Substation Automation based on IEC 61850

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Introduction

The more than 4000 Substation Automation (SA) Systems installed worldwide are proof of the acceptance of such systems and the appreciation of their benefits by the utilities and industry around the globe.

Utilities and industries have long been seeking a global communication standard to facilitate fully integrated and truly interoperable substation automation systems. Under the umbrella of the International Electrical Committee (IEC), representatives from both utilities and suppliers have jointly elaborated the new standard IEC 61850 "Communication Networks and Systems in Substations". Gaining acceptance worldwide, IEC 61850 is the first and only global standard that considers all the communication needs within substations.

To understand the main features of IEC 61850-based substation automation systems and their impact on the specification for such systems, it is important to analyse the evolution and trends going on around the world.

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Trends in the field of substation automation systems

Before the introduction of microprocessor-based equipment and serial communication in substations, protection, control and monitoring were handled separately by different, dedicated pieces of equipment and resulted in the responsibilities being split between various departments inside the organisations of utilities as well as of the suppliers.

With the first deployment of serial communication in substations, the separation between protection, control and monitoring did at first not change significantly. But very quickly users requested a common protocol inside the substation. The first approach in this respect has been made by the introduction of IEC 60870-5-103 as informative interface for protection devices. This protocol is not only restricted to information but also to some protection functions only. In addition, it led to a high temptation to use the private part of the protocol, which was intended for the purposes of ensuring backward compatibility only, for supplier-specific extensions instead.

The development in communication and microprocessor technologies, i.e. with the introduction of the serial communication on the one side, and with the facility to provide numerical multifunctional equipment on the other, has led to a change in the approach to substation automation solutions. In order to optimise a system and to reduce costs, the integration of more and more functions into less and less devices was proposed and has become an ongoing trend. Different functions such as protection, control or monitoring may be combined in one common device e.g. in a bay unit covering all the functionality needed at bay level. Consequently, the specification of such systems including all applications had to be changed fundamentally. Today, the entire functionality provided for protection, control and monitoring of a substation is not handled separately anymore, but typically contained in one common and consistent system.

This also raises the need for more information exchange between all specialists involved in substation automation and protection and therefore increases the pressure for a common communication protocol. All these needs and trends were merged into the new standard IEC 61850 „Communication Networks and Systems in Substations“.

Basics about the standard IEC 61850

The general scope of the standard is designed to support the communication of all functions being performed in the substation.

Its' main goal is interoperability; this is the ability for IEDs from one or different manufacturers to exchange information and use the information for their own functions.

Moreover, the standard allows a free allocation of these functions and accepts any system philosophy, from a distributed architecture (e.g. decentralised substation automation) to a centralised configuration (e.g. RTU based).

The standard separates the functionality represented by the data model and the related communication services from the communication implementation (stack). This makes the standard future-oriented, taking into consideration that the development in the communication

technology is moving quicker than the development of the functionality in the field of substation automation including protection.

The data model of the standard is an object–oriented one, grouping the data into the smallest possible sets referring to the smallest possible functions to be implemented independently. These smallest possible data groups or functions are named Logical Nodes. The Logical Nodes and all Data and Attributes contained are named according to a standardised semantic, which is mandatory.

Each IEC 61850-compliant IED may be configured using its dedicated tool. However, all these IED-tools have to be compliant with IEC 61850. This means that the reading, handling, and writing of configuration files has to be according to the Substation Configuration description Language (SCL) of IEC 61850 as regards the standardized data model, the data access (services) and all communication connections. This allows the system integrator to use understandable data from all devices (independently of the supplier) to build the complete system and to assure data consistency.

Advantages for the users / utilities

First at all proprietary protocols are bound to only be maintained but not developed any further, as customer requests for these will diminish over time. The new global standard IEC 61850 comprehensively addresses customer requirements for fully integrated substation automation systems and is therefore increasingly gaining acceptance with utilities, industry and suppliers all around the world.

The integration of third party equipment is facilitated and the use of a common language (SCL) avoids ambiguities.

Engineering data stored as SCL files can be reused, e.g. in case of extensions (additional bays) or refurbishment.

As the new standard IEC 61850 covers all communication needs within a substation, it also defines the communication to and from the process level, especially the transporting of samples (“process bus”). At the time being, most products available on the market cover the “station bus” only (all communication functions without the transfer of samples) but products supporting the process bus will come out very soon. Therefore, choosing IEC 61850 as communication standard means for the user to also keep the doors open for further optimization possibilities like usage of unconventional current and voltage transformers.

