THE SPECIFICATION OF IEC 61850 BASED SUBSTATION AUTOMATION SYSTEMS

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1 Abstract

The new communication standard IEC 61850 is introduced in Substation Automation replacing almost all traditional wires by serial communication. Based on mainstream communication means like Ethernet it provides a high flexibility regarding communication architectures. Due to its flexibility utilities are concerned about the process of specifying an IEC 61850 based Substation Automation systems. Based on experiences gained during the initial introduction of Substation Automation systems utilities are worried that they will not specify what is necessary. Main task for the specification is to assure that all specific requirements will be met and that at the same time a maximum use of all possible benefits is assured. This paper addresses the key issues related to the specification of an IEC 61850 based Substation Automation System. The findings are summarized as follows. Use a strictly functional specification for Substation Automation systems. Add performance and availability requirements and check whether all interfaces to the systems surrounding the SA system are covered and defined. Then allow manufactures and/or system integrators to supply a technically and economically optimized system. Finally in the specifications and the other tendering documents the role of each involved party, especially that of the system integrator must be defined and should be properly negotiated.

2 Introduction

Substation Automation (SA) was successfully introduced over the last 30 years [1]. More than 4000 systems have been installed worldwide [2]. Up to now, the communication for SA was based on proprietary serial communication mechanisms complemented with conventional parallel copper wiring. The latter is used especially from the process to the switchgear. With the advent of IEC 61850 [3] there is a comprehensive global standard for all communication needs in the substation being introduced now. The introduction of IEC 61850 compliant devices and Substation Automation systems (SAS) will be the challenge for the industry now. A big commercial impact, i.e. “saving millions of dollars” was forecasted in [4]. The question for potential users in the utilities is what has to be specified to use all these benefits, and what has to be changed compared with the existing specifications for SA systems.

3 Basic features and specification of SA systems

Substation automation (SA) is used for controlling, protecting and monitoring substations [1]. At least from a logical point of view, SA systems comprise three levels, the *station level* with the substation host, the substation HMI and the Gateway (GW) to the remote Network Control Center (NCC), the *bay level* with all the control and protection units and the *process level* with more or less intelligent process interfaces to the switchgear (Figure 1). Extended implementations show all three levels equipped with IEDs, where for example a conventional RTU comprises all three levels in one unit. All implemented levels are interconnected by serial communication links. There is not only vertical communication between the levels (e.g. between bay and station level), but also horizontal communication within the level (e.g. in the bay level between bay units for functions like interlocking).

