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Substation Automation System Using IEC 61850

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Abstract: *Substation has a critical role in power network because it is a subsidiary station of an electricity generation, transmission and distribution system where voltage is transformed from high to low or the reverse with power transformers. All devices in substation are controlled, protected and monitored by substation automation system (SAS) that collects information from the power equipment (process) and performs actions on it. Communication network is a fundamental element in all automation system and network performances can have a critical impact on the control process. In the past decade, new communication standard have been designed and retrofitted into substations. IEC61850 is a new international standard for substation automation.*
In this paper, the authors describe some important feature of IEC 61850 as an international communication standard in substation automation system, that separate this standard from other communication standard in substation.

Keywords: Substation Automation System (SAS), IEC 61850, GOOSE messages, Interoperability.

1. Introduction

Demands for better quality electricity and the evolution of the electric generation are the most significant factors for progressing substation automation. Interruption's cost in electricity supply is increasing and the electricity distribution companies want reduce it and offer better quality electricity. Substation automation has a critical role for these matters. In the other side one of the important blocks out reasons is related to device in conventional substation, also lacking of data in substation makes wrong decision especially in critical time. Therefore another way besides replacing new equipment is reduce human error to decrease block out in power network. Changing in automation system is the best way to increase reliability in online conventional substation because the new system can work beside old system as subsidiary system in parallel mode.
The automation functions for monitoring, protection and control within a substation and utilized recent improvements in the fields of electronics and communication technologies are provided by Substation Automation System.

The IEC 61850 standard based on Ethernet is the International standard for communications within substations which was established between 2003 and 2005 and has become very popular and its application has increased very quickly in these days [1, 4and 15].

In this paper substation automation system describes in part 2 and the IEC 61850 standard and its most important feature such as time synchronization and interoperability discuss in part 3.

2. Substation Automation Structure

All functions in substation automation can be divided into three levels: process, bay, and station level functions [6, 15]. See figure 1.

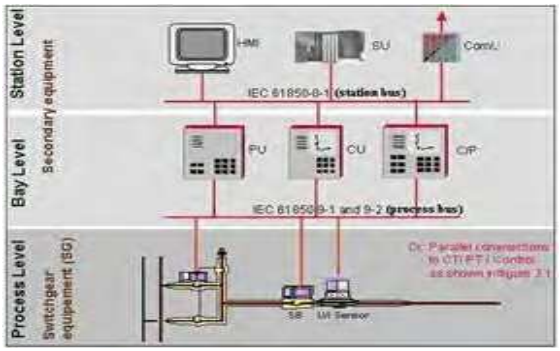

Fig 1 substation automation levels

Process level is the lowest level where the switchgear equipment is located including the sensors and actuators that are necessary to monitor and operate the switchgear.

The process level contains devices such as: circuit breakers, current transformers, etc.

The bay level is the middle level where the protection distributed control equipment is located. These devices are generally hardwired to bay level and the transferred data basically consists of binary and analogue input or output information such as voltage and current

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transformer outputs and trip controls from the protective relay.

The station level is the upper level where centralized system computers, Human Machine Interface (HMI) and gateways for connections to Network Control Center (NCC) are located [6 and 7].

At the process level may also be Intelligent Electronic Devices (IEDs), such as intelligent sensors and actuators. Process level IEDs are connected to process bus usually based on Local Area Network (LAN) technology. The future visions are that the all process level devices would be connected to the process bus, so that no hardwiring will be needed. IEC 61850 discusses in next part as a communication protocol between bay level and process level [15].

3. IEC 61850 communication protocol

The development in electric substation automation has not been particularly fast since the mixing of several communication standards were difficult; therefore single universal standard is needed. The substation standard IEC 61850 has already been proven to be reliable and suitable for this purpose. IEC 61850 is relatively new standard, and it has already been demonstrated successfully in several working substations. The IEC 61850 has been considered to replace, not only the substation communication standards, but communication to the control room too [15].

