Use spare contacts on system IEDs for future status or control needs. The system easily supports the addition of more IEDs as future requirements are identified. These masters collect metering, status, and historical records to be provided to databases that capture and store substation information. SELOGIC® control equations within the SEL relays and SEL communications processors perform programmed control of substation devices.

SEL relays are available with high-current interrupting output contacts. These contacts are rated at:

6 A continuous carry
30 A make per IEEE C37.90:1989
330 Vdc MOV for differential surge protection
Breaking Capacity 10 A 10,000 operations
48 and 125 V L/R = 40 ms
250 V L/R = 20 ms
Cyclic Capacity 10 A 4-cycles in 1 second, followed by 2 minutes idle for thermal dissipation.
48 and 125 V L/R = 40 ms
250 V L/R = 20 ms

These relays are suitable for the higher momentary current in circuit breaker control circuits. Two outputs are configured for device operation, one TRIP and one CLOSE, as default.

> **Note:** The SEL-351R Recloser Control is available as a SCADA-compatible controller for retrofit and new installation.

Metering accuracy of selected SEL relays is listed below. The metering performed by the SEL relays provides voltages, currents, phase angles, MW, and MVAR. No external transducers are necessary. Accuracies are specified at 20°C and at nominal system frequency unless otherwise noted.

Voltages	±0.1% (33.5 - 150 V; wye-connected) {150 V voltage inputs}
V_A, V_B, V_C, V_S, $3V_0$, V_1, V_2	±0.2% (67.0 - 300 V; wye-connected) {300 V voltage inputs}
V_{AB}, V_{BC}, V_{CA}, V_S, V_1, V_2	±0.3% (33.5 - 260 V; delta-connected) {150 V voltage inputs}
Currents I_A, I_B, I_C	±1 mA and ±0.1% (0.5 - 10 A) (5 A nominal) ±0.2 mA and ±0.1% (0.1 - 2 A) (1 A nominal) Temperature coefficient: $[(0.0002\%)/(°C)^2] * ((temp)\ °C - 20°C)^2$ (see metering accuracy example below)
Currents I_N, I_1, $3I_0$, $3I_2$	±0.05 A and ±3% (0.5 - 100 A) (5 A nominal) ±0.01 A and ±3% (0.1 - 20 A) (1 A nominal) ±1 mA and ±5% (0.01 - 1.5 A) (0.05 A nominal channel IN current input)
Phase Angle Accuracy	±0.5°

	Accuracy (MW / MVAR)	at load angle
MW / MVAR (A, B, C, and 3-phase; 5 A nominal; wye-connected voltages)	for 0.5 A s ≤ phase current < 1.0 A s:	
	0.70% / -	0° or 180° (unity power factor)
	0.75% / 6.50%	±8° or ±172°
	1.00% / 2.00%	±30° or ±150°
	1.50% / 1.50%	±45° or ±135°
	2.00% / 1.00%	±60° or ±120°
	6.50% / 0.75%	±82° or ±98°
	- / 0.70%	±90° (power factor = 0)
	for phase current ≥ 1.0 A s:	
	0.35% / -	0° or 180° (unity power factor)
	0.40% / 6.00%	±8 or ±172°
	0.75% / 1.50%	±30° or ±150°
	1.00% / 1.00%	±45° or ±135°
	1.50% / 0.75%	±60° or ±120°
	6.00% / 0.40%	±82° or ±98°
	- / 0.35%	±90° (power factor = 0)

Instrumentation and Control I/O Summary

- I/O possibilities are endless.
- The SEL System incorporates I/O local to the SEL communications processors and virtually limitless combinations of I/O on IEDs.
- IEDs used for automation and expanded I/O include relays, meters, controllers, load tap changers, voltage regulators, PLCs, RTUs, I/O termination, protection logic platforms, distributed high speed digital I/O, weather stations, battery chargers, etc.
- There is no limit to the number of SEL communications processors that can be connected together.
- There is no limit to the number of serial ports, master connections, or IED connections that can be in an SEL system. Each SEL communications processor can connect to a combination of 16 masters, IEDs and other communications processors.
- Windows®-based SEL-5020 Configuration PC Software and SEL product autoconfiguration simplify system development.
- SEL relays have local HMIs displaying metering, status, alarm, tagging, and custom programmed messages. RTUs and PLCs do not.
- SEL relays have pushbutton controls for default and custom programmable control actions. RTUs and PLCs do not.
- SEL communications processors incorporate communications-diagnostic LEDs to verify or troubleshoot direct IED communications. Most RTUs and PLCs rely on multidrop communication, which is much more difficult to maintain and troubleshoot.

