IEC 61850 SCL - MORE THAN INTEROPERABLE DATA EXCHANGE BETWEEN ENGINEERING TOOLS

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Abstract – The IEC 61850 SCL language for Substation Configuration description is standardized for the interoperable exchange of engineering data between engineering tools. Its model based approach allows to use it also for other purposes. As an illustration this paper explores some examples, like usage for storage of protection parameters, maintenance support, control center gateway engineering, and application configuration wizards.

Keywords: IEC 61850, Substation configuration language, Engineering, protection parameters

1 INTRODUCTION

The intended purpose of the XML based Substation Configuration description language (SCL) as defined in IEC 61850 is the interoperable exchange of engineering data for a distributed substation automation (SA) system between engineering tools of different manufacturers at well-defined stages in a general engineering process [1]. Its model based approach to system description however allows more tasks to be performed with a SCL system description, and the standardized model semantics as well as language extension facilities open up further opportunities. This paper explores some of them to illustrate the advantages of the model based description approach. First the main data parts and object models contained in the SCL are described to get a feeling for the semantic contents of the presented model. Then some applications are explained and how they use this model for additional functions.

2 SCL DATA CONTENTS

2.1 General

IEC 61850-6 [1] defines four main applications for the SCL language:

- IED capability description (ICD): the capabilities of an IED type (IED=Intelligent Electronic Device) in terms of communication functions and of the data model, which relates to application functions, as input to system engineering.
- 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 the switch yard.
- Configured IED description (CID): the IED configuration and all its needed data coming from the rest of the system.

This means that an SCL file must contain beneath version and revision handling related information the following parts, as indicated in Figure 1 and explained more in 2.2 - 2.7:

- Switch yard naming and topology description, see Fig. 1 ; (1) highlights a bay example
- IED configuration description, Fig. 1 (2) highlights an IED with its functions in terms of logical nodes.
- Communication network description, Fig. 1 (4)
- Relation between switch yard and IED functions, Fig. 1 (3): S1CSWI1 controls circuit breaker QA1
- Configuration values

The following paragraphs explain these parts as far as needed to understand the model based description approach and the applications resulting from it.

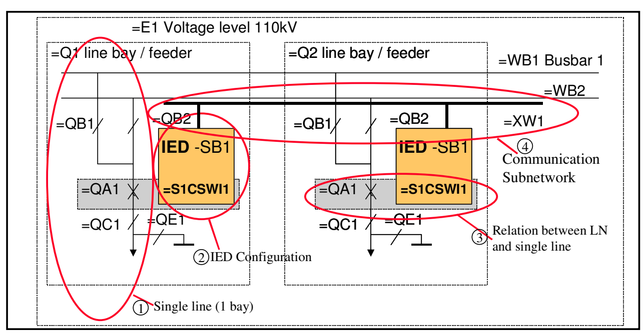

Figure 1: Contents of IEC 61850 SCD file

Further on SCL contains standardized rules for language extensions, and the IEC 61850 standard defines rules for data model extensions. This paper mentions the concrete usage of these extension possibilities at the applications where they are really needed. Although SCL extensions by manufacturers or utilities are allowed, these possibilities are mainly foreseen for extensions by future IEC standards, and for SCL language and IEC 61850 data model version handling.

The capabilities of the SCL language result from two different basic features:

- The standardized model with standardized semantics: IEDs and functions are standardized in IEC 61850-7-x, the plant function part in IEC 61850-6.

- The standardized language to describe instances of the model. This allows the exchange of model or model parts between different applications.

2.2 Document identification and revision history

Each SCL file has a header, which contains a document reference and a version/revision history, as usual for document identification and the tracking of changes in a project. SCL standardizes the way how this data is represented in XML. This allows e.g. to track different versions of IED capability descriptions, or of SA system descriptions.

2.3 IED capabilities and data model

An ICD file contains a section for the described IED type. This IED description contains (see also [1], [2]):

- The communication service related capabilities of the IED, e.g. if directory services or file transfer are supported.
- The configuration related capabilities of an IED, e.g. how many data sets or control blocks can be configured dynamically or by means of an SCD file.
- The provided functionality and data objects in terms of logical nodes (LN) and the contained data objects (DATA).

IEC 61850 has standardized logical node class names for standard SA functionality, and standardized DATA names by which this functionality can be managed in a standardized way (IEC 61850-7-4, -7-3). The function implementation as such, and with this the needed information to fulfill the function, are not standardized. However, to globally detect which function an IED can fulfill or is fulfilling, and by which data objects it can be monitored or controlled, this semantic standardization is sufficient.

