

# The Standard IEC 61850 as Prerequisite for Intelligent Applications in Substations

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**Abstract**-- The features of the standard IEC 61850 with respect to intelligent applications in substations are summarized. These features refer not only to the use of mainstream communication means but also to its object oriented modeling power and services including real-time data exchange, and to its standardized engineering support. It is shown how modeling of functions independently from its allocation to devices allows optimizing existing applications and opening up for future intelligent applications. The data model provides all information in a substation needed not only for control and protection functions but also about the IEDs and the switchgear configuration. The data grouped in objects provide comprehensive information to the level of detail needed. The compatibility of the IEC 61850 model with the Common Information Model on network level is highlighted. It is shown that all these features facilitate the implementation of intelligent applications and, especially, distributed functions with reasonable effort.

**Index Terms**-- Communication standards, control systems, engineering, modeling, object oriented methods, power system control, protection relaying, real time systems, substations, substation automation.

## I. INTRODUCTION

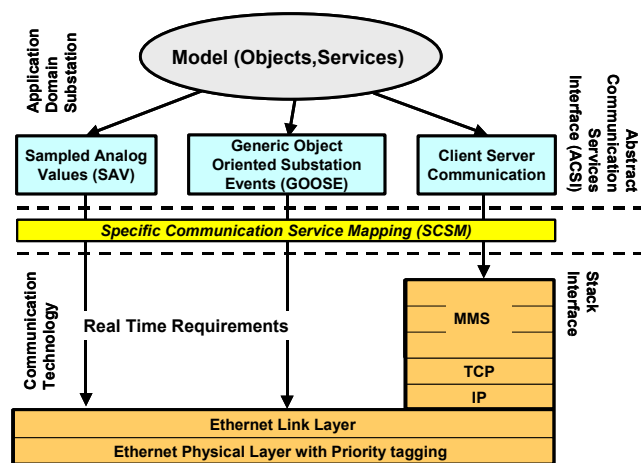
Substations are the nodes in electric power systems. All access and information retrieval for the power system management is done at these nodes. Same holds for nearly all protection functions in the power systems. In older substations these functions are performed by RTUs complemented by protection devices. Today, a lot of substations are equipped with Substation Automation Systems [1], which comprise by definition all functions to be performed in substations. Up to now, most of these systems are collections of devices with dedicated functions only connected to a station level HMI and a NCC gateway. Very often, they do not interoperate function-wise especially if the system is composed by devices from different suppliers because of the missing communication standard. Therefore, substation automation cannot exploit all benefits of state-of-the-art information technology. Both their position in the power system management hierarchy and their increased computation capacities would allow to have such systems as powerful distributed preprocessors for network control systems verifying data and commands and providing

support by local automatics. They could e.g. share the burden stabilizing the power system and safeguarding their assets. They may also reduce the risk for blackouts reasonably. But advanced functions complementing the existing ones and providing much more benefit have been discussed much more than implemented. Their main prerequisite of such intelligent applications is the full access to all data and all resources and the main feature is a dedicated interaction with all basic functions as far as applicable.

The new standard IEC 61850 “*Communication networks and systems in substations*” [2] elaborated by working groups of the Technical Committee 57 of IEC (IEC TC57) is providing standardized communication in substations using both state-of-the-art communication technology and powerful object modeling with high-level engineering support. With this strong backbone the development of new intelligent applications in substations will not only be feasible but also much more easy as before. The following sections will summarize the features of IEC 61850 and highlight its power for intelligent applications.

## II. FEATURES OF IEC 61850

### A. Approach of IEC 61850



**Figure 1 - The approach of IEC 61850**

The approach of IEC 61850 based on the separation of the object model with its data and services from the communication, i.e. from the ISO/OSI seven layer stack (Figure 1). This allows both to follow the state-of-the-art communication technology (stack) and to safeguard the

investments in functions and databases (object model). Therefore, the standard is future-proof as far as possible.

