Focus on the application – IEC 61850 experience with third party system configuration tool

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1 Introduction

IEC 61850 is an approved international standard for communications in substations that is creating opportunities for a revolution in the world of electric power systems protection and control. It represents the next step in integration of multifunctional IEDs based on the development and implementation of advanced distributed protection and control functions.

One of the primary targets of IEC 61850 is, to achieve interoperability between devices from different vendors. But IEC 61850 is not limited to define a communication protocol. IEC 61850 defines as well data objects with a well-defined semantic representing the information available from a substation automation system. And it introduces the substation or system configuration language (SCL).

SCL defines a common format to exchange engineering information between engineering tools. The use of SCL for the engineering process as described in IEC 61850 together with the standardized data models is considered to be a main driver to be able to reduce engineering time of future substation automation systems. Also, it is expected to enable the vendor independence for the utility by introducing the possibility of a vendor independent engineering.

IEC 61850 differentiates between IED configuration tools and system configuration tools. While the role of the IED configuration tool is related to everything that is specific for the IED, the system integration tool shall be used to configure everything that is needed to define the interaction between the different IEDs to fulfill the system functionality. By its nature, IED configuration tools are expected to be supplied by the IED vendors. System configuration tools however may be provided by third party suppliers.

While products supporting IEC 61850 appeared on the market soon after the publication of the standard, this was not the case for the tools; in particular not for the system configuration tools. Today, some IEC 61850 compliant system configuration tools are available; most of them from IED suppliers, only a few from third party tool suppliers. In the beginning, interoperability between tools from different vendors was limited. This is about to be changing. This paper reports about the latest experience with a third party system configuration tool.

2 The role of the tools in the IEC 61850 engineering process

The engineering process with IEC 61850 is described in part 6 of the standard. IEC 61850-6 introduces the Substation Configuration Language (SCL), an XML based file format that can be used to exchange configuration information between tools. Based on a system specification and the device capability description files, the system configuration tool is used to configure the substation. The result is the substation configuration description file that is then used for the IED configuration tools to create the configuration download.

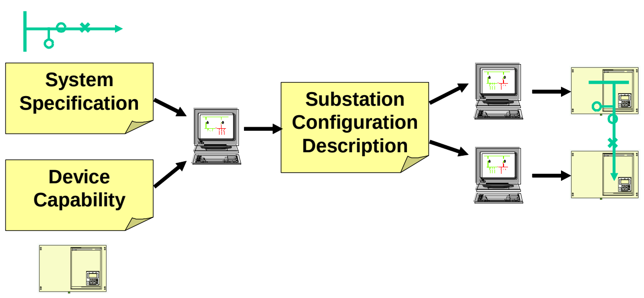

Figure 1 – The use of the substation configuration language

The substation configuration description file contains all information that is relevant to build the system. This includes the complete data models of the devices, but as well all configuration information related to the communication.

The process differentiates between three tools:

- The system specification tool used to generate the system specification
- The IED configuration tool used to do all the IED specific engineering as well optionally to produce the IED capability description
- The system configuration tool used for all system related engineering.

The information exchange between the tools is done with different variants of SCL files. An ICD file describes the capabilities and the data model of the IED and is used as interface to the system configuration tool. The SSD file is the specification ad the interface between the system specification tool and the system configuration tool. The SCD file is the complete SCL file and is used as interface between the system configuration file and the IED configuration file.

It has to be noted, that these tools have to be understood as a grouping of a certain engineering functionality. It is of course possible, to combine multiple functionalities into one single tool; e.g., it is possible to combine system configuration functionality with the IED configuration tool. In that case however, to be compliant to the standard and to support an open engineering process, the tools still needs to be able to produce and import all the SCL files required as interface. In the example of a combined IED / system configuration tool, the tool still shall be able to accept SCD files generated by another tool as input for the IED configuration.

Edition 2 of IEC 61850 added clarifications to the role of the different tools. There were in particular some uncertainties of the responsibilities of the IED tool versus the system tool. Based on Edition 2, an IED configuration tool is among other responsible of:

- The data model supported by the IED. Changes to the data model shall be in appropriate version indicators within the LN0 NamPlt DATA as values within the SCL file.
- If an SCD file is imported, an IED tool may update the version and related value information and change parameter and configuration values as well as binding external data to internal signals.