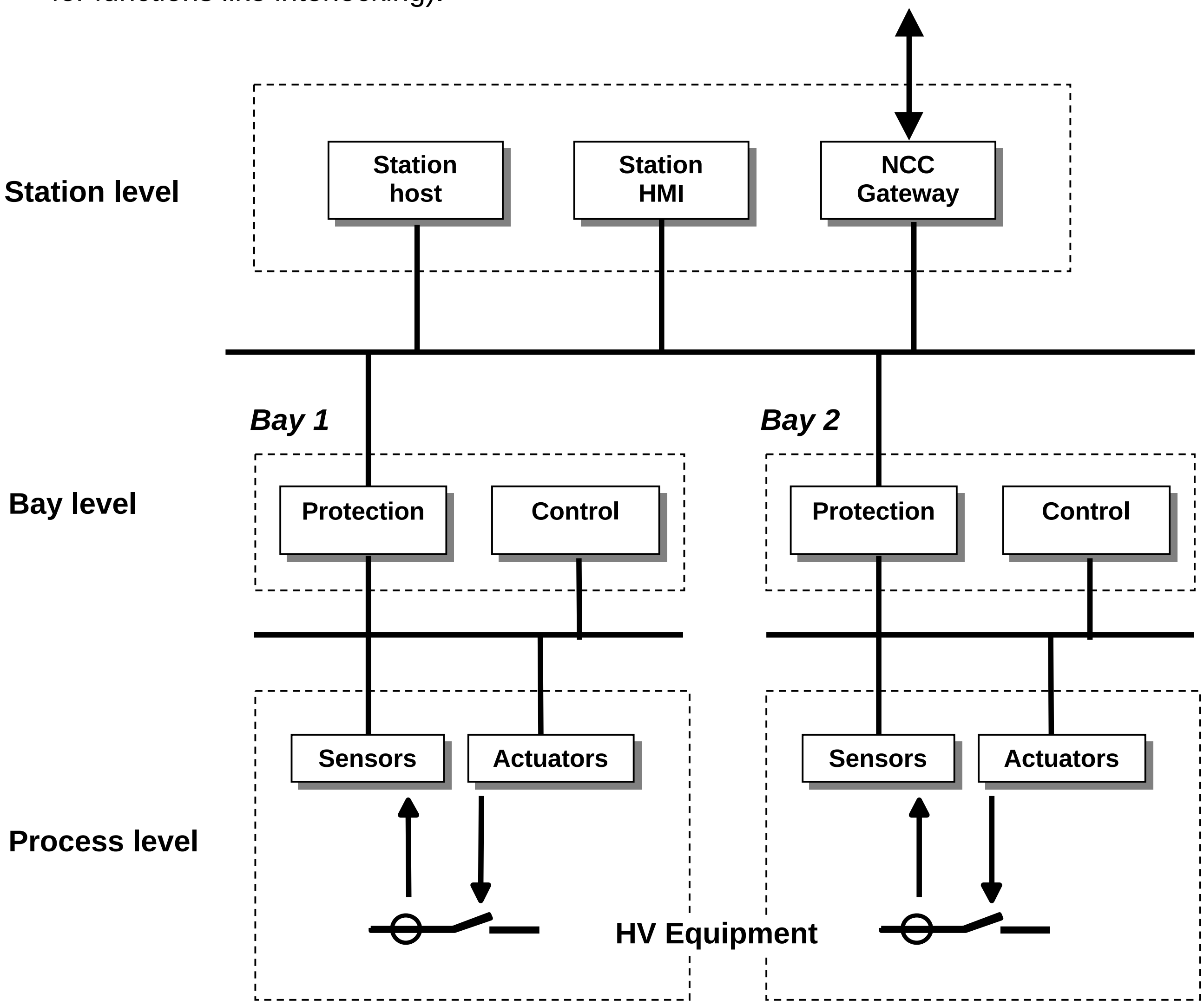

Figure 1 – Logical scheme of the three levels of a Substation Automation system

Note: Functions and levels may be merged in appropriate IEDs. Connections may be made by parallel wires instead of optical serial links. Sensors and actuators may be hardwired process interfaces.

For new substations, the Substation Automation systems are specified as part the overall specification taking into account all the relevant interfaces. Therefore the SA system specification has interaction with the switchgear specification, the auxiliary supply specification, the control centre specification, the protection system specification, etc.

For retrofit, the SA system is specified stand-alone but referring to the dedicated requirements of the existing substation as boundary. All functions needed are specified either from the functional point of view only or by referring to some predefined devices meaning control, protection and monitoring units. Dedicated devices are always the station level HMI if any, and the interface(s) to the remote NCC or dedicated service places. The *process interface* is given by the switchgear of the substation. The system is established by the communication between all IEDs employed. For any functionality covering one or more IEDs, stringent performance requirements are to be given.

4 Basic features of IEC 61850

The *scope* of the standard IEC 61850 is to support the communication for all functions being performed in substation. The *goal* of the standard is *interoperability*, i.e. the ability for IEDs from one or several manufacturer to exchange information and use the information for the their own functions.

The standard IEC 61850 supports the *free allocation of functions* to devices (IEDs) and, therefore, supports any kind system philosophy covering different approaches in function integration, function distribution, and SA architecture.

