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Choosing and using IEC 61850 SCL files, process and tools correctly throughout the complete SAS lifecycle

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Summary

IEC 61850-6 System Configuration Language (SCL) process and files were originally developed just in respect of the design phase of the substation automation system. However on the basis of the information contained therein, they can be used for many additional purposes and tasks throughout the substation life cycle as an integrated part of many other aspects of the asset management and development processes under the responsibility of various groups. In this paper we will discuss the usage of SCL for different tools, and indeed deal with the question of a "single tool" or a "single suite of tools", that may be used along the life cycle of the substation based on a case study of a utility in Australia.

To be able to state that a substation has been implemented with IEC 61850 compliance means that the engineering process has been based on the use of the SCL defined in part 6 of the standard. The SCL describes a standardized format to exchange engineering information between different engineering tools using different variant of SCL files based on the purpose. The engineering design (systems integration) process therefore uses nominally different tools with particular emphasis in creating these files. The SCL files contain all the configuration information of a system (typically a substation) that is of relevance for the information exchange in order to complete the system integration and IED configuration process.

In order to select appropriate tools it is essential to know what information is being used and created by the tools at each step of using the tools. The SCL files themselves are uniquely defined in IEC 61850-6. However many implementations by vendors and systems integrators have confused the mandated specification of these files and how they are to be used, but are still able to demonstrate compliance to the XML Schema using validation tools. This paper therefore firstly explains the correct relationship, content and use of the SCL files. This understanding allows the asset owner to specify and recognise IEC 61850 SCL process compliant files more so than just compliance to the SCL schema as tested by certain validation tools. With process compliant SCL files - some would say "tool interoperability" - the asset owner can be certain that the system integration process as well as all the other engineering phases in the life cycle of the substation can proceed coherently.

Whilst the Standard defines the SCL, the reality is that various organisations have implemented the various options in different ways to suit their particular product innovation and differentiation. If the tools are to be truly usable in the real world, they must not only be based on correct SCL implementation but also cater for these vendor specific nuances.

The second part of the paper deals with IEC 61850 systems integration phase being but one small part of the overall life cycle of the substation. There are many facets to the life cycle of asset management, development operation and maintenance engineering processes of a substation that equally rely on the information and records as SCL files. This life cycle covers planning and standardisation, design, implementation, commissioning, operation and maintenance. Indeed there are many departments and organisations involved throughout this life cycle of the SAS who undertake various specific tasks with therefore specific requirements for information and tools to undertake those tasks. This therefore demands a

close consideration of the complete life cycle and data management processes. This has been a significant process as will be discussed relative to one utility in Australia.

Keywords
IEC 61850, Tools, Life cycle

1 Introduction

The last few years have certainly seen a dramatic surge of interest in the adoption of IEC 61850 around the world. When it was released in 2004 in was often seen as "a solution waiting for a problem" and many grossly underestimated its significance considering it as "just another protocol" [1].

The early days were naturally led by the "single vendor solutions" as turnkey projects simply because it was really only the vendors who had experience in making their boxes talk over an Ethernet using the IEC 61850 communication facilities. As these single vendor solutions appeared it seemed that the engineering tools were simply new versions of device configuration tools providing setting parameters and mapping signals to an Ethernet address instead of an output relay.

It is of no surprise then that it has taken some time to see the real benefits of IEC 61850 as a new paradigm of engineering process as envisioned in Part 6 of the Standard. However as 'multi-vendor' systems started to be implemented, the vendors also began to learn how each other had interpreted the Standard. This included the importance of understanding interoperability is predicated on compliance not only to the mandatory requirements of the Standard, but also identifying the nuances of the optional implementations and vendor specific limitations built into their IED and firmware solutions. A simple example of this is the naming restrictions imposed by some vendors which result in messages not being recognisable universally.

However as the industry has learned to make the boxes work using multi-vendor implementations, we have started to see a move to the real power of IEC 61850 – the engineering process. Yes, we still have to buy boxes and they will have very similar physical appearance as we see in substation previously – perhaps smaller with less physical I/O. We also know we need to have Logical Nodes, ACSI, GOOSE and Sampled Values - these are all fundamental elements of how the technology works in real time – device to device.