The system configuration tool is responsible among other for:

- Create IED instances from IED templates
- Engineer the address information of the IEDs
- Engineer the data flow between the IEDs (datasets, control blocks)
- Bind the logical nodes to the primary system
- Allocate of data flow and report control block instances to clients, as allowed by the IED capabilities (ClientLN element at report control blocks, IEDName at other control blocks).
- Create IED input sections as seen from system engineering point of view, however without binding to IED internal signals
- Change configuration values and parameter values for an IED if the IED supports loading these values via an SCD file.

For the interaction between IED configuration tool and system configuration tool during the engineering process, e.g. for the update of the data model of the IED, an IID file has to be used. This SCL variant was introduced in Edition 2 of the standard. This is illustrated in Figure 2. If as an example during the system design, it is identified that an additional data object is required from IED 2, the SCD file is exported from the system configuration tool to the IED configuration tool. With the IED configuration tool that additional data object can be added to the model. At the same time, the value of the data model version indication in the name plate of LLN0 shall be updated. The IED configuration tool then creates an IID file to be imported back into the system configuration tool. In that exported IID file nothing may be changed that is in the scope of the system configuration tool and has already been configured by the system tool. The system tool will use this IID file to update the IED section of IED 2 in the SCD file.

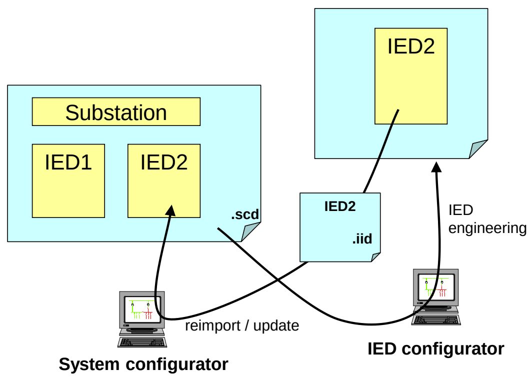

Figure 2 – use of IID file for modifications

Station level devices (HMIs, gateways, station controllers) are as well considered to be IEDs in the term of IEC 61850 engineering. As a consequence, the engineering tools for these devices shall as well be able to import an SCD file and use this as the basis for the engineering of these devices. The engineering tool for these devices can significantly benefit from the information available in the SCD file to reduce the engineering time. As a few examples:

- The information available in the substation section (single line topology; binding of logical node instances from IEDs to the primary system) can significantly reduce the engineering of the HMI if supported. The single line diagram can almost be generated automatically – the user interaction may be limited to the visual allocation of the bays and equipment. The data attribute for controlling an object or containing the information to be updated on the screen is already defined in the SCL file.
- Based on the configuration of the client / server communication from the different IEDs to the gateway, it is less work to configure the gateway database.

The system configuration language and the interaction between the engineering tools as described in IEC 61850-6 is the key element to support a vendor independent engineering. Independent of the IEDs used, the utility can always use the same system configuration tool for the integration of the IEDs. The use of the IED specific tool is reduced to the IED specific engineering work – mainly the logic design and the I/O mapping. Preconfigured libraries may support that work. For the system design of a specific project, always the same tool can be used and the system documentation can be generated in a standard way.

With a third party system configuration tool supporting virtual IEDs, a utility is able to create typical designs for their substations completely vendor independent. For a specific project using IEDs from a specific vendor, the system configuration tool can then document the mapping between the vendor independent design and the project specific realization.

3 Third party system configuration tool

As described in the previous chapter, the standard engineering process defined in IEC 61850-6 differentiates between three kind of engineering tools: the system specification tool, the IED configuration tool and the system configuration tool.

IED configuration tools are available from the suppliers of the IEDs. Many of the configuration tools for gateways and station HMIs today are not supporting IEC 61850 SCL interface.

With regard to the system configuration tool, there are some tools available from vendors to deal at least with some of the functionality required for a system configuration tool. These tools are able to do the basic tasks of the communication engineering like creating or modifying control blocks and data sets as well as configuring communication addressing parameters. Many of these tools do not support the substation section of the SCL.