Even if initiated by few suppliers and users, the increasing commitments of suppliers to use and offer the standard IEC 61850 in products and systems has been clearly demonstrated at the UCA International exhibition at the CIGRE Symposium 2004 in Paris.

Impact of IEC 61850 on specification

The standard has an impact on all activities related to the field of protection and substation automation but the main issues are how to implement the standard in practice, which is to be done by the suppliers, and how to specify protection and substation automation systems, which is to be done by the users like utilities.

The basis for any Substation Automation specification remains the single line diagram of the substation to be controlled, protected and monitored as well as the allocation of functions to the switchgear objects. In this respect the process interface given by the switchgear has to be clearly defined, whether this interface is conventional or based on the serial process bus using actuators and sensors.

As already mentioned above, some changes in the technologies used for Substation Automation and Protection have been very important like the use of serial communication and of multifunctional equipment. This means that all requested functionality is specified without reference to any possible implementation in devices. IEC 61850 is already based on this approach. This is the condition to be respected in order to allow the system integrator to elaborate an optimal solution, also taking into consideration other aspects such as the requested performance and possible project constraints of the system, which are described below in more detail.

As the standard is not defining the quality of functions, the behaviour and performance of all functions have to be specified as before. Typical examples are performance of a distance protection (precision, tripping times, etc) or interlocking logics based on the single line diagram.

One of the constraints is the allocation of functions. Each manufacturer of protection devices still decides by itself which functions can be provided in one device, what algorithms with what performance are used, and which setting information is required by the corresponding tool. Thus, if these parts are important to a user, the user still needs to add them into the specification by defining their preferred allocation to devices.

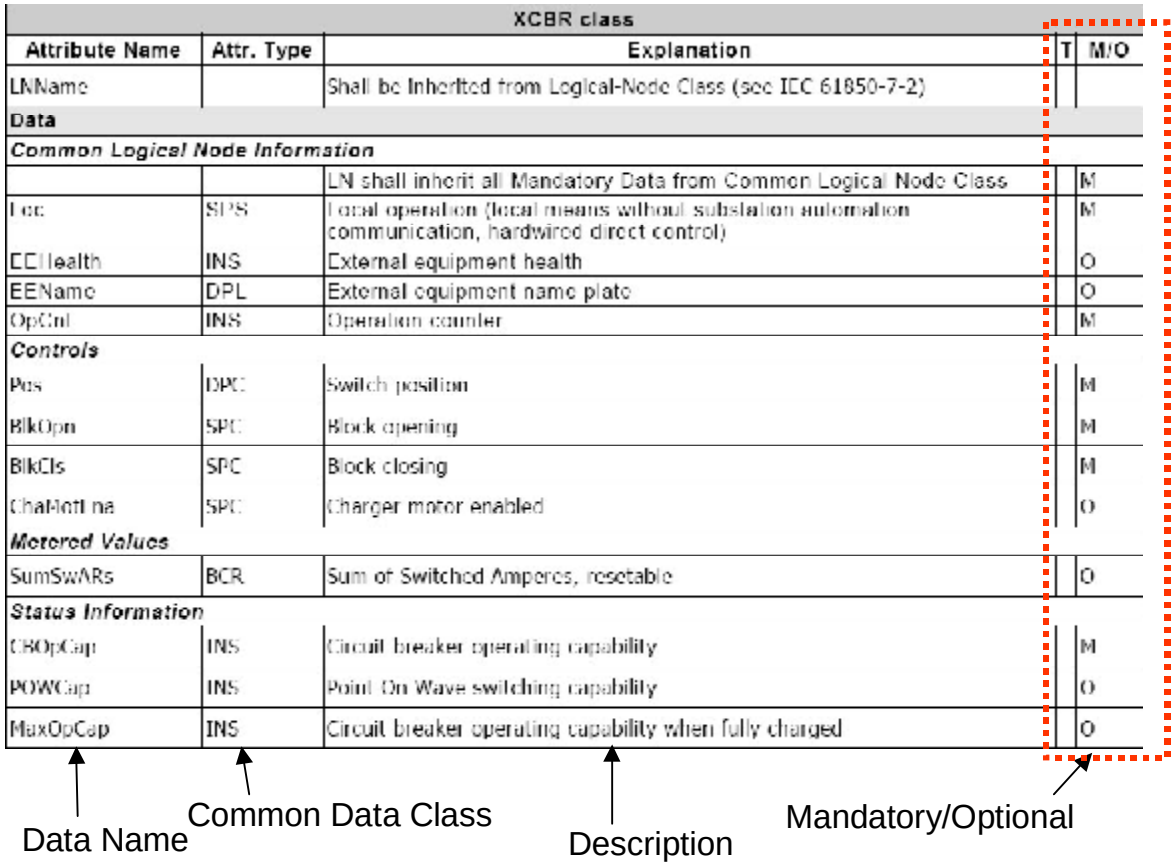
Specifying according to the standard IEC 61850 means that the entire functionality is split into Logical Nodes with their corresponding data, i.e. with the common language for the signal names defined in the standard. If this is not done in the specification already, the system integrator has to do it. Anyway, the people anywhere in charge of the project execution (design, engineering, testing, FAT, commissioning, SAT, operation, etc) will once has to learn this common language. It is an advantage to, from now on, achieve as much as possible and as quick as possible compliance with the standard.

