Demystifying IEC61850

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Abstract
Much attention and excitement has been generated around the adoption and introduction of the IEC61850 protocol for substation automation. The potential benefits that may be realized through utilization of IEC61850, the associated standardization and improved interoperability amongst the myriad of substation devices are enticing. Reduced configuration cost, easier equipment migration, shortened and simplified application development, and reduced wiring costs are examples of some of the possibilities.

For users contemplating the use of IEC61850 as a substation automation strategy and approaching this for the first time, the learning curve appears daunting. Confronted by terminology such as 7 layer communication models, data objects, logical nodes, logical devices, and acronyms such as GOOSE and MMS; an average user might be unnecessarily tempted to postpone the incorporation of IEC61850 into their own substation automation plans.

This paper will further explore these topics with the intent of providing a "layman's version" of IEC61850 as a foundation for further exploration within an individual automation strategy.

Introduction
Over the past 20-30 years, micro-processor based equipment has been deployed with great success throughout various manufacturing and process industries, including electric utilities. As the cost of this equipment continues to decrease while the reliability, flexibility, and capability increase, we see adoptions of micro-processor based technology continue to accelerate and proliferate.

A typical evolution of applying technology to a process starts with the direct replacement of older technologies. In the case of substations, this typically has included many electro-mechanical devices such as protective relays and metering equipment. Users quickly discover that one of the huge advantages of implementing these types of technologies is the ability of the device to communicate both directly with the user and with other types of equipment. At the time of initial introduction of these devices, there were only basic communication standards and tools, hence each developer implemented protocols that allowed communication but required specific information and often associated tools from the developer in order to communicate.

As these devices proliferate, users find themselves devoting inordinate amounts of time and other resources during implementation in establishing and maintaining communications between dissimilar devices. In an effort to simplify this task, many have selected a single communications technology only to later find that they have painted themselves into a corner with a particular strategy and are unable to branch out and fully exploit technologies that do not comply with the chosen communications technology.

Multi-Vendor Standards Efforts

In an attempt to address the challenge in improving the communications ability of dissimilar devices, there have been many notable efforts to development of multi-vendor supported communications standards. My first personal exposure to a multi-vendor standards effort was in the mid-1980s when I was involved in Computer Integrated Manufacturing. General Motors had initiated the effort of MAP (Manufacturing Automation Protocol), while Boeing had initiated the effort of TOP (Technical and Office Protocol); both had the stated goal of improving information flow within an enterprise, reducing integration costs, and decreasing reliance on vendor specific networks dominated at that point in time by IBM (International Business Machines) and DEC (Digital Equipment Corporation). The MAP/TOP effort ran its course never fully reaching General Motors or Boeing intended potential; however the desire for unified standards and ease of integration has persisted and manifested itself again and again with various multi-vendor standards initiatives with varying levels of success.

Twenty years later, I found myself listening to my first presentation on IEC 61850 at a protective relay conference. I heard reference to multi-vendor supported protocols, layered communications models, data objects, ease of implementation; all topics I remembered vividly from the MAP/TOP presentations of the 1980s.

After 20 years of many failed or partially successful multi-vendor standards efforts, what is different today that would cause the potential user to be optimistic that IEC 61850 will provide the promised benefits that have been so elusive in the past?

Greatly Improved Network Technologies

When protocol standards were being worked on in the 1980s & 90s, information systems technologies were still very expensive. Since then the cost of technology has dramatically decreased while the capability has increased resulting in server farms replacing mainframe computers, proliferation of the internet, computers embedded in phones and other handheld devices. Today, we are able to take advantage of the proliferation of the internet over Ethernet exploding and driving very reliable networking technologies at extremely affordable prices. This is evidenced by the availability of a standard Ethernet connection on every new PC and may also be seen in our own industry as Ethernet ports have replaced the previously ubiquitous serial port in protective relays. Additionally, fiber optic networking technologies that show great immunity to electric field interference present in electric substations are readily available today while there not in the past.

When many people think of the internet and Ethernet, they immediately think of the delays that they experience when surfing the net. They have difficulty considering the thought that these same technologies could be effective in handling time critical device communications within a substation. The simple explanation for this is that in the substation automation world, networks are designed to accommodate the communications needs of the substation and multiple networks will likely be used to accommodate divergent needs of devices instead of the single home or small office network where all devices share the available equipment.

Our own industry has had several fairly successful communication standards efforts that establish a strong basis for industry cooperation on IEC61850. In the area of data acquisition, DNP has eased the integration and interoperability of IEDs (Intelligent Electronic Devices), RTUs (Remote Terminal Units), and substation computers. While initial development was conducted by a single corporation, it was done to an IEC standard and then handed over to a users group for optimal long term support. Those involved with DNP 3 deployment will testify to the simplification of integration resulting in lower implementation costs and ease of long term support. With all these advantages, there is still the need to understand each manufacturer's implementation of DNP 3 in order to identify which data value that must be requested from large data tables.