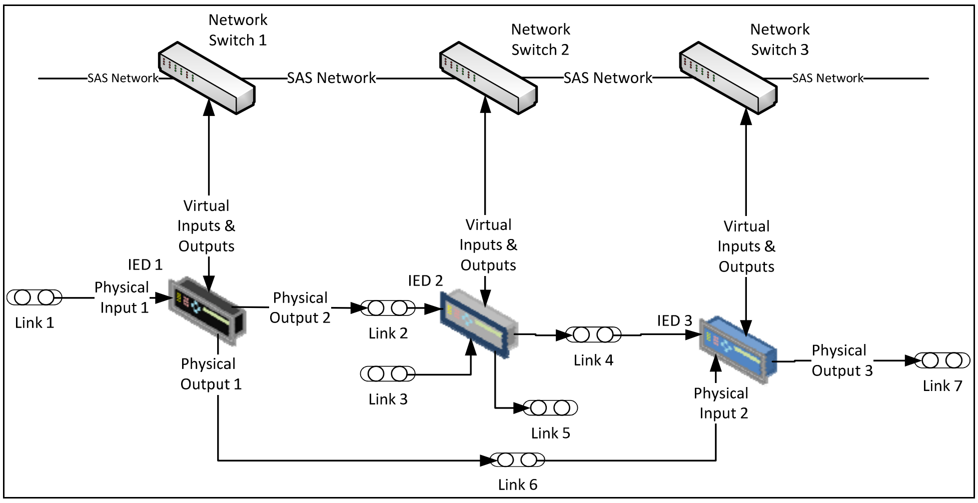
However the same IEC 61850 object models and communication definitions (and hence what makes IEC 61850 significantly different to a "mere protocol") are the fundamental elements that allows us to create a whole new engineering process that traces back to the very first steps of substation planning, long before any GOOSE messages are even contemplated or the choice of IEDs are given any consideration. This has led to the catch cry in the industry of "Think Functions, Not Boxes". This really harks back to the fundamental objective of the Standard quoted in Part 1, Chapter 1:

> *"The purpose of the Standard is neither to standardise (nor limit in any way) the functions involved in the operation of the substation nor their allocation within the substation automation system"*

Given then that the choice of box is "simply" a construction choice of hardware that supports the user's required functionality, we are now left with Part 6 of the Standard which defines the complete engineering process and the tools used at each step. Whilst this is a gross over simplification which ignores the prime requirement of having devices with appropriate and high performance protection algorithms or other specific characteristics, it is reasonable to consider that there are sufficient old, and in many cases new, vendors that will be able to satisfy the fundamental and vital power systems performance requirements – the user just has to be able to state the requirements!

The complete substation engineering process is complex and lengthy – often involving various disparate formats of lengthy documents, hundreds of drawings and many setting files. These are then interpreted and re-created in different ways from one step to the other which then has to be revalidated. IEC 61850 however builds on the information provided from the previous step in a coherent file development process.

Naturally there are many aspects to a substation automations system involving both hard wired and now Ethernet communications to varying degrees as shown below. IEC 61850 only deals with the 'virtual' aspects of the system whilst other aspects are dealt with by other tools.



This paper therefore picks up on the IEC 61850 process and the tools that support vendor independent and reusable engineering throughout the whole lifecycle.

2 The IEC 61850 Engineering process

There are numerous papers which provide details of the engineering process defined in Part 6 of the Standard [2]. This process must deal with the combination of IEC 61850 defined information and other non-defined and/or proprietary elements.

Equally there are many examples in the market where organisations – vendors, integrators and users – have attempted to create processes that jump a few steps. However as each step is intended to add to the information from the previous steps, there is great risk that the flexibility and reusability of the design is lost. Consequently it is highly recommend to avoid systems that are using an incomplete approach to IEC 61850 engineering.
In addition to the IEC 61850 configurations, the IED also requires configuration of the proprietary and non-IEC 61850 elements:

1. IED Proprietary Configuration
    a. Front panel HMI controls – pushbuttons, switches, indicators, displays
    b. Internal logic operation
    c. Physical input / output terminal characteristics and allocations to functions
2. SAS Configuration
    a. Communication configuration - IEC 61850 and legacy
    b. IEC 61850 model configuration
    c. Function parameters and settings - IEC 61850 and legacy

It is then essential to use the combination of tools to work through each stage of the process

- Systems Specification Tool – creates SSD
  Uses data from the Single Line Diagram (SLD) and the operational functions

- System Configuration Tool – creates SCD and SED
  Uses data entered regarding the LAN network configuration, information exchange, device settings etc.
- IED Configuration Tool – creates ICD, IID and CID
  Optionally creates instantiable ICD files
  Incorporates the internal scheme logic definitions, the IED user interface configuration (HMI) and any remaining settings for the IED not contained in IEC 61850 structured models.

IEC 61850 defines specific sections that must exist in each of these SCL files in order for the benefits of the Standard not to be compromised.

The Substation section is describing the topology of the substation (single line) and the functions associated with the substation elements like switches, measurement transformers and feeders. It is used to bind a function realised in an IED to the respective element of the single line so that as a consequence, it is possible to identify unambiguously which circuit breaker of the system is controlled by a specific data object XCBR.Pos. The substation section is created by the system specification tool and is updated during the system design by the system configuration tool.

The Communication section is used to define all information relevant to the communication network. It also identifies the different network segments. The communication section is created by the system configuration tool as part of the system design.

