IEC 61850 Engineering Process and Multi-Vendor System Configuration Tools Reduce Engineering Costs of Substation Automation Projects

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Abstract

This paper discusses the various costs associated with the substation automation engineering process such as change management, software configuration training, and human error. It then compares the object-oriented engineering approach as defined in the IEC 61850 standard versus traditional methods using hardwire and DNP3. A case is then made for multivendor system configuration tools by discussing the benefits and cost savings associated with following a standard engineering process. Finally, the paper describes one such tool.
As substation automation is moving towards software based IEC 61850 environments, the engineering process is becoming more complex. Consequently a greater portion of the CAPEX budget is used to develop new (or upgrade existing) substations especially in interoperable, multi-vendor environments. This can be attributed to the increasingly complex automation schemes which are now possible, and the learning curve associated with having to learn a multitude of different configuration tools currently required during the engineering process of a substation automation system.

One problem today is that many vendors of substation systems have tried to adapt proprietary methodologies into their native tools for configuring IEC 61850 communications within a substation. This leads to incompatibilities between devices and configuration tools from different vendors. It also increases the potential for incorporating human error into the process as engineers have to use multiple tools to configure a substation automation system.
IEC 61850: More than a communication protocol

Data with Context

Preparing a tabulation of functions for monitoring and control of a substation by a central SCADA system can be a complex task. With the multitude of new intelligent electronic devices (IEDs) with communications capabilities such as protection relays, controllers, remote terminal units (RTUs) and gateways, a lot of different players are now involved in the process. These players usually have very different roles and priorities. For example, a protection engineer may be involved with the data mapping of a protection relay, but their primary function is to configure the protection settings of the relay. As dataflow progresses up the hierarchy from device to SCADA, data must be passed through many different systems, and through teams with different competencies, which makes it difficult to ensure the data context stays intact.

With traditional SCADA protocols such as DNP3, many engineers would use spreadsheets and other forms of documentation to pass the context of the data from level to level. An alarm at a protection IED would be mapped to a DNP3 index; this index could be mapped to data concentrators by a controls engineer, and finally mapped to a SCADA front-end processor. As the data is mapped from index to index, it is easy to lose the context of the data through human error when compiling such mapping tables.

With IEC 61850, data is mapped to logical nodes with pre-defined, meaningful names in the context of an electrical substation. This standardisation between different devices and players ensures that the data never loses its context at different stages of the substation engineering process.

Peer-to-Peer Messaging

With new technologies, protection schemes are becoming more complex. Inputs and outputs are traditionally hardwired between different IEDs. During the engineering process, a small change in the protection scheme logic could require a substantial amount of effort to implement, especially during later stages of the engineering process. This change could require updating engineering drawings, making modifications to, or adding new wiring between devices. These changes can be time consuming and labour intensive, requiring different trades to accomplish what could be considered a trivial change to some digital logic. IEC 61850 Generic Object-Oriented Substation Event (GOOSE) messages are high-speed messages optimised to be multicast over an Ethernet network. These messages allow for digital representations of hardwire I/O to be published on the network and received by the subscribers within a 4 ms timeframe. The major benefit of using GOOSE messaging for I/O is that adding new logic variables and virtual inputs and outputs is simplified, requiring the engineer to only modify the device configurations. The potential now exists for much more complex, distributed protection schemes.

Removal of physical I/O limitations of protection relays allows for hundreds of virtual input and output signals – internal to a relay and not typically used in today’s schemes – to be shared between multiple devices.
Substation Configuration Language

Based on eXtensible Markup Language (XML), IEC 61850 provides a configuration language that can be used to describe the functional specification of the substation switchyard equipment, and how it relates to communication systems and IEDs. This information is stored in various types of files with different subsets of data, described in Table 1. These files allow for data transfer between different engineering tools and devices, independent of the manufacturer.