There are now a limited number of system specification and system configuration tools available from vendor independent suppliers. These tools typically fully support the engineering process as described in IEC 61850-6 and introduce the possibility of a vendor independent engineering.

For our investigation, we used the system specification and configuration tool from Helinks in Switzerland (HELINKS STS). STS combines a system specification and a system integration tool.

System specification is performed by drawing the single line diagram and adding functional specifications. The result of the specification process is the SSD file (System Specification Description) and a human readable PDF documentation.

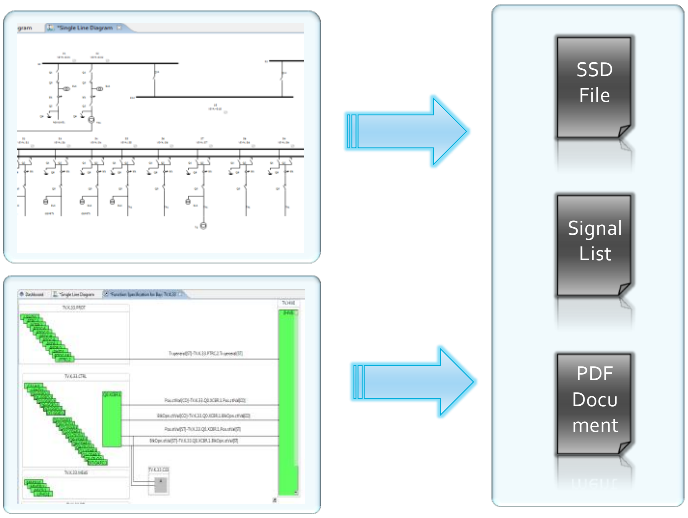

Figure 3 – result of system specification

STS allows loading all kinds of SCL files. ICD files are added to the palette of the system diagram editor and can be used to instantiate IEDs. Loading IID and SCD files result in showing the loaded IEDs directly in the system diagram editor. The system diagram editor represents the IED and Communication section of the project SCD file.

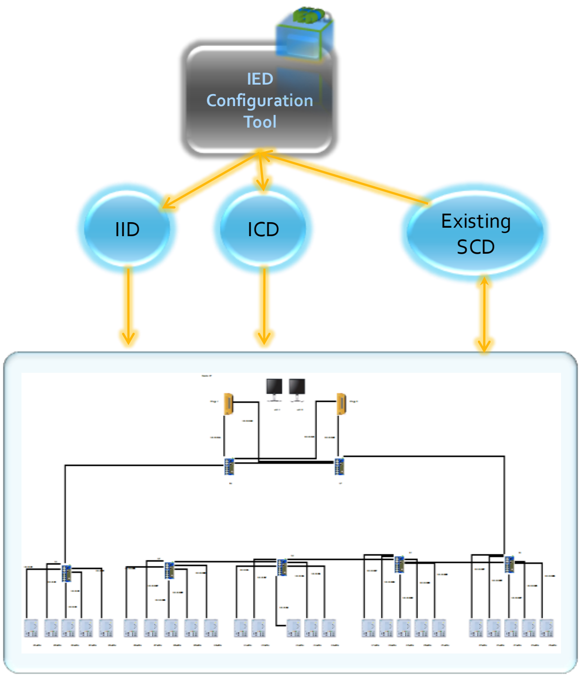

Figure 4 – system integration

Similar as the functional specification, also the communication engineering can be done partly vendor and IED independent.

The vertical communication is configured by assigning client logical nodes (LNGroup I) to the process signals.

Horizontal communication (GOOSE) is specified by connecting Data Attributes of a source Logical Node to one or more target Logical Nodes.

During system integration IEDs are assigned and Logical Nodes are mapped. Once this is done STS automatically creates or merges Data Sets, Controls and Inputs sections.

Using vendor specific plug ins STS allows also the creation of non SCL configuration files for gateways and RTUs. (Excel or XML)

Finally STS produces the SCD file and a PDF documentation of the station.

4 The station level environment

Our pilot project used as station level devices (gateway and local HMI) StreamX, a product from Infoteam SA Switzerland. The basic functions supported by that environment are shown in Figure 5. The engineering environment of this product supports the import of SCL files. To further optimize the engineering process, a product specific plug-in was added to the Helinks tool supporting a direct data exchange with the engineering environment of the station level devices.