The IED section is used to describe the data model of the IED, any configuration of the control blocks and other parameter values, the input signals to a function and the service capabilities of the IED. The IED section is created by the IED configuration tool. It is updated by the system configuration tool with all information relevant to the data flow within the system as well with configurations of parameter values as needed.

IEC 61850 supports both a “top down” as well as a “bottom up” engineering process.

In the top down process, the design starts with the creation of the single line diagram including the required functionality (eventually already provided as part of the specification). The next step is then to select the IEDs and prepare the ICD files as templates that suit the requirements. This is followed by the system design with the system configuration tool which includes the instantiation of the IEDs. The SCD file is exported to the IED configuration tool. The IED tool extracts the information related to the IED and is then used to do the detailed functional engineering of the IED.

In the bottom up engineering approach, in a first step the IEDs are designed in the IED tool. The IED tool then exports a number of IID files that are then used by the system tool to do the system design with the information flow and the engineering of the communication network.

Unfortunately it is still the case to date that many available IED tools do not yet fully support the SCL process. As an example, it is possible to create an SCD file by any system configuration tool based on the instantiation of ICD files from an IED, but it is almost impossible to then create the project in the IED tool by importing that SCD file due to the limitations of many of the IED tools.

3 The life cycle of the substation and tool elements

The focus of IEC 61850-6 is on the design, configuration and commissioning process of a substation. However, through the whole life cycle of a substation automation system, there are engineering, operation and maintenance activities which require a range of software tool elements. These tools create or rely on information in the IEC 61850 SCL files.

An asset owner's ultimate objective is to obtain a complete suite of tools which can be used by all the parties throughout the life cycle of a substation. This is not limited to system specification, system configuration and IED configuration tools as described in IEC 61850-6. This objective will require a range of tools to be integrated – the desire for an integrated solution cannot be too highly emphasised.

The IEC 61850 tool suite will form part of the total substation engineering process. There are additional activities which in principle are not part of, but are related to, the IEC 61850 tool environment, e.g. physical wiring schematic drawings.

As an overall requirement, the tools must be usable in a multi-user multi-project collaborative engineering process involving the asset owner and various third parties using the asset owner's or their own individual computer environments directly or by remote access. However tools are required to incorporate relevant role based access and use permissions (view/edit) as well as single user edit control (check in/out) features to maintain integrity of the SAS design and operation.

The life cycle of a substation can be broadly categorized as the following general Tasks, each with a wide diversity of activities undertaken by various personnel according to the organisation policies, in/out sourcing models and responsibilities within the life cycle chain:

1. Pre Design / Libraries
2. Design, quality assurance, validation and approval
3. Implementation (including construction, configuration, FAT, SAT and commissioning)
4. Operation
5. Maintenance (including monitoring and testing)

Along the life cycle, there are different tool elements supporting the tasks that manipulate and use various pieces of information including but not limited to:

- Power system topology arrangement
- the run time information made available by the IED (the data model)
- the description of the data flow between IEDs
- communication parameters
- IED specific information related to the functionality (e.g. protection and control parameters, description of logics)
- I/O connectivity of the IED (hard-wired and communications based)
- Documentation of inputs and outputs in support of activities

The tasks of each of the different tool elements is described below.

3.1 Pre design / library Tasks

These tool elements are required to support the design and modification of libraries including the following elements:

- Specification of typical feeder / bays (single line diagram, data model, functional requirements)
- Specification of typical protection and control schemes
- Specification of testing requirements / testing scripts for the typical functions
- Specification and evaluation of IED capabilities in respect of the asset owner's requirements to be included in the library of accepted IEDs
- Specification of naming standards and restrictions

3.2 Design Tasks

These tool elements are required to support the different steps of the design of a substation including the following elements:

- Specification of the substation (Single line diagram, data mode, functional requirements)
- IED pre configuration
- IED instantiation
- Scheme development
- IED logic development (proprietary / IEC 61850)
- IED parameterisation for the specific application
- IED I/O assignment / hard-wiring
- Legacy IED interface design and configuration (physical digital/analog and virtual)
- Gateway configuration including the configuration of the communication part towards the Master station
- HMI configuration
- Import and conversion of legacy IED configuration
- SAS communication network and time synchronisation system
- Telecom infrastructure configuration
- Desktop testing of SAS configuration (operation simulation and verification without using the IEDs)
- SCL file conformance validation

3.3 Implementation Tasks

These tool elements are required to support the different steps during implementation of the SAS, the FAT and final SAT including the following elements:

- Device level testing (IED parameters; IED logics; IED I/O wiring)
- Functional system level testing and debugging including function oriented communication analysis
- Performance testing including verification of communication network configuration and time synchronisation
- Gateway testing
- HMI and alarm testing
- SAT – verification of field wiring
- End-to-end testing of distributed schemes – inter-substation and intra-substation
- Failure mode performance verification
- Interoperability and Factory Acceptance Testing - configuration and testing

3.4 Operation Tasks

These tool elements are required to support the different activities during daily operation of the substation. In addition to support the configuration of information as designed, it is required to also support the history cycle (creation, approved, issued, applied, modified) of configuration changes and the “as operating” information.