The standard contains an object-oriented *data model* that groups all data according the common user functions in objects called Logical Nodes (LN), e.g. for switch control (LN CSWI) or distance protection (LN PDIS). All related data attributes are contained and defined in these Logical Nodes. The access to all the data is provided in a standardized way by the *services* of the standard, which are defined to fulfill the performance requirements.

The data model and services of the standard are mapped to a *mainstream communication* stack consisting of MMS, TCP/IP and Ethernet with priority tagging (Figure 2). By this selection, IEC 61850 is not only open for advances in communication technology but also for a lot of communication architectures. The use of fiber optics and switches overcomes to a large extend the limitation of the non-deterministic behavior of Ethernet regarding collisions and length extensions.

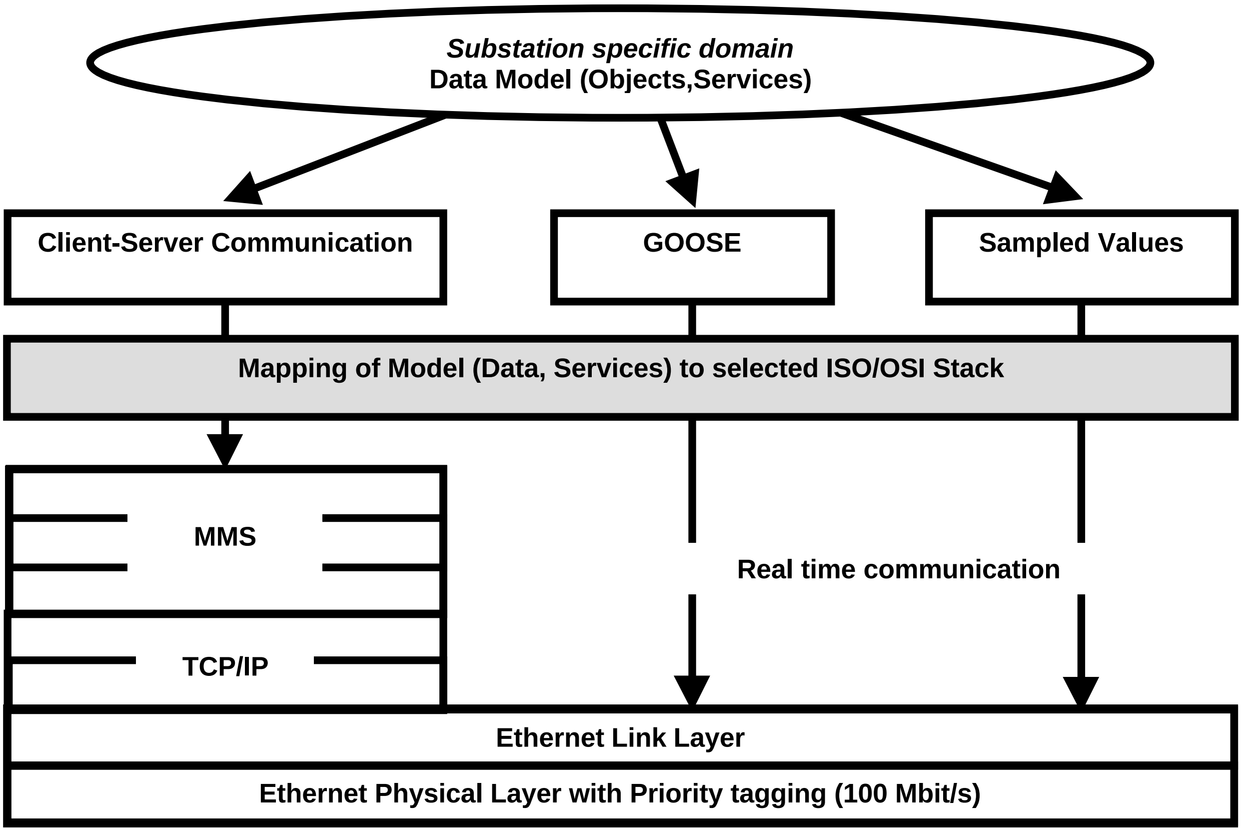

Figure 2 - The mapping of the IEC 61850 data model and services – for details see [3]

The engineering of interoperable Substation Automation systems is supported by the *Substation Configuration description Language (SCL)*, which allows a standardized engineering process by providing the means to exchange standardized configuration data between engineering tools.