In the mid-1990s, there were two notable utility communications standards efforts. EPRI and IEEE led an effort to define a Utility Communications Architecture (UCA); while there was a concurrent effort by Technical Committee 57 of the IEC. These two groups agreed to work together beginning in 1997 and have since harmonized their efforts into today's current IEC61850 specification. The development of this standard is particularly interesting because of the number of influential equipment suppliers and large electric utility organizations throughout the world that have been involved in the standard development and committed to the implementation within products and into utility systems.

At this point, a user might be tempted to obtain a copy of the IEC61850 specification; while these are readily available, I would caution against this. The specification provides a meticulous level of detail that a developer would need in order to deliver a product capable of communicating via IEC 61850, but details that the typical user would find bewildering and unnecessary. The user should instead focus their efforts in understanding how the implementation of IEC61850 would be used in their future projects.

What is IEC 61850?

The first global standard for the utility industry, the IEC61850 "Communication Networks and Systems in Substations" provides a framework that will ease the integration and interoperability of intelligent devices in the substation. This in turn, will ultimately result in significant improvements in performance of substation systems while lowering the cost of implementation.

The standard document is structured as shown below:

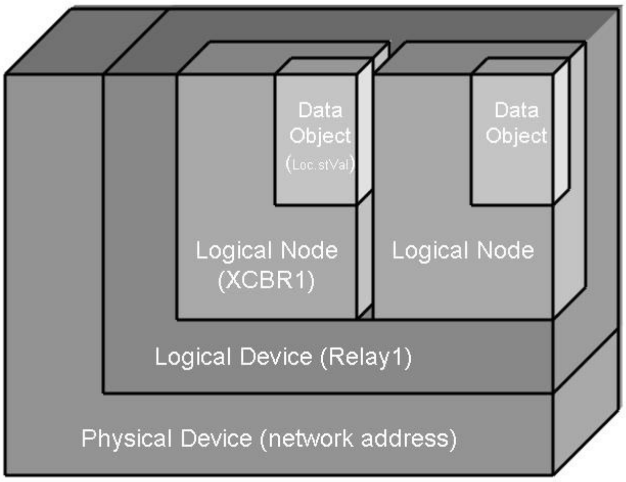
Table 1 – IEC 61850 Standard

Part	***Title***
IEC 61850 - 1	Introduction & Overview
IEC 61850 - 2	Glossary
IEC 61850 - 3	General Requirements
IEC 61850 - 4	System and project management
IEC 61850 - 5	Communication requirements for functions and device models
IEC 61850 - 6	Configuration description language for communication in electrical substations related to IEDs
IEC 61850 - 7	Basic communication structure for substation and feeder equipment
IEC 61850 - 7-1	Principles and models
IEC 61850 - 7-2	Abstract communication service interface (ACSI)
IEC 61850 - 7-3	Common data classes
IEC 61850 - 7-4	Compatible logical node classes and data classes
IEC61850 – 8	Specific communication service mapping (SCSM)
IEC 61850 - 8-1	Mappings to MMS (ISO 9506-1 and ISO 9506-2)
IEC 61850 - 9	Specific Communication Service Mapping (SCSM)
IEC 61850 - 9-1	Sampled values over serial unidirectional multidrop point to point link
IEC 61850 - 9-2	Sampled values over ISO/IEC 8802-3
IEC 61850 - 10	Conformance testing

By the scope of the specification, it quickly becomes evident that the specification for IEC 61850 is beyond that of a typical communications protocol specification.

In order to allow the user to develop applications that are not tightly coupled to a specific technology, the specification focuses on naming every element in the IED that is involved in communication. Part 7 of the specification defines the data model that must be used. Logical Nodes are the smallest functional units which offer data objects for communication with other logical nodes in order to implement the needed functions. Multiple Logical Nodes are named within Logical Devices which would then relate to a specific physical device as shown in Figure 1.

Figure 1 – Data Model



By developing models using common naming conventions shared by all devices participating in an IEC 61850 based system, data may be easily exchanged throughout the system without the need of specifically identifying items such as: device driver, physical wiring between devices, data register, and network address.

Figure 2 provides an example of a data object for a circuit breaker logical node XCBR1 assigned to logical device Relay1 which will indicate if the breaker is in the remote or local mode of operation [1].

Figure 2 – Data Object

Relay1/XCBR1.Loc.stVal

Relay1:	**Logical Device**
XCBR1:	**Logical Node**
Loc:	**Data**
stVal:	**Attribute**

A significant amount of work is necessary in order to define and tie together all of the various elements into a complete, working system. In order to facilitate this, part 6 of the specification defines an XML based Substation Configuration description language (SCL) that provides the interoperable exchange of engineering data for a distributed substation automation system between engineering tools of different manufacturers. The specification defines four main applications for the SCL language [2]:

- IED Capability Description (ICD): defines the capabilities of an Intelligent Electronic Device (IED) in terms of communication functions and of the data model, related to application functions.
- System Specification Description (SSD): the formal description of the substation single line diagram together with the functions to be performed at the primary equipment, in terms of logical nodes.
- System Configuration Description (SCD): the communication and function configuration of a SA system and its relation to the switch yard.
- Instantiated IED Description (IID): the portion of an IED configured specifically for usage within a desired location of a Substation Automation system.