The international standard, which has been developed with major manufacturers, its main purpose is to bring new common communication rules to the substation automation, which would replace older communication standards. It provides an effective response to the needs of the open, deregulated energy market, which requires both reliable networks and extremely flexible technology and the standard is flexible enough to adapt to the substation challenges of the next twenty years. IEC 61850 has not only taken over the drive of the communication technology of the office networking sector, but it has also adopted the best possible protocols and configurations for high functionality and reliable data transmission. And the more advantages and the Main features of IEC 61850 are: [17, 6, 8, and 10]

- Interoperability by various manufacturer's IEDs as An integrated system [8]
- High data transfer among IEDs considering peer to Peer communication model instead of master-slave Communication model in previewed protocols [16]
- Data definition based on advanced object-oriented Model which contains whole data specifications Instead of single-oriented model with each data Definition by numeric addresses [7]
- Supporting functionality of devices to provide better Communication [7]
- Communication extendibility and data integrity
- Providing integrated communication system.
- Support of sampled value exchange.
- File transfer for disturbance recordings.
- Communication services to connect primary equipment such as instrument transducers to relays.
- Increasing reliability by proper bus topology
- IEC 61850 offers a complete set of specifications covering all communication issues inside a substation.

3.1 Interoperability

The objective of the IEC 61850 was for designing a communication System that provides interoperability between the functions to be performed in a substation although residing in devices from different vendors, with the same Functional and operational requirements.

Since the emergence of the microprocessor relays, manufacturers have had their own protocols for communication between IEDs (Intelligent Electronic Device). Because of the different protocols in multi-manufacturer SAS (Substation Automation Systems), costly protocol converters have to be used. It creates large amounts of engineering work for system designing, testing and etc. All these reasons have generated needs for a single universal protocol that satisfies both manufacturers and the end users. Interoperability between different manufacturers IED's is a major factor in developing substation automation. With interoperability all vendors provide manufacturer independent system with flexible extensibility and functionality [10]. The main purpose of the new standard is that products from different vendors can easily be integrated to one substation infrastructure. This is done by defining the station bus. [8, 9]

3.2 Horizontal Communication

Horizontal communication is a service that can be best describe as fast peer to peer communication between devices see figure 2.

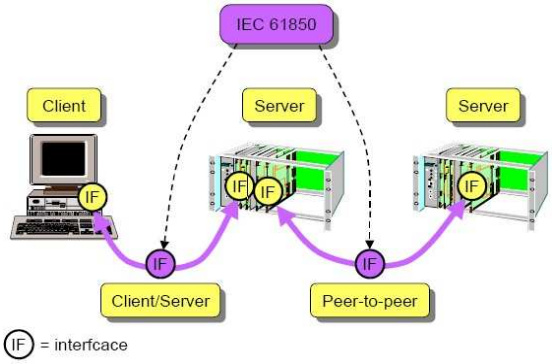

Fig 2 peer to peer communication

This kind of communication is very important especially in time critical function that must be highly reliable. It is based on multicast asynchronous reporting of an IEDs digital outputs status to other devices enrolled to receive it during the configuration stages of the substation and it defined as GSE (Generic Substation Event) with two below form in IEC61850;

- GOOSE (Generic Object Oriented Substation Event)
- GSSE (Generic Substation Status Event)

GOOSE messages are used in distributed recording and also some example of use GOOSE include sending a high speed peer to peer message for breaker failure protection and provide distribution bus protection based GOOSE messages from the IED feeder protection [16].

3.3 Distributed function using object oriented model

A One physical device can be defined by one or many logical devices. Multiple logical devices are used to separate functions in single physical device, which Logical nodes are construct from data classes or data objects, each of which contains data attributes, See fig 3 [16] .The standard defines concepts and some rules for physical devices and for logical devices and Logical devices are defined by logical nodes. The logical nodes describe the functions and functional interfaces. A function may be constructed from multiple logical nodes and the logical nodes can be located in different physical devices. Then the function is called distributed, see fig 4 [7]. The logical nodes are linked by logical connections, which are independent of the physical connections with the use of Ethernet solutions [3 and 16].