The standard indicates mandatory and optional data. An example concerning the Logical Node for a Circuit breaker is given in figure 1.

It is recommended to check the “old” lists of all signals and evaluate which ones are really needed, what purpose they have and which functions they belong to. If no details are specified, all data defined as mandatory are provided according to the data model in IEC 61850. Otherwise, all needed optional data have to be listed. If only signal lists are provided, the system designer and integrator will translate these into the data model and associated services.

The use of the already mentioned standardized Substation Configuration description Language (SCL) has an important advantage, i.e. the integrity of data is ensured by using one single data entry. For example, if the specification is already using SCL of IEC 61850, the system designer and integrator can take this information directly into its design and engineering tool.

For interoperability, not only data have to be standardized but also the access to these data called services refer to the part 7-2 Abstract Communication Services (ACSI) in the IEC 61850 standard. The communication services are used for vertical and horizontal communication but also for time synchronization and file transfer.



XCBR class				
Attribute Name	Attr. Type	Explanation	T	M/O
LNName		Shall be inherited from Logical-Node Class (see IEC 61850-7-2)		
Data				
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class		M
Loc	SPS	Local operation (local means without substation automation communication, hardwired direct control)		M
EEHealth	INS	External equipment health		O
EEName	DPL	External equipment name plate		O
OpCnt	INS	Operation counter		M
Controls				
Pos	DPC	Switch position		M
BlkOpn	SPC	Block opening		M
BlkCls	SPC	Block closing		M
ChaMotEna	SPC	Charger motor enabled		O
Metered Values				
SumSwARs	BCR	Sum of Switched Amperes, resetable		O
Status Information				
CBOpCap	INS	Circuit breaker operating capability		M
POWCap	INS	Point On Wave switching capability		O
MaxOpCap	INS	Circuit breaker operating capability when fully charged		O

Figure 1 Data of the Logical Node for a Circuit Breaker

- Vertical communication

Station control and monitoring are the basis tasks of a substation automation system. This comprises:

- Local operation of the switchgear and other high voltage equipment
- Acquisition of switchgear information and power system measurands
- Handling of events and alarms.

This application is related to human operation of the station. The data communication for this application is directed *vertically*, i.e. from station control level down to bay level (commands of any kind from the operators place) or reverse (binary indications like breakers or isolators position, measurands from instrument transformers and other sensors, events, alarms). This vertical communication (bay - station) is based in client-server concept and the following services are used (see figure 2):

- Reporting
- Commands

- File transfer.