If an IED is used within a system, then based on its ICD type description an instance of the IED is inserted as an IED section into the system SCD file. These instance gets a system specific IED name, and the IED section must be enhanced by all project specific communication definitions – see (2) in Figure 1.

2.4 Single line topology

The SCL Substation sections contain the model of a switch yard at single line level, and might also contain connections by power lines between several substations – see (1) in Figure 1. Beneath the hierarchical structure of function naming with the main levels Substation - Voltage level - Bay - Primary Equipment this part contains the topological respective electrical connections between primary equipment, and allows also to identify phase related parts of primary equipment. Additionally to this power system related functionality also other functions existing in the switch yard can be modeled in a hierarchical way, like fire alarm systems and intrusion control systems. The general model behind the power network part is harmonized with the network model used in IEC 61970-301 (CIM, Common Information Model for power networks). The hierarchy in general is chosen to be compatible with the plant designation system according to IEC 61346. The main purpose of this SCL section is to indicate, which function (logical node) of which IED is allocated to which part of the switch yard. The topology information allows further intelligent applications, as described later.

2.5 Logical node relation to primary equipment

As already mentioned above, the connection between the power process and the SA system is described in SCL by attaching logical nodes to elements of the primary equipment, as shown in Figure 1 (3). This can be done on any level from Substation down to the phases of a primary equipment, and also to the connections within the single line topology. The level has to be chosen according to the function of the logical node. Typically a switch control logical node of class CSWI is attached to the switching device, while a measurement logical node e.g. of class MMXU, or a protection function logical node e.g. of class PTOC (time overcurrent function), are allocated to the bay. This means that the semantic meaning of a function within a SA system is determined by the logical node class (CSWI, MMXU) as well as by the switch yard part to which it is allocated.

2.6 Communication connections

Communication connections are modeled on several levels:

- SubNetwork, Network: which IEDs can directly communicate with each other within a SubNetwork by which address parameters (see (4) in Figure 1), and which communication possibilities between SubNetworks exist by means of routers.
- Message, telegram: how is data (signal values) grouped into messages, and with which characteristics are they send. This allows to determine respective analyze the communication behavior, when mapped to a physical network. IEC 61850 uses for this the concept of data sets.
- Signal flow: which data objects or attributes (signals) from which IEDs are input to a function, represented by one or more logical nodes. This allows a modeling at the level of IEC 61131 function charts or similar.

2.7 Configuration and parameter values

The SCL language allows to specify typical or individual values for data attributes residing in an IED. This can be used to

- specify values for configuration attributes and setting parameters.
- state values used during the engineering process or during operation, even if they are not online accessible at the IED.

The specification of setting values belonging to different setting groups allows also to load as well as archive protection parameter values in a standardized way.

3 SCL APPLICATIONS

3.1 General

As explained above and illustrated in Figure 1, SCL contains or might optionally contain

- A model of the substation at single line level.
- A model of the logical communication connections between all used IEDs.
- A functional model of the SA functionality by means of logical nodes, logical devices, and the data flow between them.
- The connections between the models: allocation of logical nodes to the switch yard equipment and to the SA system IEDs.

All this together forms an overall model which describes beneath the IEDs and the primary substation functions the connections between them communication-wise and function-wise. The following examples show some applications not explicitly addressed in IEC 61850, or beyond those intended to be solved by IEC 61850, based on these models.

3.2 Keeping distributed systems consistent

An SA system is a distributed system. A lot of IEDs are communicating with each other to fulfill the intended functionality. A distributed system can not be set into operation within one moment. One IED after the other has to be loaded with the project specific configuration data, and then put into operation. Further, if a distributed function has to be maintained, at least two IEDs are concerned: the one providing needed data, and the one using this data. For more complex functions even more IEDs are concerned. To assure correct working of such a distributed system at startup as well as during configuration changes, IEC 61850 has introduced configuration revision information for the

- data model in terms of logical devices, logical nodes and data objects.
- communication related definitions in terms of addresses and revision information for the grouping of data into data sets.

This information can, and in case of safety related real time services like GSE (Generic Substation Event) and Sampled Values must be checked at the receiver to assure that his assumptions about the message contents are consistent with the actual configuration state of the sender. The intended sender revision information is provided to the receiver by means of the SCD file during its configuration, which assures a consistent system view. The really used revision information is available online, for real time services even in each sent telegram. So, if a receiver is loaded with a new definition, however the sender still provides data according to the old definition, then the receiver can detect this by comparing the online revision information with its configuration based expected revision information, and sets safety related information to invalid, until also the sender is updated to the new SCD system configuration version.