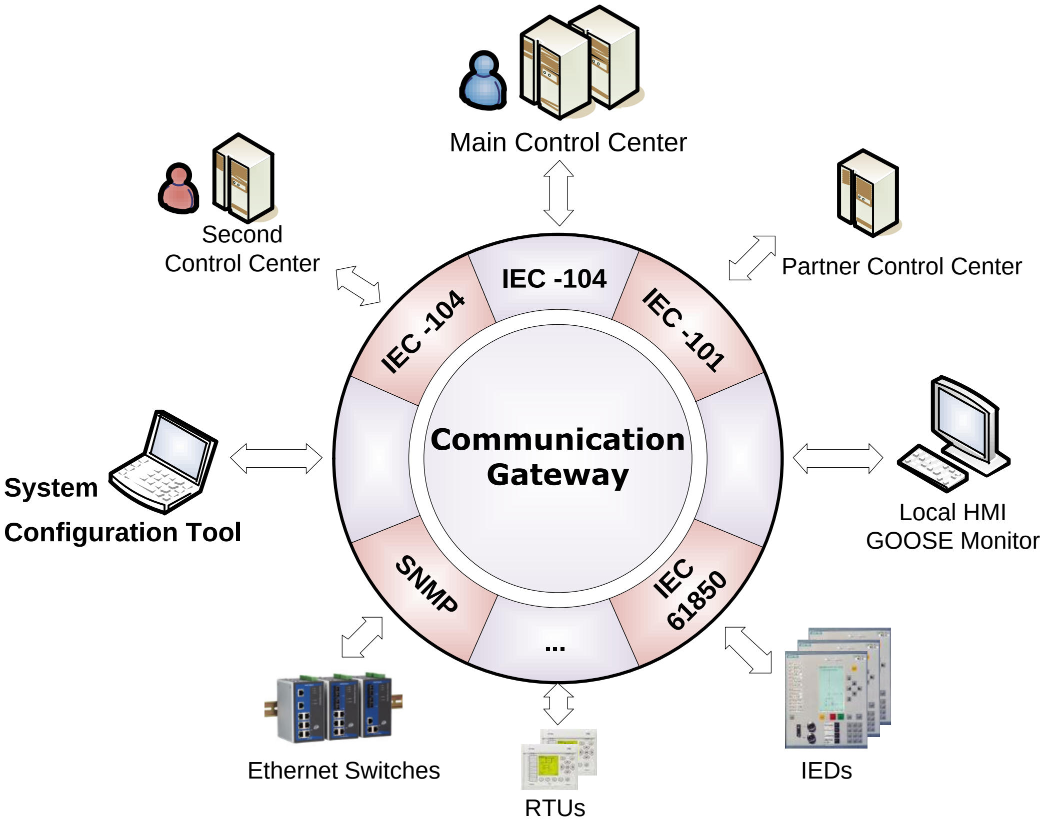

Figure 5 – Gateway functionality

With that plug-in, it is possible in an integrated engineering environment consisting of the Helinks tool and the engineering environment of the station level devices to perform the following engineering tasks:

- Load the ICD files created using the IED configuration tool
- Load and map to the existing signal list (Excel file)
- Do the IEC 61850 substation engineering (single line diagram, function specification, system configuration, GOOSE messages, etc…)
- Produce the substation SCD file for the IED configuration tool
- Compare and list differences between revisions of SCD files
- Configure the data acquisition from non IEC 61850 RTUs
- Choose the data to transmit to the control center
- Generate automatically the IEC 60870-5-104 addresses for the communication to the control center based on the utility existing specific rules
- Communication engineering for the gateway between the substation and the control center

- Generate automatically the communication settings for the acquisition servers of the control center
- Report the complete IEC 61850 configuration and gateway settings as a PDF file

With that approach, the engineering environment to design the substation is based on the following tools (see Figure 6):

- The vendor specific IED configuration tools for the IED specific engineering.
- The third party system configuration tool integrated with the gateway configuration tool for the system and station level engineering.