### B. Communication

The communication uses mainstream technology, i.e. an ISO/OSI stack consisting of Ethernet (layers 1 and 2), TCP/IP (layers 3 and 4) and MMS (layers 5-7). The object model and its services are mapped to the application layer of MMS (layer 7), only time critical messages like Sampled Analog Values (SAV) and Generic Object Oriented Substation Events (GOOSE) like status indications, blockings and trips are mapped directly to the link layer of Ethernet (level 2) as seen in Figure 1. Note that today most efforts and money are invested in Ethernet communication technology and that Ethernet goes also nearer and nearer to the process competing with the traditionally field busses [3].

### C. Object Model

Depending on the scope of the standard, the object model is related to the domain substation [4]. All functions including the data images of the process devices are broken into the smallest feasible pieces, which may communicate with each other and - very important - may be implemented separately in dedicated devices. These bricks are objects and called Logical Nodes (LN) in terms of IEC 61850 [4],[5]. Each LN contains data, which may be mandatory, conditional or optional [5]. The data itself contain attributes which may be seen as values or detailed properties of the data [6]. The attributes itself carry values. Missing LNs, data or attributes may be added according to the strict and restrictive extension rules of the standard including name spaces as unambiguously reference (see normative Annex of [5]). These rules preserve interoperability also in case of extensions. Since the names of LNs, data and attributes are standardized, they provide the semantics of all exchanged values. LNs may be grouped into Logical Devices (LD) with non-standardized names. LDs are implemented in servers residing in IEDs (see Figure 2). There is also a Logical Node taking care common properties of this physical device (LPHD). For the full identification of data a hierarchical plant designation system shall be used, preferentially according to IEC 61346 [7].

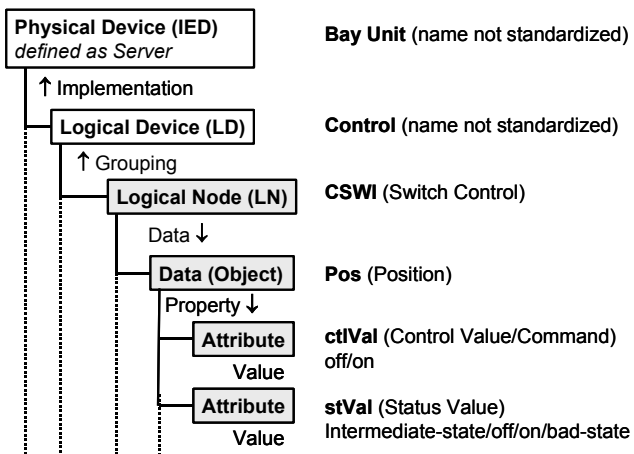


Figure 2 – The object model of IEC 61850

The services to access and retrieve the data are mostly of client-server type. Most common, simple services are *read* and *write*. Dedicated to the application domain are services like *Select before operate* and *Reporting*. Determined by strong time requirements are the services *Transmission of analog samples* (data stream) and *Transmission of GOOSE messages* (peer-to-peer) [8]. The mapping of the model to the stack is defined in [9], [10] and [11].

### D. Engineering Support

Both the device capabilities and the system configuration may be described very conveniently by the Substation Configuration description Language (SCL) [12] based on XML. It comprises the data model including all relevant services, all communication interfaces and communication links. It takes care the allocation of functions to devices and the relationship between the substation automation system and the switchgear. This comprehensive formal description of the configuration allows both tool supported engineering and future extensions by all IEC 61850 compliant tools. The use of such a tool is sketched in Figure 3). The device configuration is imported into the system configurator, which considers the system configuration and provides device configuration files with system information to be downloaded into the IEDs either directly or with help of a device specific tool.

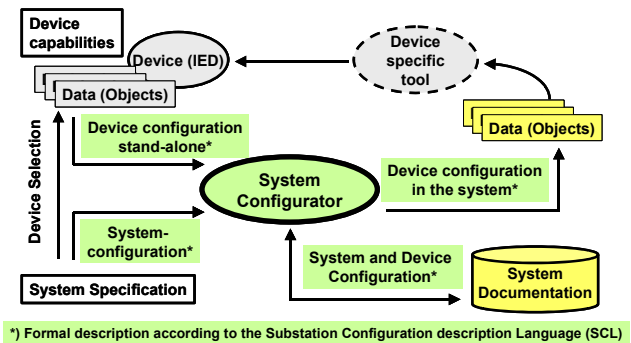


Figure 3 – The use of the Substation Configuration description Language (SCL) for System Engineering

### E. Future development of IEC 61850

#### 1) Applications closely related to the substation

The line protection was not in the original scope of IEC 61850 but the standard contains all logical nodes and services to model both *line distance protection* and *line differential protection* from the communication point of view. Examples for both protection types are given in the informative Annex of [5]. IEC 61850 may also replace the IEEE Std C37.94 regarding optical fiber interfaces between Teleprotection and Multiplexer Equipment [19].