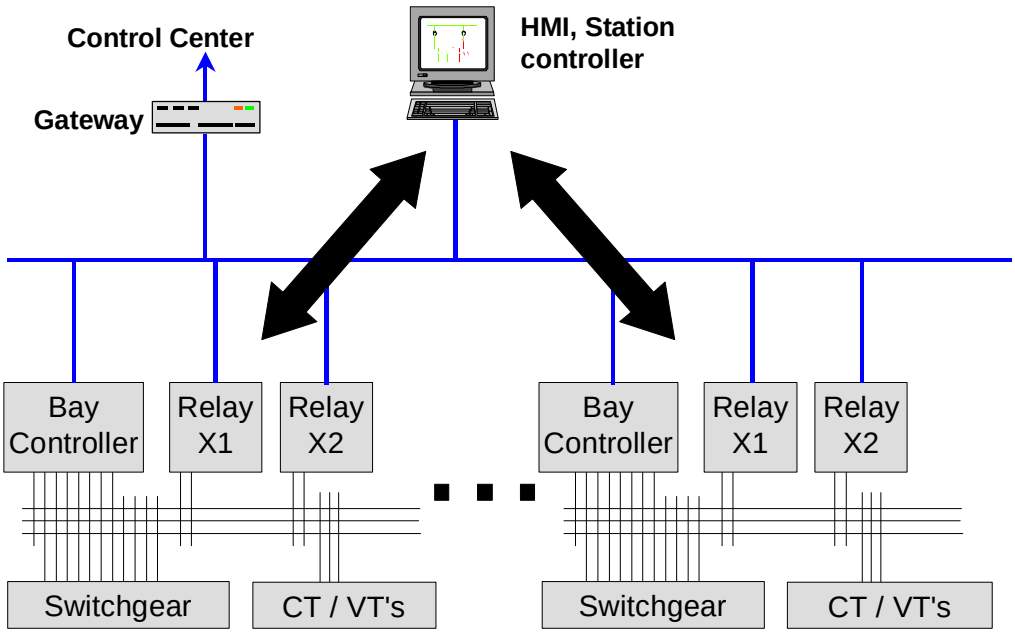


Figure 2 Vertical communication in the substation automation system with hardwired process interface

The reporting is mainly used for the communication of the bay level devices to the station level devices. Data like status information events and measurements are sent using the reporting. The standard describes several methods for the reporting. Where as the buffered reporting is the preferred one to ensure that no information is lost during a communication interruption.

Commands are used to control different object within the system. The standard defines also concerning the control different methods. It covers control for primary equipment as well as for other functions. For the control of the primary equipment the use of the control model select-before-execute with enhanced security is the preferred one to ensure save and secure operation. For other control like e.g. reset of LEDs the simple direct control fulfils the requirements.

To transfer disturbance recorder files from e.g. a protection device to the station computer the file transfer service is required. Depending on the used products either FTP or IEC 61850/MMS are the most accepted methods.

Even considering that IEC 61850 also defines certain response time classes for various data exchanges, it does not consider the complete performance per function or per system. It is therefore recommended to outline the function and system performance in the specification by

defining at least the minimal response times for sending commands (e.g. from closing or opening command until the command reaches the breaker; breaker time is part of the specification of the primary equipment) and receiving process data.

In terms of vertical communication, also the interface (protocol) to the NCC (Network Control Centre) has to be defined. This needs a gateway for conversion from IEC 61850 to the NCC protocol.

- Horizontal communication

In the horizontal communication (see figure 3), time critical information exchange may be done using copper wiring with contacts and auxiliary relays or using the serial communication. This concerns exchange of information between bays (e.g. station interlocking) and exchange of information between functions inside the bay (e.g. exchange of information between line protection and recloser).

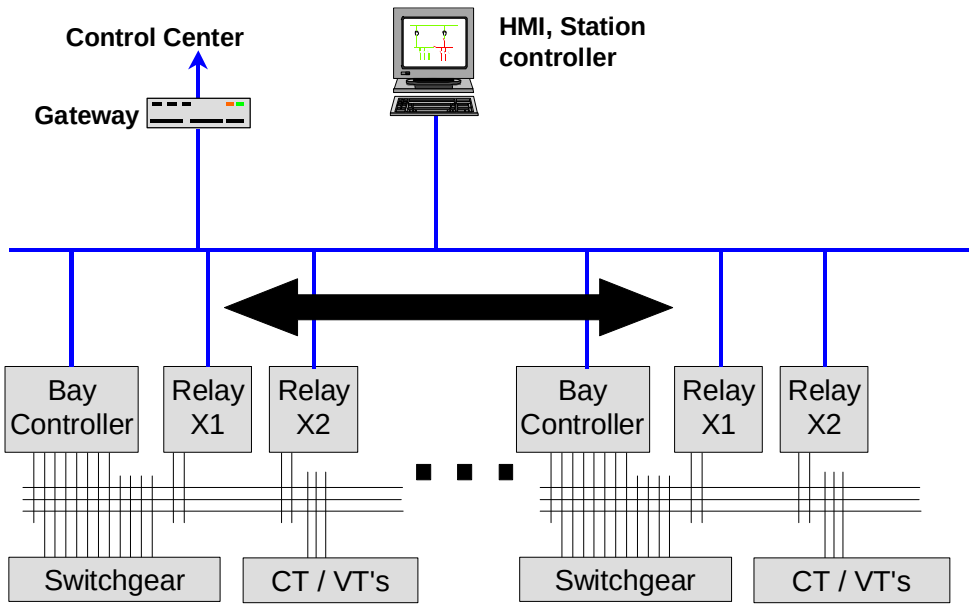


Figure 3 Horizontal communication in the substation automation system with hardwired process interface

Without further statement, the system designer and integrator will be free to choose the most appropriate solution. It is recommended that the user indicates if this exchange of information should be done via serial communication. Depending on the required functionality, performance and availability used IEDs either hardwired or serial communication can be used. It is today not possible to make a general statement that one or the other method is

superior. Depending on the previous mentioned criteria's the decision has to be made on a case-by-case basis.

