GRAPHICAL SPECIFICATION FOR IEC 61850 BASED SUBSTATION AUTOMATION SYSTEMS

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ABSTRACT

IEC 61850 supports the use of functional designs for specifying substation automation systems. However, specifying IEC 61850 based substation automation systems is not standardized. This means that utilities are left in the dark and still have to use traditional and proprietary ways to specify their requirements.

In this paper a graphical specification method is introduced that does not only specify the LNs used by a function, but also the interconnections needed and performance classes. This can be done for every function required in a substation and will result in a set of so called 'function layers' that together describe that total functionality of a substation. After this abstract specification, the utility can select the IEDs that implement the required functions.

The benefits of this method is that it combines several specifications in one document, using as much graphical means as possible, making it easier to understand for humans and that is processable by computers.

INTRODUCTION

Renovation versus innovation is the challenge utilities are facing when coping with aging secondary equipment and the installation of new substation automation systems (SAS). The difference in lifecycle between equipment, demand for new functionality and an increasing demand for quality data from the field, request a different strategy for SAS design and implementation. This strategy led to the use of the IEC 61850 standard [1], since it offers flexibility, inter-operability and a semantic data model. The IEC 61850 standard introduced a new paradigm for designing SAS, by supporting the use of functional designs. No longer were the devices the most important part of a SAS, but the functionality a SAS should perform. With the use of functional designs and the possibility to use multiple vendors in one system a clear definition of all the system specifications are of most importance. There is a need for a clear (unambiguous) specification to reduce technical, interoperable and performance issues.

In IEC 61850 part 6 the System Specification Description file (.ssd) is introduced, but the .ssd file only specifies the logical nodes that should be used, but not the interconnection nor the performance requirements. Also it does not offer a way to get from a functional design to real devices. For an unambiguous specification not only the logical nodes are of importance, but also their interconnections, the data objects that logical nodes should contain and the performance requirements. Manufacturers of secondary equipment have several means to specify the capabilities (.icd), data model (MICS) and services (PICS) of their products. Utilities, on the other hand do not have a standardized way to specify their requirements.

In this paper a graphical specification method is introduced to specify per function the data model, communications and performance requirements. This new graphical specification method does not only specify the logical nodes used by a function, but also the interconnections needed and performance classes. The benefits of this method is that it combines several specifications in one document, using as much graphical means as possible, making it easier to understand for humans and processable by computers. With this visual functional specification a managed development process has been created that builds a bridge between a single line diagram and an unambiguous specification.

VISUAL SPECIFICATION METHOD

The Visual Specification Method (VSM) is a method with which utilities and system integrators can specify the functionality and information exchange for IEC 61850 based systems in a graphical way. The method is based on the IEC 61850 [1] .ssd file that describes the single line diagram, the functions of the system and the required logical nodes. The VSM however extends this base information with logical communication paths, data exchange and requirements for communication performance. All this is presented in a graphical way. In short the VSM:

- defines the single line diagram (SLD);
- describes one (1) system function per page;
- defines the IEC 61850 logical nodes for each system level (process/bay/station) per system function;
- defines all logical connections between the logical nodes;
- defines the required transfer of information between the

logical nodes (PICOMs);

- defines the required communication performance.

The VSM can be used both on sheets of paper or by a computer application. The latter can be an existing application like a spreadsheet program or a VSM application (to be developed). The method consists of four main components:

- Single Line Diagram;
- Logical Node allocation per system level;
- Communication and Performance table;
- IEC 61850 service definitions.

Single Line Diagram

The single line diagram is the basis of the specification. It unambiguously describes the primary equipment, their topology and interconnections. The SLD is also a well known symbolic representation of the real world equipment. any power engineer knows what is meant with the electrical symbols in the SLD. In IEC 61850 the SLD is defined in the .ssd file. In Figure 2 on the left side an example of an SLD is drawn.

Logical Node allocation per system level

The IEC 61850 concept of free allocation of logical nodes is known and means that the definition of the system functionality is done without defining the hardware. It is also possible to group logical nodes per system level. In a substation these levels are known as Process-level, Bay-level and Station-level. The reason to group logical nodes on these levels is because the type of communication (the message types) between and within the different levels can be different. An example of logical node allocation per system level is shown in Figure 1. The choice of the logical nodes is strongly related to the system function, but additional logical nodes can be added for specific functionality (e.g., IHMI). After all the required logical nodes have been placed in the three substation levels (see Figure 2), the next step is to define the logical communication paths between these logical nodes. In this stage of the VSM the following communication paths have to be taken into account:

1. Communication between logical nodes that is inextricable bound up with a specific system function. E.g., interlocking data (CILO) needed to perform a control action;
2. Communication between logical nodes needed to transfer user specific information. E.g., the sum of switched amps (SumSwARs,CSWI) that can be used for condition based monitoring.