AUTOMATION PHILOSOPHY

As part of our overall mission to make electric power safer, more reliable, and more economical, SEL develops and provides innovative, simple to use, robust technologies to protect, automate, control, monitor, and analyze power systems. An essential element of this strategy is the development of automation features in all of our products. The key to success of the state-of-the-art automation we are performing is the interaction of SEL and non-SEL IEDs with the SEL communications processor. Although systems work well with various components, using SEL relays and SEL communications processors together allows the elimination of substation RTUs and PLCs while performing true substation automation rather than just SCADA.

SEL customers have installed and proven many automation functions as part of integrated systems using SEL communications processors and SEL relays. These automation features include:

- Protection
- Event recording
- Fault location
- Monitoring actions of electromechanical relays
- Metering
- Device control (front-panel, local, station, or remote)
- Circuit breaker control
- Motor operated disconnect control
- Motor operated gang control
- Remote/local control
- Protection enable/disable control
- Control tagging
- Control permissives
- Coordinated blocking
- System time synchronization of IED clocks
- Environmental monitoring
- Periodic exercise of ancillary equipment
- Equipment condition monitoring
- Breaker failure and reset
- Capacitor control
- Reclosing
- Automatic dead line swap
- Substation SCADA (via HMI)
- Remote SCADA (via DNP 3.00 link to SCADA)
- Substation wide and IED front-panel HMIs
- Redundant communications
- Redundant control
- Station battery monitoring
- System sequential events recorder
- Power quality voltage sag swell interrupt monitoring

- Dial-in
- Annunciator (via HMI)
- Mimic bus (via HMI)
- Load profiling
- Dial-out
- Manual/automatic communications access control
- Load tap changer control
- Auto regulation on/off control
- Automatic reclosing on/off control
- Automatic event collection
- Primary and backup instrumentation comparison for alarm

SEL automation eliminates the need, cost, maintenance, and unreliability of RTUs and PLCs. Further, SEL relays and SEL communications processors work together to perform this automation. Many of the listed features are not possible if you chose an RTU or PLC instead of the SEL communications processor.

COMMUNICATION PHILOSOPHY

Another essential element of our automation strategy is the development of appropriate communications technologies and protocols. Our product development and customer support continues in the spirit of the following philosophy:

- Invest in research and development to continually improve the state-of-the-art of integration, automation and communications, and protection technology.

- Continue technology exchange with the market through participation in committee meetings, conferences, and seminars.

- Invest resources to develop and support interoperability with devices from other protection, SCADA, and communications vendors.

- Implement standard protocols where possible and develop and implement SEL protocols when necessary to advance technology. Continue to offer free and/or licensed use of SEL protocols.

- Implement standard protocols using the intended standard nonproprietary interoperability at the most appropriate system level through interfaces within SEL relays, separate SEL communications products, and third-party communication devices.

- Protect customers' investments through backward compatibility to all generations of SEL products and a migration path to all future development.

- Implement technologies to support systems of all sizes through features and functionality developed to accommodate a variable device count and wide range of communications infrastructure.

- Support customer implementation of SEL technology without dictating what protocols or communications media will be used. Continue to create and offer the most robust and efficient technology while making SEL products flexible enough to support other vendor or end-user topologies and strategies.

Protocols

SEL Development of Others' Protocols

As mentioned above, to this date, standard interfaces have not been adequate to create safe, reliable and economical systems. Standard interfaces are developed for ease of interoperability between vendors and not optimized for performance. These protocols include:

MODBUS® – A popular protocol with industrial users that has also become somewhat popular in substations. Designed to emulate PLCs transferring register data to one another.

DNP 3.00 – An increasingly popular SCADA protocol, governed by a standards committee, that was designed to optimize efficiency through report by exception, remote modem connections, and multidrop capabilities. Predominantly popular in North America.

IEC-870-5-101 – The European partner to DNP 3.00 but not yet as popular.

UCA – Utility Communications Architecture, designed by North American utilities, vendors, and consultants to satisfy every possible requirement in substation feeder equipment and eventually all equipment.