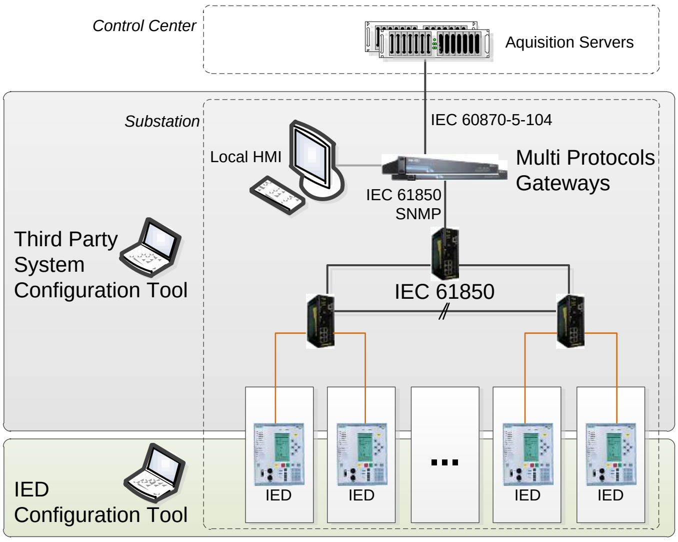

Figure 6 – System overview

5 Pilot project

5.1 Project description

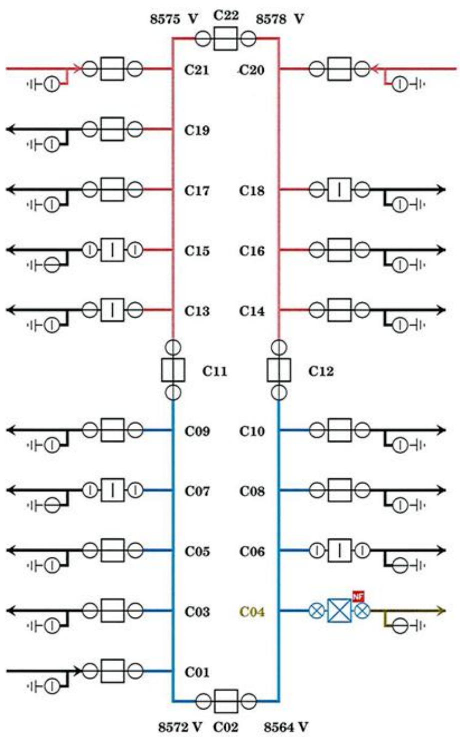

Figure 7 – 8kV substation of the project

With the setup described in the previous chapter, a first case study was realized in 2009 to verify the approach and to get some first experience [1]. In 2010, a first project was realized. The substation under consideration (see Figure 7) comprises one 8 kV busbar with 22 bays arranged in a ring configuration, where the supply is achieved by two 60kV/8kV transformers (C20, C21).

Each bay is controlled and protected with one IED, whereas the customer decided to use the same IED type from one supplier in order to cover all bays of the 8 kV busbar. Furthermore, in order to take the full advantage of the system configuration tool, four bay types have been identified for which template configurations have been created in the system configuration tool. Following bay types were defined:

- Transformer feeder
- Bus coupler
- Feeder (cable feeder)
- Feeder with autoreclosure (air feeder)

Apart from the bay protection scheme, the customer wanted to implement the reverse blocking scheme based on Generic Object Oriented Substation Event (GOOSE) messages, using peer-to-peer communication within the substation. In case of a short circuit located in an 8 kV feeder, the instantaneous overcurrent protection functions of the transformer IED would trip the supply of the 8 kV busbar if this particular protection function is not inhibited. For this reason, a common practice is to block the instantaneous overcurrent protection functions of the transformer IED by the use of the starting signal of the feeder overcurrent protection function. The blocking signal is sent using GOOSE messaging (see Figure 8).