When defining the logical communication paths we have to keep in mind that the communication defined in 1) will be implemented by IED manufacturers and is partly not visible (inside an IED) and partly made available through services (e.g., GOOSE for tripping). As an end-user it is therefore often not possible (or wanted) to redefine this type of communication in a completely different way. The communication defined in 2), nevertheless, has everything to do with end-user requirements and is closely related to the data and communication services made available by the IED manufacturer. An example: the end-user specifies that SumSwARs shall be communicated to a station computer (HMI) by buffered reporting. Not every manufacturer shall be able to comply with this requirement as SumSwARs is an optional data of CSWI and buffered reporting might not be supported by the IED. The VSM will unmistakably make clear what is required by the end-user.

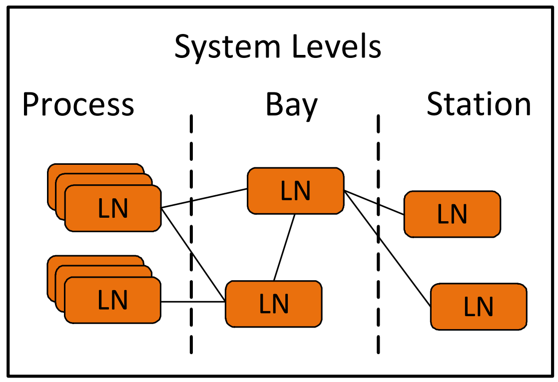


Figure 1: System levels and logical nodes

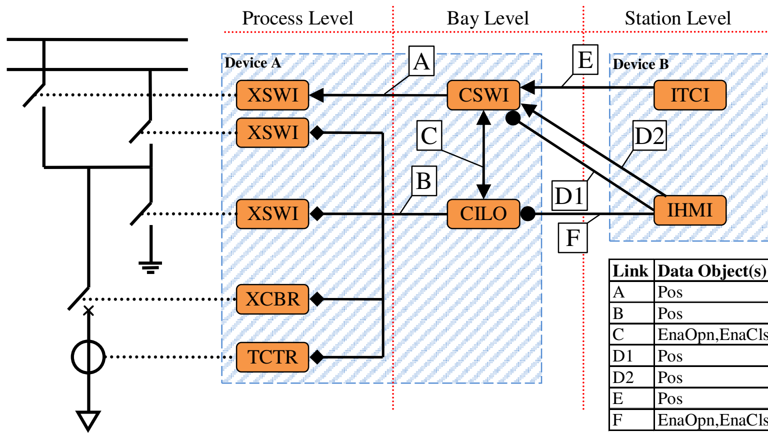
Communication and Performance table

After specifying the SLD, Logical Nodes and logical communication paths, that next stage of the VSM is the definition the communication and performance table. In this table each data to be communicated (link) is defined in terms of the Data Object, the Data Attribute(s), the Message Type and the Performance Class (PC) with the associated Transfer Time (TT). Each message type defines one or more performance classes (PC) and each performance class has a transfer time (TT) [2].

Link	Data Object(s)	Data Attribute(s)	Msg. type	PC
A1	Pos	stVal, q, t	3	P2(TT2)
A2	OpCntRs	stVal,q,t	3	P2(TT2)
B	…			
…				

Table 1: The communication and performance table

It is possible to define multiple links for a single logical communication path. As shown in table 1 there are two links called A (A1 and A2), meaning that for a specific logical communication path there shall be two links. Each link defines one or more data objects or data attributes. In case the data attribute column is empty the whole data object shall be transferred. The message type column defines which of the 7 message types [2] shall be used. In Table 1 link A requires twice the message type 3 to be used, but also different message types can be combined for a single link.



			Legend	
Link	**Data Object(s)**	**Data Attribute(s)**	**Msg. type**	**PC**
A	Pos	[control structure]	7	P2(TT2)
B	Pos	stVal/q/t	1B	P2(TT4)
C	EnaOpn,EnaCls	stVal/q/t, stVal/q/t	2	P1(TT3)
D1	Pos	stVal/q/t	2	P1(TT3)
D2	Pos	[control structure]	7	P2(TT2)
E	Pos	[control structure]	7	P2(TT2)
F	EnaOpn,EnaCls	stVal/q/t, stVal/q/t	2	P1(TT3)

Figure 2: Example of one graphical function layer used for System Integration

IEC 61850 service definitions

Next to the specification of the communication and performance table is the definition of the IEC 61850 services. The VSM provides a means to describe this with the following set of communication services:

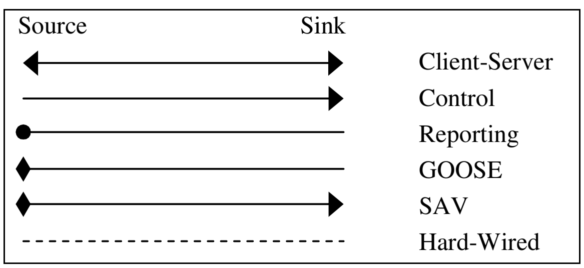


Figure 3: Graphical communication services

All input and output links of the defined set of logical nodes (the IED) can be replaced by one or more of the communication services described in Figure 3. For example Link A in Table 1 can be replaced by a single reporting line (in case the data objects and/or attributes are within the same IEC 61850 data set) or by two reporting lines (in case two data sets are defined).