- Time Synchronization

Also the time synchronization for tagging is realised using the serial communication. The standard defines two possibilities for the time synchronization. The one that is used today for the synchronization is SNTP. This protocol allows sufficient accurate time stamping for the bay level and station level devices. Usually and accuracy of 1ms is achieved.

- Ethernet architecture considerations

To set up an appropriate system architecture, the requested availability should be specified. But in many cases it is more convenient to define failure scenarios with accepted and non-accepted losses instead of figures for availability providing the same information for system design.

Also the geographical layout (extension, buildings, cable channels, etc) may have an impact on the choice of the optimal architecture and the number of needed Ethernet switches. These Ethernet switches of course have to fulfil the hardened requirements as for numerical protection in respect of temperature, EMC, power supply (from the station battery). To fulfil all the different real-time performance requirements the switches have also to support priority tagging. Highest flexibility for switch selection and maintenance is given by external switches (not integrated in the IEDs). In this case no communication degradation of the Ethernet network (especially valid for Ethernet rings) happens in case a bay device is taken out of service. To maintain interoperability, a commonly accepted mechanism like the spanning tree algorithm for recovery after a communication network failure is needed as long as these network features are not yet defined by IEC 61850 left as task for a future version.

- System design main aspects

With the basic features of the specification mentioned up to now, the system designer has a lot of freedom in respect of function allocation and communication. But in many cases several constraints may limit this choice.

The main aspects influencing the system design are:

- The geographical arrangement of the SA equipment in the substation (e.g. decentralised kiosk, centralised rooms for the whole secondary technique; requirements for decentralised busbar protection scheme)
- Already existing devices or "homologated" devices to be used
- Requirements to use third party equipment (e.g. main 1 and main 2 from different manufacturers)
- Requirements from operation or maintenance philosophy or dedicated practices (e.g. the level of functional integration not allowed or requested: main 1 / main 2 in separate

cubicles, recloser in the controller accepted or not, integration of control and bay protection functions in one single device per bay, necessity for "Select-before-Operate")

- Indications from the user if he already intends or imposes the use the serial communication at all possible levels: for exchange of signals between bays (e.g. station interlocking), for exchange of signals between devices inside a bay (e.g. between distance protection and recloser), for some distributed functions as synchrocheck or breaker failure protection. Probably the first step will be to request the use of serial communication for all communication between bays and station level but to be compliant for all data inside the substation.

A prerequisite for reasonable project execution is the use of components, which are proven to be compliant with IEC 61850. It should be requested that the IED-supplier provides a test certificate for each device to be used in the offered system. It has to be mentioned that an IEC 61850-compliant device has to be documented also with a SCL file called IED Capability Description file (ICD).

In case of refurbishment, additional important requirements have to be specified and considered like

- Necessary adaptation respectively interfaces to the part of the existing equipment, which will not be immediately replaced
- Maximum acceptable interruption time to migrate to the new system
- Strategy for the refurbishment: one step refurbishment or step-by-step migration in order to have as quickly as possible a completely refurbished and IEC 61850-compliant substation. IEC 61850.

All the abovementioned constraints will strongly influence the choice of the right and optimised solution and its implementation.

- Some other aspects of the specification

- HMI at station level:
  The HMI at station level is to be defined as before
- Documentation and maintenance:
  The system engineering is done and documented with the help of the Substation Configuration description Language (SCL). The object-oriented data model with its standardised services provides very easy access to all data in the system and prevents misunderstandings about their semantic meaning. The SCL-files are a much clearer guideline for searching and fixing failures in the system than any printed description. They may be reused at any time for the engineering of adaptations, extensions and also future refurbishment as long as not only the IEDs but also the tools stay compliant with IEC 61850.

Conclusions

The standard doesn't impose any restriction concerning the system architecture.

The standard defines common naming for a common understanding

The introduction of IEC 61850-based solutions means for the user an investment into a future-proof system. It already takes into account the possible evolution of the technology, e.g. the introduction of the process bus with new sensors and actuators.

The standard IE 61850 gives a methodology, which will now be applied in other applications as for example for wind farms, hydro power plants, distributed energy resources (DER)

Communication aspects outside the substation (e.g. between both ends of the line) will be addressed also soon.

In this respect any expert of utilities, manufacturers or consultants will have the challenge to learn and use IEC 61850 compliant solutions.

References

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