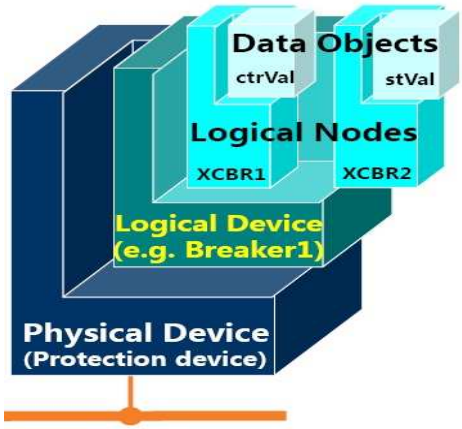

Fig 3 IEC 61850 class model [16]

The standard defines rules for creating new logical nodes and common data classes. The rules for creating new objects have been defined to preserve interoperability.

The data point reference constructs like the IED is modeled but instead of an index number this reference that are understandable without additional decoding aid. Naming systems are universal and easy to understand with IEC 61850 standards. See fig 4.

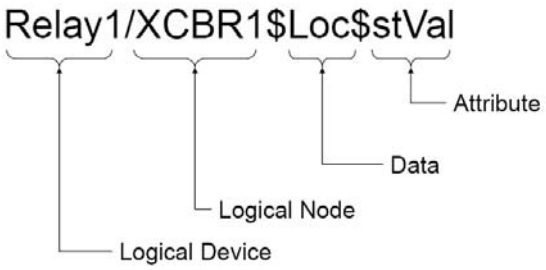

Fig 4 object name structure

The logical node concept is in major role in the whole standard. The logical nodes are the basic objects that exchange information and the "backbone" to model real devices. The logical nodes contain some mandatory predefined sets of data objects with specific data attributes. All these concepts have a logical structures and strong semantics related to real substation automation devices and tasks. The information contained in logical nodes is exchanged by services with well-defined rules and performance requirements [16].

IEC 61850 standard has been created to be functionally flexible and expandable. See fig 5.

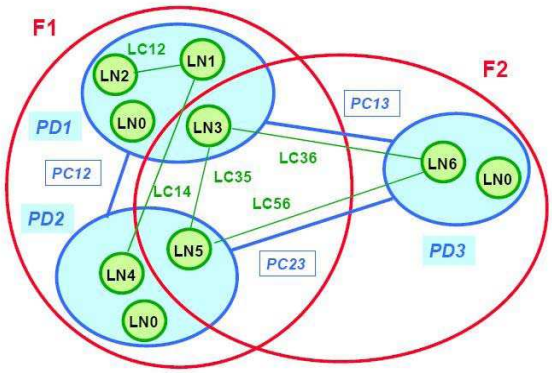

Fig 5 flexible functionality of LNs in different IEDs [7]

It uses communication information technology, which support variety of services with selection of performance requirements with Fast communication between individual IEDs that enables bay to bay communication. With bay to bay communication for example interlocking function can be executed trough communication lines. So with IEC 61850 IEDs can communicate with each others, by publishing and subscribing Generic Object Oriented Substation Event (GOOSE) messages. And also this message can increase reliability which discuss in reference [5]. Utilization of Object Oriented model improves functionality of system because with GOOSE messages and horizontal communication, the information is accessible over the substation from different IEDs, See fig 5, [2, 3and 7].

3.4 Time synchronization

Because of substation events have strict performance requirements the time synchronization has important role in IEC 61850. With the IEC 61850 a vast amount of information is available in a fast rate and in order to organize for example events from several IEDs in a database, the time source must be able to provide coherent time to all IEDs. When a substation even occurs the event information has to be organized in the storages in the same order as they are published. This way the right sequence of event can be restored and right decisions and calculation can be made.