The IEC 61850 service definitions are an important factor in the VSM. At some point in the design process the logical nodes are allocated to real devices. By simply drawing a dotted line around a set of logical nodes the designer indicates that the encircled logical nodes belong to a certain IED. This set of logical nodes shall be given a meaningful name (tag). This name can be re-used in the definition of a different system function (in the VSM this is a different page) that resides in the same IED.

EXAMPLE AND EXPERIENCES

The use and practicality of visual specification method for the design of a substation automation system will be explained using a real life example following the different parts of the substation automation life cycle. This will be done by giving an overview of the experiences from the viewpoint of specification, system integration, functional testing and commissioning.

Specification

IEC 61850 specifications are a key factor in the process to come from the functional design to a real solution consisting of devices. However the current specification methods defined in IEC 61850 have proven not to be sufficient for the purpose of specifying the entire system. The visual specification method is an extension to the standard IEC 61850 .ssd file. The standard .ssd file specifies the logical nodes which should be used, but not the interconnection between them nor the performance requirements. The VSM allows for the specification in one model the single line diagram, the logical nodes, the data objects/attributes, the logical node interconnections and the required communication performance. With the visual specification method it is therefore possible to translate the functional design into an independent IEC 61850 design and requirements, which can be further used in the design, implementation, testing and maintenance processes.

Experiences using the visual specification method for IEC 61850 design and specification benefitted the specification phase in the following ways:

- IEC 61850 specification is still independent of vendor or technical architecture. This leaves all options open to choose the optimal technical design;
- IEC 61850 design and requirements are (unambiguous) documented at the same time;
- Requirements are directly linked to the related functions. The influence on the requirements of any change in the functional design is directly clear.

System integration

For the functions required in the substation a set of so called 'system function layers' is defined in the specification phase. During the system integration phase this set of function layers is used to allocate the logical nodes over the devices. An example of the visual specification method used for system integration is given in Figure 2. In this example one function layer is shown for the functions control and interlocking of a switch. The figure shows the distribution of the needed logical nodes over the system levels and their allocation in physical or virtual devices as well as the logical interconnections between the logical nodes and between the devices. The power of the VSM can now be observed. Not only is the data model necessary to implement the required functionality specified, but also the specification of the communication services, the performance classes, the message types and the allocation of the functions to virtual or physical devices are identified in this way. It is therefore very easy to see which messages need to be communicated between Device A and Device B and how the functions are to be implemented:

- Device A needs the capability to send control messages to Device B with performance class 2 (link D2 and E);
- Device A need to send one report message to Device B with performance class 1 (link D1);
- Device A need to send one report message to Device B with performance class 1 (links F);
- The logical connection between CSWI and XSWI becomes an internal signal in Device A.

For each function layer the process of allocating logical nodes to real devices has to be repeated, which for each device results in the required data model, services and performance.

In our experience using the graphical specification method improved the process of selecting a device for our IEC 61850 design and specifying device requirements. The VSM specified unambiguously the MICS, PICS and performance requirements.

Functional testing

During functional testing the system is handled as a black box. Functions are tested by verifying the output considering the input of the system, internal programming is not considered during a functional test. The VSM can offer assistance when the system fails to pass a functional test by identifying the messages which should be present in the system with the required performance requirements. Also when there is a performance conflict for a functional test, this model makes it clear which device should deliver a specific performance.

Commissioning

Commissioning often consists of functional, system and device tests. For the system and device tests this model specifies what is expected from each device with respect to data model, services and performance. Graphical view of the functions and desired layout makes it easier to set up test cases for commissioning.

INTEGRATION WITH OTHER STANDARDS AND OUTLOOK

The VSM has been successfully used by the Dutch utility Alliander as a part of their SA specification. Currently the VSM is focused mainly on the specification part of projects, but the goal is to further develop the methodology in a way that it can be used for automatic functional testing as well. A very interesting option is to make use of the existing IEC 61499 standard [3]. This standard describes the encapsulation of functionality in so-called function blocks. It is also possible to model most IEC 61850 logical nodes as function blocks [4]. Once function blocks are defined the automatic testing of functionality becomes a step closer. It will also make the task to verify the as-build substation against the specification (FAT/SAT) easier as the VSM output can be the input for functional testing tools. Also there is an option to integrate the VSM into an UML communications diagram for functional testing [5]. Another goal is to extend the current IEC 61850-6 .ssd schema to describe the VSM components.

CONCLUDING REMARKS

- The model is a powerful tool that can be used throughout the design process. It can be the basis for discussions inside a company between designers and stake-holders, and also towards manufacturers of IEDs, network equipment, etc.;
- There is no direct need for specialized software programs to start using this method. A spreadsheet program or CAD program is enough to get started;
- Although no special software program is needed, a specialized VSM program would enable the user to read .ssd files, match IEDs with the specification, generate signal lists, etc.

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