5 The specification of IEC 61850 based Substation Automation Systems

5.1 Basic considerations

Using IEC 61850 may imply the change of all the relevant specifications, which are the basis of any project. The main question is what has to be changed since the standard does not standardize functions? This paper focuses on the most important aspects specifying IEC 61850 based Substation Automation systems by utilities or other users. The aspects to be considered are not only functionality and all the data to be communicated and reported but also the requirements for performance and availability. This results in a strict functional specification of the substation, including the requirements for the switchgear, the Substation Automation system, the protection and all other relevant systems and subsystems. On top of this functional specification the utility can add a specification of preferred or required architectures, devices, systems and subsystems.

An important aspect that is outside the specification but that allows to exploit all benefits, is that utility engineers and system integrators may have to consider changing the traditional approach in engineering and applying Substation Automation systems. Especially, the user has to consider what functionality is really needed and what is the behavior of the devices installed up to now.

5.2 Definition of functions and allocation of devices

The single line diagram was up to now the basis of any SA specification. It will continue to be in the future since it gives the context of the Substation Automation system and allows the allocation of functions to the switchgear objects to be controlled, monitored and protected (Figure 3). The behavior and performance of the functions has to be specified as before. Care shall be taken with the full specification of the control centre interface, as long it is a gateway connecting to different protocol worlds. The process interface given by the switchgear must be clearly defined also. There especially the definition of the interfaces being “intelligent” or conventional is important.

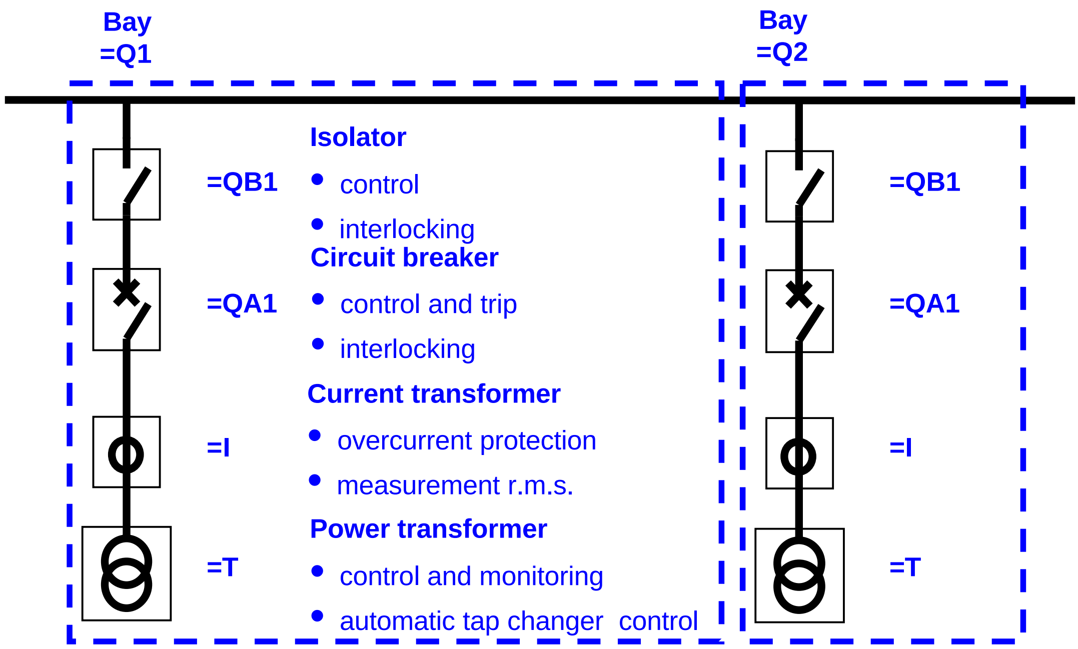

Figure 3 - The single line diagram and the allocated functions (example)