We have a three-pronged third-party interface development approach:

- Connect SEL relays as an RTU, PLC, or HMI slave, by sharing SEL interleave protocol specifications with SCADA vendors and system integrators, and through the SEL communications processor.
- Connect directly to substation networks as a Modbus slave in the SEL-2020 or SEL-2030 Communications Processors and SEL-701 Motor Protection Relay, or as a Modbus Plus® slave in the SEL-2030 Communications Processor. The SEL-351 family of relays is often applied outside of the substation fence. We added the slave DNP 3.00 to these products and the SEL communications processors to allow flexibility in the selection of radio or other media for their communication with the substation hub or SCADA master.
- For the long term, we believe that a local high-speed network in the substation will be the method of choice for third-party interconnection, such as an application protocol running on Ethernet like UCA/MMS or DNP 3.00.

SEL Proprietary Protocol Research and Development

SEL technology has been developed so that we can build the most robust, economical, and efficient systems to serve our customers. In general these are built around the direct connection communications topology. Several SEL communications processor stars can be combined in a peer-to-peer fashion or a tier-to-tier fashion. EIA-485 options in many of our products also support multidrop networks and peer-to-peer connections support protection functions. This flexibility in design affords redundancy in communications and protection that cannot be matched by other vendors.

Internally Developed SEL Protocols

LMD - Distributed Port Switch Protocol – A software method to add addressability to standard SEL EIA-232 serial ports that are by design point-to-point, allowing SEL relays to exist directly on a multidrop network.

MIRRORED BITS™ – A point-to-point protection protocol for reliably transferring small amounts of data at high speeds.

SEL Interleave Binary and ASCII – Interleaving data streams is a simple innovative way to perform multiple conversations. Metering, system automation, control, supervisory, SER, and device diagnostic data are all of similar priority, second only to protection data, and are often grouped into one multipurpose conversation. Multipurpose, file transfer, virtual terminal, and time synchronization conversations can occur simultaneously on a single communication channel. Control of the relay and data acquisition are prioritized. The meter, system automation, control, supervisory, and device diagnostic conversation occurs deterministically, or in a predictable fashion. SER data and alarm summaries are forwarded in an unsolicited fashion. An IRIG signal is broadcast in a deterministic fashion and file transfer and settings conversations are interleaved as time permits.

RTU, PLC, or Communications Processor Communication Connections

There are several useful methods for communicating IED data to RTUs, PLCs, and communications processors. Unfortunately, the choice is usually made based on protocol language rather that functionality. The possibilities can be narrowed down to variations of the choice to use a SCADA or integrated protocol at the IED interface. In order to understand which communications method to use, we must first start by identifying which types of data the various enterprise applications require and understanding which conversation types can convey that information. Finally, we need to select one or more communications protocols to support the requirements.

Enterprise Application Data Requirements

Table 5 illustrates the data types that many enterprise applications require. These enterprise applications represent multiple locations, multiple departments, and multiple information systems.

Table 5: Example Data Types Required by Enterprise Applications

Enterprise Applications	Commanded Control	Metering	Status	Alarms	Event Notification	Fault Records	SER Reports	Local Profiling	Power Quality	Equipment Health	Weather/ Environment	Protection Quality
Substation and Distribution Automation	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓
Equipment Monitoring	✓	✓	✓	✓	✓			✓	✓	✓	✓	
SCADA	✓	✓	✓	✓	✓			✓		✓	✓	

EMS, Maintenance Mgmt., and Asset Mgmt.	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓
Automatic Report and SER Collection	✓			✓	✓	✓	✓	✓			✓	
Revenue Metering	✓	✓	✓					✓			✓	
Dial-In/Dial-Out	✓			✓	✓	✓	✓	✓	✓			✓
Data Archive	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Industry Conversation Types

Communicating with the data types listed above requires, various types of conversations. These are illustrated in Table 6.

Peer-to-Peer

Peer-to-Peer examples include end-to-end power line protection and control and distributed bus protection.

Unsolicited Data Notification

Unsolicited data notification examples include event alarm reports and SER reports automatically sent from IEDs. These are notification messages of power system actions and do not necessarily map to a system database point.

Commanded Control

Commanded control examples include operator-initiated or automatic supervisory control actions.

Solicited and Unsolicited Data Acquisition

Solicited and unsolicited data acquisition examples include metering, status, and monitoring values. These values do populate database point fields in automation and SCADA system databases. Most systems support only solicited data acquisition in which data is sent to the host only in response to a request by the host. Systems that support unsolicited data acquisition can perform faster because the system does not have to wait to be asked for indication of changes. Some solicited data acquisition systems support report by exception; the system responds to a host request for information with only the information that has changed since the last request.