<table>
<thead>
<tr>
<th>SCL File Description</th>
<th>File extension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IED Capability Description</td>
<td>ICD</td>
<td>The ICD contains a description of the functional capabilities of a specific IED type. It acts as a template to be configured by the engineer in a system or IED configuration tool.</td>
</tr>
<tr>
<td>Instantiated IED Description</td>
<td>IID</td>
<td>The IID contains a pre-configured instance for a single IED for a specific project. It may already have some components already configured such as project addresses or datasets. This data can be imported to a system configuration tool.</td>
</tr>
<tr>
<td>System Specification Description</td>
<td>SSD</td>
<td>The SSD describes the single line diagram of the substation, the required substation switchyard equipment, their functions, and the required IEC 61850 Logical Nodes.</td>
</tr>
<tr>
<td>Substation Configuration Description</td>
<td>SCD</td>
<td>The SCD contains the complete system configuration including the substation specification, all configured IED instances, and the communications configuration.</td>
</tr>
<tr>
<td>Configured IED Description</td>
<td>CID</td>
<td>The CID file is meant to be sent directly to the IED for configuration. It contains information related to configuring the communications for a specific IED.</td>
</tr>
<tr>
<td>System Exchange Description</td>
<td>SED</td>
<td>The SED describes interfaces for data that needs to be exchanged between different projects.</td>
</tr>
</tbody>
</table>

This eliminates some of the intermediate steps that are required when using current methods for typical substation engineering projects, and helps to maintain data coherency.
Engineering substation communication systems

Engineering Challenges

Distributed, Multi-vendor Environments
With the progression of Ethernet based networks inside the substation, functions are increasingly being distributed amongst many different devices. Since open standards are not restricting designers into a vendor proprietary solution, designers are free to choose the best solution for their application. This can lead to multi-vendor environments. To configure the communications between the different devices inside a substation, system engineers must learn to configure multiple devices from different vendors. These vendors can take vastly different approaches to their configuration methodology. This can lead to increased costs in terms of additional training time for engineers.

Manual Engineering
With the multitude of different configuration tools available for the different devices in a substation system, creating links between diverse devices can be a manual process. This can lead to the introduction of human error into the system.

Change Management Implementation
One common consideration to make when deciding whether to permit a change during the substation system engineering process is the amount of effort the change will take to implement. It is often difficult to completely plan for all contingencies during the design phase of the system. Realistically, new requirements and problems can arise during the implementation phase of a project. The change can require updates to engineering drawings, modifications to already implemented wiring, and many device configuration updates. This can be costly in terms of the time to implement the change and the effort of personnel with different roles and competencies. Another consideration has to do with how the desired outcome of the change is evaluated. If the outcome of the desired change does not have the intended results, it can be difficult and costly to undo or modify this change.
The IEC 61850 Engineering Process

The IEC 61850 standard defines a methodology for engineering a substation automation system in an object-oriented, multi-vendor environment. The data flow for this process is shown in Figure 1. Most organizations have a process to choose the standard IEDs used in their substations, based on their specific protection and control philosophies, and the required logical nodes for their power system. Native vendor IED configuration tools contain a mechanism to export ICD files, which act as a template for a specific IED containing the device's supported logical nodes and capabilities. In some cases, an organization may have standardised configuration parameters such as network addresses or preconfigured datasets. In this case an IID file can be used. The IID file would contain the same data as the ICD file, and contain additional parameters regarding the configuration for a specific IED. In parallel, substation engineers define the substation specification based on their operating methodologies. This includes defining the primary switchyard equipment, their functions, the single line diagram and choosing the necessary logical nodes. This data can be contained in the substation section of the project SSD file. Once the group of IEDs and the system specification has been defined, they can be imported into a system configuration tool. Within the system configuration tool the engineer can define specific instances from the different IED templates and link them to the electrical process. The engineer can then define project-specific addressing and configure the data model by defining the datasets and GOOSE publishing/subscribing amongst the various IEDs. The complete substation description, all IEDs and communications configuration can then be exported to a SCD file. The SCD file can then be imported to various IED native vendor configuration tools to complete the protection, control, and device-specific configuration. The IED configuration tool is fully aware of the data available to it from the system, and can make use of this data in the protection logic. After the IED specific configuration is completed, the configuration can be placed on the IED through proprietary means, or by transferring a CID file to the IED. If changes are made to the communications configuration or the IED instance in an IED configuration tool, they can be reintegrated into the system by importing the IID file back into the system configuration tool.

Fig. 1 - Data and information flow in the IEC 61850 engineering process
System Configuration Tool Example

An example of one such system configuration tool allows designers to start developing their substation automation system, by importing a copy of their single line diagram schematic from sources such as a CAD drawing. Through automatic recognition of the substation primary equipment, the common logical nodes associated with the detected equipment are added to the project. The associated voltage levels and bays can then be defined for the substation based on the single line diagram layout and the utility’s standard substation philosophies.