For IEC 61850 based systems, the object oriented data model based on functions and the free allocation of functions does not request to specify devices and, therefore, allows providers to offer an optimized SA system. This is a benefit that users should consider when specifying their Substation Automation system. By specifying more than the functional requirements the specification may prohibit or limit the supply of a technically and economically optimized system

The *functions* specified by the user define the components of the data model, i.e. the *Logical Nodes (LN)* and all its data and attributes. If only mandatory data are needed, no actions are required. The need for optional data or extensions has to be specified.

Last not least the most devices on the market will have a maximum data model supported. The task of the supplier is not to fulfill exactly the requirements but to show how the implemented data model maps on the requirements in the specification.

5.3 Services and signal list

The data being transferred according to IEC 61850 are based both on the necessary *data model* and the applied *communication services*. *Data sets* e.g. for reporting define finally the subset of the data from the data model to be transferred to other applications. The *reporting* is a client-server service mainly between a bay unit and a station level client (substation host, HMI or gateway). In addition, there is a communication service between the bays, or more general, between IEDs called *Generic Object Oriented Substation Events service* GOOSE) mostly used for peer-to-peer communication between IEDs. Therefore, all the *data sets* and the related *transmission conditions* (to be used for the Report and GOOSE control blocks) have to be specified. The standardized data model, however, is implicitly specified by specifying the functional requirements. The result can then be compared with the classical signals list. If the signal list is given only, some backward engineering has to be made by the supplier to match the data model and the data sets with the requirements of this list. However it can also be requested that the system integrator supplies this backward engineering.

5.4 SA system communication architecture

The most of the existing proprietary systems for communication in substations are very inflexible regarding the possible communication architectures. Therefore, no additional requirements have to be stated. The use of mainstream communication means by IEC 61850 such as Ethernet allows for much more flexibility. This flexibility has to be limited both by *availability* and *performance* requirements that the utility has to provide in the specification.

Nearly in all cases, the use of *switched Ethernet* with *priority tagging* is required since this will meet the performance requirements of specific functions within the SA system. For the communication components like switches the same requirements as for protection devices in substations should be specified. This refers to the support of *priority tagging*, *EMC*, the acceptable *temperature range* and the *auxiliary supply* from the station battery (e.g. 110 V or 220 V DC). For the time synchronization, also the *jitter* in the switch may be important. For long sequences of switches like in ring configurations, the *delay* per switch will contribute reasonable to the response time. Jitter and response time are implicitly defined by the requested performance of the impacted functions, the other requirements must be clearly stated e.g. by reference to protection devices. Then any supplier is able to select the proper switches. Examples of SA systems with the same functionality but with different performance requirements are given in Figure 4 (see also [6]). For some level of communication availability, response time and cost, the star type solution may be acceptable, for an higher level in communication availability, the ring with its given ring-redundancy ((in case of loosing one switch only one bay is affected) is the proper solution. The SA functionality of both architectures is exactly the same.