This includes the following elements

- Condition monitoring of primary and secondary equipment (including communications equipment)
- Permanent / Temporary settings for power system topology operational changes
- Alternate settings
- Isolations
- Routine test of equipment and functions
- Primary equipment maintenance
- Power system events extraction, storage and analysis
- Equipment failures extraction, storage and analysis (Primary, Secondary and Communication network equipment)

Tool elements dealing with equipment failure are required to handle the mechanisms for graceful degradation of the system. The replacement / repair part is supported by tool elements of the maintenance group.

3.5 Maintenance Tasks

These tool elements are required to support the different activities during maintenance of the substation in case of equipment failures or retrofit / extensions of the substation. In addition to support the configuration of information as designed, it is required to also support the history cycle (creation, approved, issued, applied, modified) of configuration changes and the "as operating" information. Some of these activities imply use of the same or similar tools as used in Design and Implementation Tasks or as in operation tasks.
This includes the following elements:

- Topology changes in the substation primary arrangement including extensions of the substation
- Refurbishment of primary or secondary equipment
- Scheme enhancements in terms of performance or functionality
- Isolations
- Telecom network modifications and performance testing
- Repair / replacement of primary equipment
- Repair / replacement / upgrade of secondary equipment
- Configuration changes of secondary equipment (Settings, Logic, etc)
- Repair / replacement / upgrade of communication network equipment
- Configuration changes of communication network equipment including managing IP and MAC address changes

4 Conclusions

The interoperability of the tools is still a first important step that needs to be improved. The UCA international users group is preparing for the future tool conformance tests based on Edition 2 of part 6. Edition 2 added the tool conformance statements and a better definition of the responsibilities of IED tools versus system tools. It is expected that this will significantly improve the situation soon.

Looking at the engineering requirements for the substation life cycle, specification tool, IED configuration tools and system configuration tool will be the major tools to be used. All these tools may be enhanced by library capabilities to support the predesign phase. HMI and gateway configuration tools are like IED configuration tools and shall be able to import the SCD file and extract all available relevant information in order to reduce the annual engineering effort.

System configuration tools may be enhanced by adding integration capabilities for non IEC 61850 specific engineering tasks like wiring, legacy IED integration or telecom infrastructure configuration. These tasks will benefit from information already available in the IEC 61850 engineering environment.

An additional element for a suite of tools is a testing tool package. This may integrate many testing tool elements like simulation of IEDs, automated generation of test sequences or communication analysis. These elements can be to a large extend configured automatically based on information available in the SCD file.

For operation and maintenance, the tools that have been used for the design and implementation phase will again play an important role. They will be complemented by a tool package that allows partial isolation of elements of the substation automation system including the necessary configuration and setting changes in a safe way.

The scope of IEC 61850 engineering specifications is, to enable a interoperable engineering environment with a mix of product specific tools and product independent tools. The engineering process defined in the standard supports this. However, a utility may consider to define a "IEC 61850 life cycle process" to provide a integrated tool environment for the whole life cycle of the substation.

Bibliography

[1] PAC World magazine Autumn 2009 "Is IEC 61850 just a protocol?" C Brunner. http://www.pacw.org/issue/autumn_2009_issue/iec_61850_update/iec_61850_status_update.html

[2] CIGRE Australia SEAPAC 2011 "Experiences of IEC 61850 Engineering – Designing good systems the right way." (paper 37 March 2011)

[3] CIGRE SEAPAC 2011 38 Brunner IEC 61850 Edition 2 – what does it mean for the end user? (paper 38 March 2011)

[4] CIGRE SEAPAC 2011 39 Hughes Experiences in organizational development and specifying IEC 61850 systems (paper 39 March 2011)

Biography

Rodney Hughes
Rod Hughes has over 30 years' experience in protection and automation systems. Rod is now an independent consultant specialising in assisting organisations through the change management, business case, specification, implementation and training for IEC 61850 systems. Rod is currently Convener of CIGRE Australia B5 Panel for Protection & Automation and Australian representative to the international Study Committee B5.
Rod has been a co-author of CIGRE Technical Brochure 326 "Implementation of IEC 61850" and has been involved in a number of other TBs as author or final editor. Rod is convener of CIGRE Working Group B5.39 "Guidelines for documentation of digital substation automation systems". Rod also owns the patent for the Operator & Test Interface unit for IEC 61850 systems.
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