Virtual Terminal

Virtual terminal examples include command line interaction with the IED and proprietary user interface connections.

File Transfer

File transfer includes sending large files of data such as event reports, load profile reports, historical archive reports, and settings.

Time Synchronization

Time synchronization is necessary to align the time in each IED clock so that time-stamped data is relative. This conversation consists of constantly sending synchronization information so that IED clocks can be frequently synchronized to reduce the effects of time drift.

Table 6: Industry Conversation Types

Applications	Peer-to-Peer	Unsolicited Data Notification	Commanded Control	Solicited Data Acquisition	Unsolicited Data Acquisition	Virtual Terminal	File Transfer	Time Synchronization
Substation and Distribution Automation		✓	✓	✓	✓	✓	✓	✓
Equipment Monitoring		✓		✓	✓	✓	✓	✓
SCADA		✓	✓	✓	✓			✓
EMS, Maintenance Mgmt., and Asset Mgmt.		✓	✓	✓	✓			✓
Automatic Report and SER Collection		✓	✓	✓	✓		✓	✓
Revenue Metering				✓			✓	
Dial-In/Dial-Out						✓	✓	
Data Archive				✓			✓	
Protection	✓			✓		✓	✓	✓

Challenges to Using SCADA Protocols

Table 7 illustrates the types of conversations that several popular protocols support.

Table 7: Conversation Types Supported by Several Popular Protocols

Required Conversation Types	DNP	Modbus	SEL Interleave	MIRRORED BITS™ Communications
Peer-to-Peer	✓*		✓	✓
Unsolicited Notification			✓	

Commanded Control	✓	✓	✓	✓
Solicited Acquisition	✓	✓	✓	
Unsolicited Acquisition	✓**		✓	✓
Virtual Terminal	✓***		✓	
File Transfer	✓****		✓	
Time Synchronization			✓	

* DNP was designed to support peer-to-peer but this has not been implemented.

** DNP supports unsolicited data acquisition but some masters do not support it.

*** Virtual Terminal is a recent addition to standard DNP. Very few devices support it.

**** DNP recently incorporated a proposal for standard file transfer. No devices yet support it.

Industry standard SCADA protocols support various types of data and conversations. It is clear, however, that if we implement a SCADA protocol at the IED interface, we will restrict the IED data to which we have access. Without another connection to the IED, we essentially abandon the remaining data to remote use. We may be able to access the data via a local maintenance connection but not in an integrated fashion. This is like having a flight data recorder that cannot be retrieved for analysis and can only be accessed manually where it is found.

In general, standard SCADA protocols such as DNP 3.00, Modbus, and IEC 870-5 support only a small subset of the required conversations. Required conversations not presently supported by standard SCADA protocols include unsolicited notification, file transfer, virtual terminal, and time synchronization.

In addition, most hosts do not support unsolicited data acquisition even if the protocol does. DNP 3.00 as a standard does describe a virtual terminal implementation. To date SEL has created the only IED known to support standard DNP 3.00 virtual terminal, however, no hosts have been developed that support this feature by communicating with it.

Therefore, since SCADA protocols support only a subset of the necessary conversations, they do not adequately support the data requirements of the enterprise applications.

Innovative Interleave Protocol Solves SCADA Protocol Shortcomings

SEL addressed the multiple conversation requirement issue many years ago when interleaved data communication was invented. Interleaved data communication is a simple innovative way that multiple conversations can occur simultaneously on a single communications channel. This protocol prioritizes synchronization, control of the relay, and data acquisition. It moves the meter, system automation, control, supervisory, and device diagnostic data deterministically, or in a predictable fashion. It also broadcasts an IRIG signal in a deterministic fashion and interleaves historical and settings conversations as time permits. The IED reports SER messages and event alarm summaries as they occur, in an unsolicited fashion.

The IED transmits virtual terminal and file transfer conversations using whatever communication channel idle time is available after sending out the solicited and unsolicited data acquisition, and IRIG messages.

When the I&C system is extremely busy, a virtual terminal and file transfer conversation may be slow because there is less idle time. This is acceptable as an alternative to losing visibility and control of the relay or to expensive and sophisticated communication that would be necessary otherwise.