The interface between Substation Automation and the *Network Control Center* (NCC) was also outside the scope of IEC 61850 but the ad-hoc working group (AHWG) 07 of TC57 has proven the feasibility of using IEC 61850 for this communication link also [17] Adding the terms “LN” and “Data” to the CIM model [18] and “Measurement” and

“Conducting Equipment” to the IEC 61850 model (already done) will provide compatibility between both models. All the information enforces the request for *seamless communication* from the switchgear up to the network control center (NCC). It is clear that for wide area connections instead of Ethernet also other lower ISO/OSI layers like micro waves, PDH, SDH and ATM may be used without violating the benefits of such a seamless communication.

First experience in implementing IEC 61850 has shown some few unclear definitions but having no impact on the market introduction of the standard in 2004. The use of IEEE 1588 [13] for hard real-time requirements is not yet stated in the mappings. User groups like UCA@International [14] will collect all such experience and the WG10 of IEC TC57 will create proper *amendments* for IEC 61850. Anyhow, the issue of *Power Quality* will be more elaborated according to a newly accepted work item [15]. More details about *switchgear monitoring* will be added by the product standard for switchgear equipment IEC 62271-003 being now under work in IEC TC 17 [16].

### 2) Applications outside the substation

The IEC TC 88 has adopted approach of IEC 61850 for the communication part of the standard IEC 61400-25 [20] referring to *control and monitoring of wind power plants*. This standard is already in preparation. Based on the same approach a new work item for *communication in Hydro Power Plants* [21] and in the area of *Distributed Power Generation* [22] has been issued for voting end of 2003. It is assumed that in the first quarter of 2004 all new work items will be accepted.

The impact of these new activities on IEC 61850 will be e.g. that some existing Logical Nodes like XGEN (Generator) are elaborated more in detail to fulfill the requirements of power stations and additional data like valve position and wind properties will be available for modeling. Since all these new objects have to be identified by a dedicated name space according to the extension rules in [5], no confusion will arise and interoperability maintained.

### 3) Benefits of the trend using IEC 61850

The intensive use of IEC 61850 in more and more areas of the power system will make the object model more comprehensive for the complete power system and support standardized communication structures in the power area. This trend is a challenge for the development of intelligent applications for the power system (see section III. ).

## III. BENEFITS FOR INTELLIGENT APPLICATIONS

### A. Open communication

#### 1) Benefits of Ethernet

There are a lot of benefits using mainstream communication technology like Ethernet. This technology allows peer-to-communication as early introduced in substations already by ABB using LON [1] with 1.25 Mbit/s. But Ethernet supports this feature openly in the standard at higher and higher speeds starting from 10 MBit/s up to some ten GBit/s for the time being and more in the future. In addition, today the most money for communication is invested into Ethernet

technology and Ethernet is used more and more in process near applications [3] as mentioned above. Switches mitigate or avoid the well-known message collision problems. The communication topology is scalable according to the substation requirements and may also support redundancy without having any impact on the implementation of functions since IEC 61850 makes no definitions of redundancy at application level but leaves it to the communication stack.