The possibility to read all this revision information online allows a simple tool to check if all IEDs are really loaded with the version information as provided by the SCD file.

However, this is only the operational side of the problem. The other side is that on any change of a sender data model or communication definitions all concerned receivers have to be updated, so that they know the new version information and can check consistency with the eventually changed data model or data set layouts. Here the usage of the data flow definitions at data set level between IEDs within a SCD file provides all necessary information to automatically determine the concerned IEDs. This minimizes the number of new configuration downloads after a change. Further, if only syntactic information like message layouts has to be reloaded, then this could even be automated, if the IEDs support the standardized SCD / CID file download.

3.3 SA system maintenance support

In addition to the data model and data set related version information mentioned before, the data model as such contains revision information about the IED base software and hardware, down to the implementation of each logical node. This information can also be stored within a SCD file, and is very useful in case that a defective IED has to be repaired or replaced. The already mentioned possibility to read this information online allows to compare the online version with the latest version information from the up-to-date system configuration SCD file, and thus notify to the maintenance personal that incompatible hardware or firmware versions reside in the replacement IED. Naturally, if a new backward compatible IED version is used, this can be stored again in the latest SCD file version.

Additionally to the configuration information of the system the Private elements of SCL can be used to link SCL objects like IEDs or switch yard equipment to maintenance documentation, like user manuals, installation manuals and erection drawings.

3.4 Protection parameter handling

As already been pointed out in chapter 2, an SCD file can contain values of configuration attributes as well as setting parameters inside and outside of setting groups. This allows to use SCL as a standardized data exchange format for applications needing protection parameters, like

- Initial loading of configuration and parameter values into the IED either according to IEC 61850 by means of the IED tool, or optionally directly with a CID file.
- Export / Import of parameter values from tools checking consistency or generating consistent parameter sets for the whole power network.
- Export / Import of parameter set values from / to protection test tools.
- Protection parameter set version handling and archiving.

A problem with parameter set version handling is that parameter values may be changed online, without any indication in the IED or the SCD file. This is taken up as an issue in IEC TC57 WG10, so that in the future beneath configuration versions, indicated by the configRev attribute, also parameter value versions can be distinguished, indicated by a paramRev attribute which has to be maintained by the IED and incremented at any online change of parameter values. This paramRev attribute value for the last commissioned parameter set can then also be documented within an SCD or CID file.

3.5 Gateway engineering

A substation automation (SA) system gateway to the network control center (NCC) converts the data from the communication protocol used within the substation to that used between SA system and NCC. Gateways work up to the layer 7 of the ISO/OSI stack. However, the actual meaning of 'application layer' is dependent on the used protocol. For standard NCC protocols like IEC 60870-5-101 and –104 the layer 7 defines the communicated data types in form of ASDUs (Application Service Data Units) and the services used on or with them. For IEC 61850 the application model also includes the functional semantic of logical nodes and the contained data objects. This higher level of application semantics is lost, if for gateway engineering the IEC 61850 data objects at the NCC side of the gateway are just mapped to ASDUs and addresses, which are pure house numbers.

Just allocating addresses to the data objects of the IEC 61850 side and selecting ASDU types for the services and data formats for them is not a big problem. The ASDU can be determined from the IEC 61850 common data class (CDC), and the address can be freely chosen as long as it is unique. The real work is then at the NCC side, to connect the NCC protocol signals, identified by the signal address, again to the application. For this work-intensive and error prone task the harmonization of the SCL substation model with the CIM model of IEC 61970 at the NCC side can offer an automatic solution [3]. The SCL substation modeling is at model level practically identical with that of the CIM. If the naming of primary equipment is also chosen identically, e.g. according to IEC 61346 – what seems to be plausible for the same equipment – then the SCD model can be related also application-wise to the CIM power equipment model. The automation of the second step, the relation of the IEC 61850 data objects to the CIM measurements, is under investigation within IEC TC57. With this also the application level integration into the NCC can be completely automated, irregardless if the NCC protocol address of a signal has been provided by the SA gateway engineering, or by the NCC SCADA level engineering.