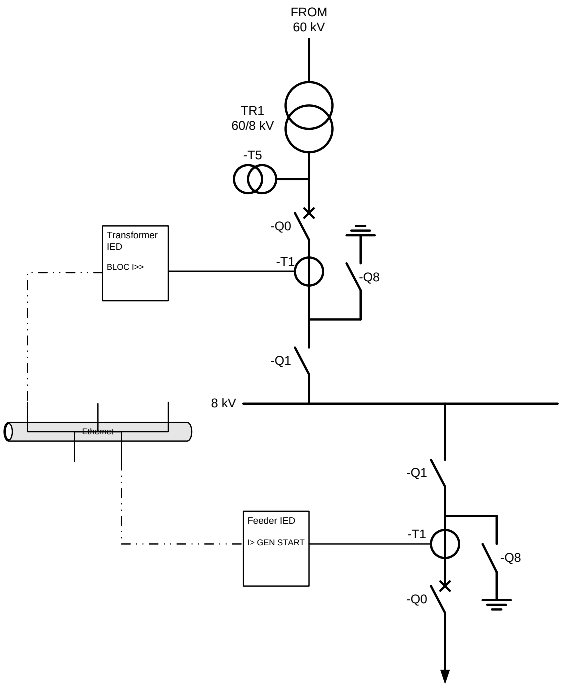

Figure 8 – Reverse blocking principle using GOOSE messaging

The use of a system configuration tool here in particular helps the design engineer in his job by keeping the GOOSE engineering process to a high level of abstraction.

Finally, the Excel signal list with the signals to be transmitted to the control center created by the customer prior to the project had to be used and imported in the system configuration tool in order to produce the export file to be loaded in the gateway to the dispatching and to support the configuration of the IEC 61850 client / server communication.

5.2 Engineering approach

The engineering process for this project following the basic principles of IEC 61850-6 was then the following:

- Select an IED type to cover the functional requirements of all bays of the 8 kV substation

- Define the configuration variants – as described above, 4 bay types were defined
- With the help of the IED configuration tool, pre-engineering of the four bay types and export of the four ICD files to the system configuration tool
- Do the system design using the system configuration tool.

The system design includes the following steps:

- Creation of the typical bay types based on IEC 61850. For each of the four bay types, this includes the single line diagram of the bay including the data model for the functions and the mapping to the IED types created.
- Complete single line diagram based on the typical bay types
- Create instances of the required IEDs based on the four ICD files
- Import the customer Excel signal list and map the signals in the list on the IEC 61850 data model
- Communication engineering
- Export of the substation configuration description SCD file to be loaded in the IED configuration tool in order to be able to create the download file for the IED

The system configuration tool includes a product specific extension for the engineering of the gateway. In addition to the standard SCD file the system configuration tool produces a specific file for the gateway. That file is created based on information from the customer signal list as well as the system design. The SCD file contains the IEC61850 MMS Signals. The additional configuration file contains the SCADA and network Control Center designations and signal mappings to IEC 61850 data. Creating the SCD File and loading it to the Gateway and the IEDs was straight forward. Creation of additional signal mappings for the SCADA and network control center configuration required some additional modeling work. The semantics of these attributes needed to be mapped to the IEC 61850 substation structure. Once this mapping done, these attributes were created just by drawing the single line.

Powerful copy and paste functions and the consistency between the signal configuration and the SCD file are clear advantages of this approach.

5.3 General experiences from other projects

IEC 61850 defines about 100 Logical Nodes (without considering the additional application domains like wind power, hydro or DER). In current IEDs we only find a small subset of these Logical Nodes implemented. In current projects not all the Logical Nodes are properly used. This is due to different implementations from the vendors and to missing application modeling know how of the project engineers. The challenges to benefit from the semantic power of IEC 61850 remain:

- IEC 61850 application modeling know how is missing
- Engineering templates are not yet based on IEC 61850 data objects
- The engineering process and the tool interaction are not yet very clear and smooth.

6 Conclusions

With this pilot project, it was possible to verify the engineering concepts of IEC 61850 with regard to a vendor independent engineering approach. As part of this, it was as well possible to identify, where the products that are on the market today have still limitations.

The positive experience is that SCL allows data exchange between tools of different vendors. The interoperability between these tools becomes better. Third party tools can communicate and integrate with vendor tools.

The negative experience is:

- There are still detail problems in tool interoperability. These are related to interpretation differences of SCL and incomplete implementations.
- The configuration philosophy of communication elements (Reports, Controls and Inputs) differs between the vendors. This may lead to inefficient process steps during system integration.