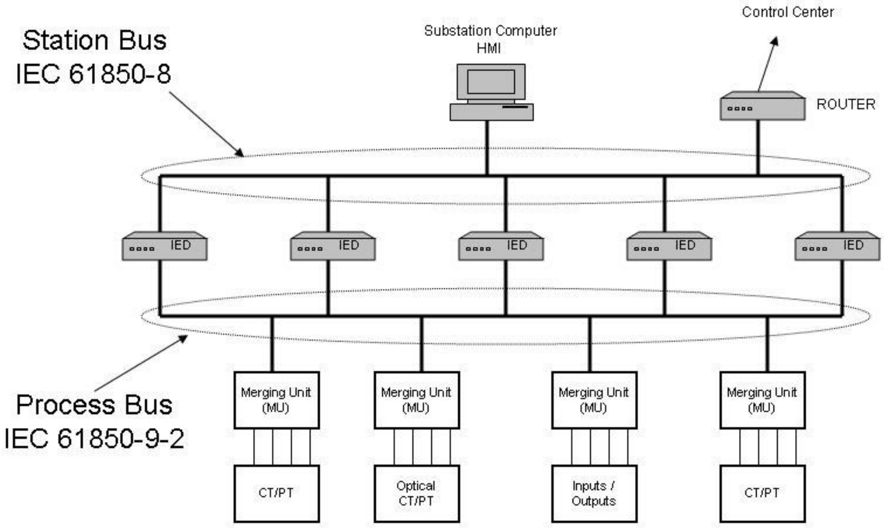
Once the data model of the system has been developed; the individual objects then need to be mapped to a specific communications technology which has been defined within part 8 of the specification and commonly referred to as the "Station Bus". Taking advantage of previous multi-vendor protocol standards efforts, part 8-1 maps the data objects and network services to the Manufacturing Message Specification (MMS) protocols of ISO9506.

This station bus serves as the communication vehicle for devices to exchange data as varied as UTC time synchronization, file transfer for large data blocks such as disturbance records or programs, changing data values, and high speed event status. An acronym frequently heard in discussion of station bus is the Generic Object Oriented Substation Event (GOOSE). A GOOSE message may be used for fast transmission of substation events which traditionally has been accomplished by hardwiring of IED input and output contacts. A device will broadcast a GOOSE message throughout the network where any device that has subscribed to this type of message will receive and take appropriate action. Typical applications of GOOSE would be transfer tripping or interlocking.

With the goal of eliminating the complex wiring between IEDs and process equipment such as switchgear and instrument transformers, part 9 of the specification defines the "Process Bus", or better services to transmit analog sample values. Support is provided for two different transmission methods; part 9-1 defines a point to point service using serial links and pre-configured datasets as defined in IEC60044-8, while part 9-2 defines a multi-cast service over Ethernet using SCL user-defined datasets and Sampled Measured Values (SMV) data transfer.

Usage of samples for protection and other real time functions needs highly accurate time synchronization, which is at the moment not standardized. Therefore the UCA International introduced a device concept called a Merging Unit (MU), which provides for the analog/digital conversion and time synchronization of all four current and voltage channels of one line / bay at sampling rates up to 256 samples/cycle.

Figure 3 – IEC 61850 Communication Architecture



Potential Benefits

By utilizing IEC 61850, it is fair for the user to expect significant benefits in various areas. These include:

- Reduced implementation time in application development and integration
- Reduced cost of wiring
- Ease of equipment upgrade and application migration to new technologies
- Wider selection of equipment that will easily integrate
- Separation of application modeling from physical implementation
- Better availability of engineering tools due to standardization naming semantics
    - Failure analysis, maintenance, system simulation
- Use of standardized models allows flexibility in current and future physical technology implementations.

Challenges

Because IEC 61850 is a relatively new standard, the general availability of products that enable the user to easily engineer and implement a working system at this point in time is somewhat limited, although at least at the level of all other communication protocols. This is rapidly changing and will continue to accelerate as product developers gain expertise and experience. Initial interoperability demonstrations and projects uncovered differences in interpretation of standards by developers; as these differences are discovered, the developers are modifying their products and providing input for revision of the standard to help avoid these issues in the future.

Initially, users will encounter learning curve challenges in gaining familiarity with the new techniques and terminology. However, because of the multi-vendor support of this standard, the amount of training overall will be reduced due to the commonality of data models and communications techniques between vendors.

IEC 61850 depends heavily on Ethernet networks which will require better understanding by utility engineers of network design issues affecting reliability and communications volume. Fortunately this skill is widely available within other utility departments and through network service consultants. As project teams are put together to implement an IEC 61850 based solution, care should be taken to ensure that an appropriate networking resource is assigned.

References

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