#### 2) Process bus, process data and NCITs

IEC 61850 includes for the substation all process bus features like the transmission of samples of currents and voltages and provides a common interface for any kind of instrument transformer starting or increasing the acceptance of Non-Conventional Instrument Transformers (NCIT). The multi-use of these data will serve not only protection but also disturbance recording, phasor measurement and metering. The interface providing this standardized data will be a merging unit (MU) today and maybe the sensor itself in some future. The complementing actuators will be breaker IEDs as seen in

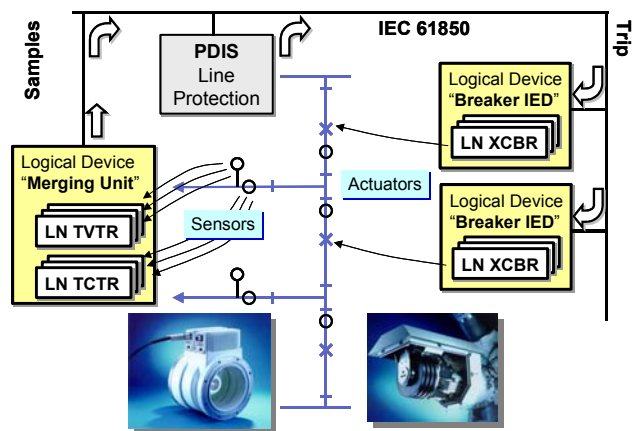


Figure 4 – The use of the process bus according to IEC 61850 for non-conventional switchgear interfaces

Figure 4.

#### 3) Standardized access to all data and resources

The object structure and the communication provide to any intelligent application a standardized access to all data and resources from other functions if applicable (Figure 5).

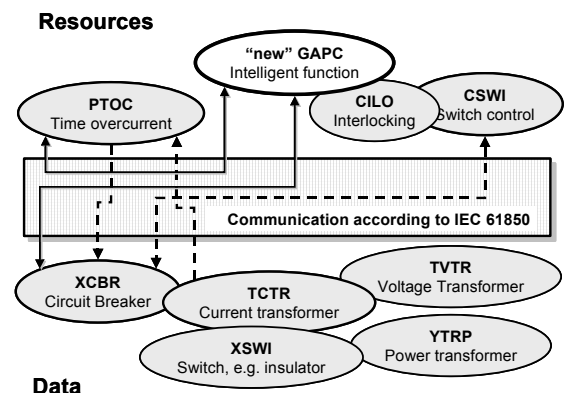


Figure 5 – Data and resources in a substation interlinked

#### 4) *The free allocation of functions*

IEC 61850 makes no prescriptions where the functions are implemented. Mixed configurations may run without notice of the operator. The free allocation allows not only optimizing the existing applications in substations but also optimizing the implementation of new intelligent applications knowing the logical sources of the data only. The allocation of such sources to IEDs is known from the System Configuration Description (SCD) file but of importance for maintenance people only. Optimizing the allocation may also result in more intelligent applications.

#### B. *Interoperability*

##### 1) *Common grammar and semantic understanding*

The common identification of all data according to IEC 61850 regarding syntax, semantics and allocation to switchgear will provide interoperability without complex coding and without reference to manuals. Text fields for self-explanation support this identification for human beings.

##### 2) *Object model*

All substation (and in future all power system) objects are available. The object model allows to access data as single items or in the context of a complex process object. This allows easily tracing the data back to the logical and physical source if necessary. Any new intelligent application may trust at least on the existence of mandatory objects and data. More details about implemented optional data may be extracted by the service *Get directory* or may be taken from the System Configuration Description (SCD) file written in SCL. The mentioned compatibility with CIM allows exploiting the full power of seamless communication.

##### 3) *Common configuration control*

Rules for controlled updates and extension avoid any negativ impact on existing functions and support the add-on of intelligent applications. Configuration changes need no manual re-programming of communication but are controlled by system tools to keep interoperability (see SCL, section II. D).

## IV. CONCLUSION

#### A. *IEC 61850 as prerequisite for intelligent applications*

The features of IEC 61850 show its power for introducing new intelligent applications being more complex and efficient for the power system management, system stability and asset management. Only such clear, standardized and object-oriented communication system gives simple access to all data and resources and allows developing and implementing new intelligent applications with reasonable effort and without disturbing existing ones

#### B. *Creation of intelligent functions by engineers*

IEC 61850 is a high-level communication standard with a lot of additional features regarding functions and engineering. It comprises the know-how of many engineers worldwide in the areas of communication, substations and substation automation including protection. Nevertheless, the new intelligent applications are left as challenge to the creative engineer but IEC 61850 is facilitating his task.

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