As a second element, the possibilities of integrating the engineering environment for the station level products (HMI, station controller and gateway) with the system configuration tool where investigated. When doing this, it is important that the integrated engineering environment maintains all the properties of the IEC 61850 system configuration tool including the export and import of the relevant files.

The IEC 61850 engineering process and the classical SAS engineering process are not well integrated. Today signal lists containing IEC 61850 signal mappings to other protocols and client data objects are created and maintained manually. Excel is the favorite tool for this work. Without doubt Excel has powerful editing features, but the lack of semantic support, standardized representations and consistency with the SCD file are clear limitations. Here the system integration tool plays an important role in consistently integrating IEC 61850 and gateway and SCADA engineering.

Using a system configuration tool supporting all the features provided in IEC 61850 SCL in particular the inclusion of the substation section with the single line diagram provides a couple of benefits. These include:

- IEC 61850 substation structure is the core structure to organize functions, signals, test cases, etc
- IEC 61850 substation structure gives the structure and granularity for engineering templates
- IEC 61850 substation structure allows to define and standardize automation and protection functions device and vendor independently

The experience shows that there is still the need to improve the interoperability between the tools. Edition 2 of IEC 61850 with a more clear specification of the responsibilities of the different tools as well as with the tool implementation conformance statements certainly helps to improve this. But there is as well a need for tool interoperability testing and tool conformance testing. The UCA international users group started the work on defining test procedures for tool conformance testing.

Utilities should contribute to this evolution by explicitly requesting tool conformance statements from their suppliers.

7 References

[1] Ch. Brunner, E. Cottens, M. Genier, D. Muller, N. Nibbio, J. Reuter: *"Engineering approach for the end user in IEC 61850 applications"*, D2/B5_115_2010, CIGRE 2010, August 23 – 27, 2010, Paris, France.

8 Biography

Christoph Brunner has graduated as electrical engineer at the Swiss Federal Institute of Technology in 1983. He is Utility Industry professional with over 25 years of industry experience with both knowledge across several areas within the Utility Industry and of technologies from the Automation Industry. He is president of it4power in Switzerland, a consulting company to the power industry. He has worked as a project manager at ABB Switzerland Ltd in the business area Power Technology Products in Zurich / Switzerland where he was responsible for the process close communication architecture of the substation automation system. He is convenor of the working group (WG) 10 of the IEC TC57 and member of WG 17, 18 and 19 of IEC TC57. He is senior member of IEEE-PES and IEEE-SA. He is active in several working groups of the IEEE-PSRC (Power Engineering Society – Relay Committee) and member of the PSRC main committee and the subcommittee H. He is international advisor to the board of the UCA international users group.

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Joerg Reuter is the CEO of Helinks LLC based in Switzerland providing vendor independent solutions for IEC 61850 systems. He used to work as software architect and R&D Manager in the process automation and substation automation industries. Joerg is a member of IEC TC 57 WG 10.

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Denis Muller is an electrical engineer who has over 35 years of experience within Energie Ouest Suisse (EOS) in high voltage and automation technologies for substation's engineering from 65 kV up to 380 kV in the French part of Switzerland. He is member of TC 57 Swiss national committee. He is one of the ''fathers'' of the Stream's concept and works since 2004 within the Energy Solutions department of Infoteam SA, Villars-sur-Glâne Switzerland.

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Eric Cottens has graduated as ETS/HES electrical engineer in Switzerland in 1991. From 1991 to 2000 he worked at ABB in Baden at the department of protection and substation automation, where he occupied various jobs from engineering, testing and commissioning to project management. In 2000 he joined the utility EOS in Lausanne, where he was involved in both maintenance and refurbishment of HV substations. In 2007 he founded the service company Cottens & Badoux Energie Services (CESSA).

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Daniel Badoux has graduated as ETS/HES electrical engineer in Switzerland in 1990. Since 1990, he worked at Sprecher Energie AG (Alstom) as substations turnkey projects engineer. In 1995 he joined the utility EOS in Lausanne, where he was involved in network protection systems & refurbishment of HV substations. In 2004 he joined the team of first subway in Lausanne as project coordinator and contract manager. In 2009, he joined the service company Cottens & Badoux Energie Services (CESSA) as co-owner.

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