Each selected IED used in the project should have the supported logical nodes defined in an ICD file, which is imported into a database of approved IEDs. These IEDs can then be selected, instantiated, and placed into the appropriate bay on the single line diagram. Additional logical nodes can be added at any level of the hierarchy for enhanced customisation. The System View allows the system designer to visualise the network architecture. It includes all network devices, such as Ethernet switches and printers. The designer can then set all of the specific network addressing for each device, such as the IP address and subnet. This view can help the designer to develop complex network topologies potentially spanning multiple networks.

Switching to the logical view allows the designer to view the IEC 61850 dataflow between the functional elements of the different devices. Based on the logical nodes available from each IED, the data sets for reporting can be defined for each IED, as well as an instantiated data model of each IED used in the project. This SCD file will contain all of the addressing and configured data sets required for the project. The next step is to import the SCD file into the vendor-specific IED configuration tool and complete the device-specific configuration and logic for each IED, such as protection settings for protection relays or legacy protocol configuration for protocol convertors. The last step would be to send the complete device configuration to each device.

for peer-to-peer messaging between IEDs. The view can easily be rearranged to view only the dataflow associated with a specific device, making troubleshooting much simpler.

Fig. 2 - System configuration tool: Defining the primary equipment, voltage levels, bays, and associating IEDs

Fig. 3 - System configuration tool: Overview of the network architecture and defining device addressing

Fig. 4 - System configuration tool: Overview of the network architecture and defining device addressing
Conclusion

Cost savings associated with IEC 61850

Apart from the traditional cost savings of adopting IEC 61850, such as reductions in physical copper wiring used for I/O, there are significant cost savings to be found in the engineering process, due to the efficiencies that can now be realised.

1) Reduction in the amount of time needed to configure a substation automation system

System configuration tools have the capability of significantly reducing the amount of time required to configure a system. These tools can reduce configuration time by automating as much of the addressing as possible within the system, and eliminating the need to individually configure the communications/data flow for each individual IED within the native vendor IED tool.

One such study – testing the configuration of a system of 7 protection relays engaged in a GOOSE-based protection scheme – found that there was a time savings of 72% using a system configuration tool versus configuring each protection relay individually using the native vendor tool alone. For this test only one brand of protection relay was used, and of the two engineers selected for the test, the less experienced was selected to work with the system configuration tool.

2) Increased virtualisation

The substation data model can be developed and tested before the implementation phase of the project. A stronger initial design allows for a reduction in modifications later, when they could be more costly. Virtualisation also allows the engineer to focus on designing for the functional requirements of the substation automation system project and selecting the functional elements that are necessary for its realisation. Conversely, using current design methods, significant effort is spent on integrating the physical devices from different vendors and trying to make them fit into an eventual solution. Virtualisation allows utilities to define the outcome without defining the means of the solution. This allows for the development of more innovative and cost-effective system solutions without sacrificing functionality.

3) Reduced reaction to design modifications

Changes to the design that require modifications to the system during the implementation phase can be made through software, minimizing physical reconfiguration. This means the system design is solely in the hands of the engineer and that it is simple to quickly revert back to previous versions of the configuration if the change does not have the desired results.

4) Increased standardisation and object-oriented engineering

The object-oriented approach to substation design enabled by the IEC 61850 standard allows designers to develop standard bay configurations for elements of their power system. This means that the building blocks of a project do not have to be re-engineered from scratch every time a substation automation system engineering project comes along. Standardisation also allows for a high level of reusability and efficient repeatability.

Future uses outside of the substation

A comprehensive data model can be produced for each substation in the system which can be exported to a number of other systems. Harmonization of the IEC 61850 model with the IEC Common Interface Model (CIM) standards (IEC 61968/61970) will allow for communication and integration of the substation data model with any number of enterprise applications. From automatic configuration of local human machine interfaces (HMI), to enterprise level applications such as distribution management systems (DMS), the opportunity to develop innovative integrated solutions are boundless.


Adam F. Gauci was born in Toronto, Ontario, Canada and received a Bachelor of Science in computer engineering from Queen’s University at Kingston, Ontario. His previous work experience includes Hydro One Networks as a Protection and Control Engineer and Cooper Power Systems as a Field Application Engineer. Currently he is working with Smart Grid Solutions at the Schneider Electric North American Energy Automation Center in Toronto, Ontario. Mr. Gauci is currently a member of the IEEE Power and Energy Society, and a registered professional engineer in the province of Ontario.