One of the problems which might arise for 'legacy' systems is that IEC 61850 also standardizes some application level services, like giving switching commands. Previous protocols left the freedom to use different ways to do this on signal level. In this case either the legacy application has to be adapted to the IEC 61850 way of doing things – with still using the 'old' protocol, but another mapping to signals -, or the gateway must be intelligent enough to translate the legacy NCC side of the application to the IEC 61850 way of doing this. In any case here a legacy system specific protocol mapping additionally to a pure protocol mapping has to be found.

3.6 Application configuration wizards

Applications have to be configured on several levels. Within an IEC 61850 based system on communication level the data set based data flow between IEDs has to be configured. For this the data has to be grouped according to the performance and safety requirements, possibly restricted by the service capabilities of the IEDs. The latter are known from the ICD descriptions of the IEDs. The former have to be set up for all application functions. Then a configuration wizard can determine the needed data sets and services, allocate data sets to appropriate communication control blocks, and configure these. Some general rules to be used by the wizard e.g. for vertical traffic and for safety critical traffic in case of protection related or interlocking related functions can be found in [4] .

At functional level the marshalling of signals between logical nodes has to be configured. As addressed in [5], this can also be automated to a big extent. The following provides an example:

An application function in IEC 61850 is represented by one or several logical nodes. If we take synchrocheck as an example, this is one logical node RSYN which provides a block/release output to the circuit breaker control logical node CSWI, and needs as inputs the voltages left and right from the circuit breaker. After allocation of logical nodes to the primary equipment, an application configuration wizard knowing the needs of a function can automatically determine the needed inputs. In case of the synchrocheck function it 'knows' from the SCD file, which RSYN and CSWI logical nodes belong to the same switch, so the output of the RSYN can be marshaled to the correct CSWI. Further, by analyzing the single line topology, it can find the VT at the line side of the circuit breaker, and on the bus bar side, and the allocated TVTR logical nodes, which supply the voltages in form of sample values. All this information comes from the SCD file. Now, the RSYN configuration wizard has also to know about the implementation of the RSYN itself: Does it need samples as voltage input, or time stamped phasor data? Can it receive data via the process bus, or only from IED internal data sources? To which internal inputs of the RSYN have the (external) data to be wired? According to this information it can check, if the found TVTR logical nodes can provide the needed data, and marshal this data to the correct RSYN inputs.

As can be seen, such configuration wizards get all information about the IED environment from the SCD file, however they also have to know something about the internal implementation of the function to be configured: the algorithm to determine the needed input data and its performance properties, and the internal data structures of the IED to concretely do the configuration.

Another possibility is the configuration of system related functions. Examples are:

- the representation of the switch yard on an operator console (HMI); in terms of IEC 61850 logical nodes this means the configuration of the IHMI logical node.
- the station level interlocking function; this implements a lot of CILO logical nodes providing block/release interlocking signals for several switches.
- switching sequences; configuration of specialized GAPC logical nodes (GAPC = Generic Automatic Process Control), or may be just a part of the IHMI.

All above functions have in common, that the main configuration information for them can be taken from the single line diagram. Generation of pictures out if single line topology information is already used at network control level. Topology based interlocking is known since some years [6]. The same is true for topology based configuration of switching sequences [7]. Usage of the SCD single line topology information can thus be used to configure all these applications functionwise. Additionally the SCD file also contains the links from the single line diagram to the needed data sources. The switch positions needed for all three applications can always be found with the name CSWI.Pos.stVal. The concrete CSWI name (including prefix and index), and on which IED respective logical device it is located, can be identified with this link.

So, SCL provides a standardized way to exchange the same configuration data to different application configuration wizards, providing data for the function configuration as well as for the connection to the 'real' process data.

4 CONCLUSION

As has been shown in the previous chapters, an SCD file in SCL language describes a model of the substation, the IED functions in terms of logical nodes, and the communication connections. The IEC 61850 data model also contains references to and identification of switch yard equipment, which can therefore also be modeled and exchanged by means of SCL files. This model can beneath the IEC 61850 relevant communication configuration of IEDs also be used for more tasks, from system maintenance up to automated engineering of (distributed) functions. A first step for this is currently undertaken by IEC TC57 WG19 in integrating the IEC61850 models into the CIM models at network center level. By integrating these models further into the utility infrastructure, e.g. for network control level applications, switch yard maintenance applications etc., and using the standardized language to exchange the model between different applications, a huge potential for further rationalization of engineering, planning and maintenance tasks opens up. The higher level of standardization within IEC 61850 allows also a higher degree of automatisation.

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