RTU, PLC, or Communications Processor Communication Connections Summary

- Protocol connection possibilities are endless.
- RTU and PLC serial ports are often not rated to meet IEEE C37.90 standard
- Multidrop connections are more failure prone than direct connections and are often difficult to achieve with fiber media to provide optical isolation.
- All SEL communications processors have the ability to support one DNP 3.00 connection, three Modbus RTU connections, as well as other combinations to support multiple masters.
- Multiple SEL communications processors are easily connected to support multiple DNP 3.00 connections.
- The addition of the SEL-2701 Ethernet Processor will combine Ethernet connectivity with this existing functionality. Many simultaneous DNP 3.00, MMS, FTP, and Telnet connections will be possible.
- SEL communications processors support SCADA protocols like Modbus and DNP 3.00 as well as other protocols that support true automation.
- SCADA protocols do not support substation automation needs of virtual terminal, file transfer, dial-out, unsolicited alarm, SER reports, or IRIG synchronization.
- SEL Interleave is the ONLY existing protocol that presently, simultaneously supports SCADA, file transfer, virtual terminal, unsolicited alarm, SER reports, and IRIG broadcast. The SEL communications processors support SEL Interleave and DNP 3.00.
- RTUs and PLCs support SCADA protocols for IED interface but not integrated communication. Therefore RTUs and PLCs do not support all substation automation needs.

SUMMARY

- Although RTUs and PLCs support features and protocols to perform SCADA and local automation, they do not adequately support true substation automation.
- SEL communications processors share many features and protocols in common with RTUs and PLCs, however, SEL communications processors also support many additional necessary features that most RTUs and PLCs do not support, including:
  - File transfer and collection

  - Message brokering
  - Message routing
  - Dial-out
  - Communication switching for file transfer and virtual terminal
  - Time synchronization broadcast
  - Protocol message emulation
  - Communications eavesdropping
  - Autoconfiguration
  - Station-level SER
  - Tier-to-tier topology
  - Peer-to-peer topology
  - Substation-hardened design

- RTUs and PLCs support expanded I/O via additional termination panels, transducers, and wiring. This results in redundant procurement, documentation, installation, and maintenance costs. Although the SEL communications processors support a small amount of local I/O, the star topology effectively reuses points already terminated at the IEDs. All extra station points are instrumented by spare inputs on various IEDs. The cost and complexity is reduced by incrementing inputs close to the source.

- Choosing an SEL communications processor allows the use of an integrated protocol interface at the IED. This integrated interleave connection supports all the communications connections necessary for true substation automation including:
  - Peer-to-peer
  - Unsolicited data notification
  - Commanded control
  - Solicited data acquisition
  - Unsolicited data acquisition
  - Virtual terminal
  - File transfer
  - Time synchronization

- SEL IEDs support various different connection configurations supporting SCADA protocols similarly to RTUs and PLCs. These SCADA protocols allow new IEDs to support traditional SCADA functions, but not many of the new innovative substation automation functions. SCADA protocols do not, or very rarely, support the following connections:
  - Peer-to-Peer
  - Unsolicited Data Notification
  - Virtual Terminal
  - File Transfer
  - Time Synchronization

- In mission-critical protection, monitoring, control, and automation applications, reliability of devices and systems is critical. Industry average MTBF should not only be considered as a value of how long to expect a device to remain in service. Instead MTBF also tells us how many devices we can predict will fail each year. Industry average MTBF for RTUs is 11 years and for PLCs is 17 years. SEL measures the MTBF of our relays to be 210 years and our communications processors to be 182 years.
- MTBF allows us to predict the reliability of products and also the annual downtime of each device from failure. Comparison of RTUs, PLCs, and SEL communications processors yields the predicted annual downtime across the system shown in Table 8.

Table 8: Predicted Annual System Downtime

Device	Availability	Annual Downtime
Medium RTU	99.952%	252 minutes
PLC	99.968%	168 minutes
SEL Communications Processor	99.997%	16 minutes

- Many conclusions can be drawn from the fault tree analysis of substation systems.
    - SEL star topology is many times more reliable than other architectures
    - Redundant devices and connections dramatically improve system reliability
    - High MTBF devices dramatically reduce maintenance costs
    - High MTBF devices dramatically improve system reliability
    - Highly reliable systems dramatically reduce system downtime
    - Highly reliable systems dramatically reduce total ownership costs
- SEL communications processors vary in cost from $2,000 to $4,000 depending on model and options. At this price, the SEL communications processor is much more economical than buying all of the products it replaces, including an RTU or PLC, communications switch, time synch broadcast, dial-out device, SER, protocol gateway, etc. The economy grows if you implement some of the numerous substation automation features.
- With its feature versus price mix, the SEL communications processor is economical for a single relay or IED connection.

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