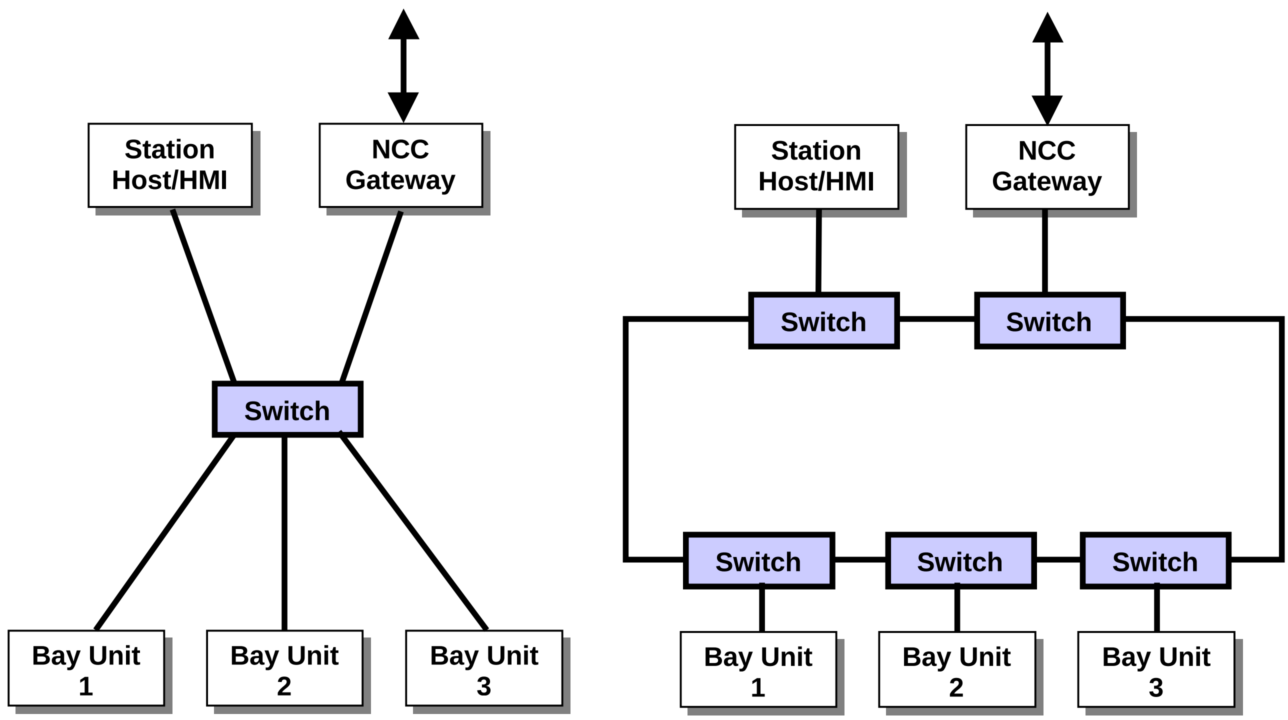

Figure 4 - Different architectures supporting the same functionality with different performance requirements (left star, right ring, three bay units assumed for the example)

5.5 Boundary conditions

For the design of the overall communication system the geography or geometry of the site has to be known including – if applicable - the operators' room, bay houses in the switchyard, cable channels and ducts, the power supply system, and the process interfaces at the switchgear. This is a normal process that is independent from the use of IEC 61850.

5.6 Pre-defined components

Pre-defined components compliant with IEC 61850 can be used at any time but may restrict the optimization process. The same applies to pre-defined subsystems and system architectures. Not all performance and availability requirements specified may be reachable given the demand to use predefined components, subsystems or architectures.

The re-use of existing components and subsystems not compliant with IEC 61850 may be specified. Care should be taken however since this calls for an individual and utility specific *migration strategy,* which is outside the scope of this paper. The process associated with the setup of migration strategies is described in [4]

5.7 System integration and the associated responsibilities

Building multi-vendor SA systems according to IEC 61850, the responsibilities for the different suppliers must be specified in detail. The integration of all components to a system fulfilling the specified behavior and performance is within the responsibility of the *system integrator*. Such a role must be defined in the specifications and the other tendering documents and should be properly negotiated.

6 Conclusions and outlook

How to come from the specification to the SA design was sketched first time in[6]. But nevertheless, the proper specification was and will be the starting point both for a clear offer from suppliers and the user's satisfaction exploiting the benefits of IEC 61850. The basics given here will be studied in much more detail in the ongoing work of WG11 "The introduction of IEC 61850 and its impact on protection and automation within substations" of the Cigré SC B5. This work will not only handle the specification in detail but also the user benefits, procurement, testing, commissioning and maintenance of Substation Automation Systems which is intended to be published at the end of 2005.

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