The IEC 61850 standards states that the time synchronization method with accuracies in range of millisecond in LAN that should be NTP (Network Time Protocol) and SNTP (Simple Network Time Protocol). Radio signals and GPS (Global Position System) can be used also to implement time synchronization. It is theoretically possible to achieve high precision synchronization with the GPS, but such system would be very expensive compared to LAN solutions. [11]

The problem with conventional solution with SNTP is that it is only able to provide accuracy about 1 millisecond, which is not enough for raw data sample values and for merging units. One solution is using PTP (Precision Time Control) described in IEEE 1588 standard has been developed to meet these requirements. With PTP it is possible achieve less than one microsecond accuracy with the distributed clocks through Ethernet.PTP is becoming more popular solution not only in substation automation, but in all automation which needs time synchronization. It had been available in network switches for several years however unfortunately until recent years it was not implemented practically in any protection and control IED [11].

3.5 Substation bus topology

There are three basic topologies to implement physical communication: bus topology, ring topology, and star topology. The solution for substation bus is widely researched topic. Since Ethernet provides flexible base for the bus, and the IEC 61850 series does not require a specific type of solution, the different solution has to be tested and discussed for redundancy, performance, disturbance and network security on different articles. Different topologies have different pros and cons. Some topologies are better for performance and some for redundancy. Often the availability and reliability requirement demand for a ring type of bus topology, but in some cases the star type is acceptable. It depend on substation that important substations need robust and reliable topology. Reference [14] classifies substation and propose suitable architect on bay level; so is possible to find the best solution for every substation type. For example star-ring topology proposed because Reliability can be achieved by connecting the cascaded switches by the end switches in a loop via one extra switch connected to the station level devices [12]. And the other side in small and non important destination, that no real redundancy is required and multiple Ethernet switches would cost too much, start topology is justified [1and13].

Usually mixed approaches are used in substation projects for meeting the standards requirement, lowering communication system costs etc. one of the best Communication Network Architecture for improving reliability that shown in Fig 6. Also The performance evaluation of the proposed architecture are fault proof and has fast and deterministic data-delivery characteristics that discuss in reference [1].

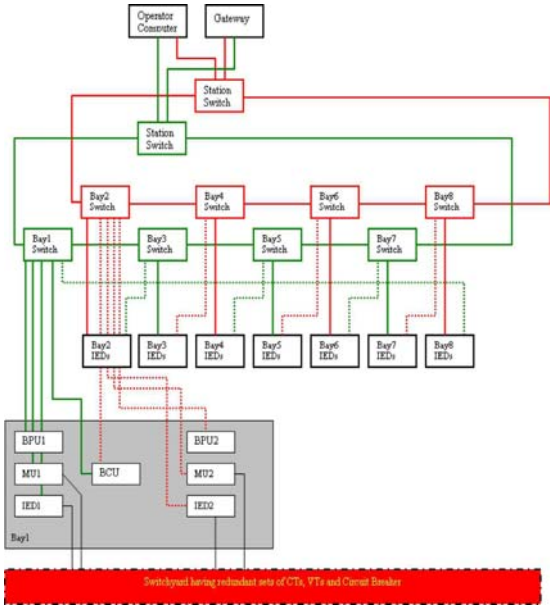

Fig 6 proposed structure [1]

4. Conclusion

Organization all data in IEDs is major role in every communication protocol but the older protocols did not specify how the data should be organized in substation, they only defined how the data should be transmitted through the wire. Whereas IEC 61850 standard organize all of data in IEDs. And also the most important object of implant IEC 61850 is interoperability between IEDs from different vendors.

This new standard is more powerful to flexibility and functionality by implement Object Oriented model and fast GOOSE messages between IEDs and also possibility to achieve less than one microsecond accuracy with the distributed clocks through Ethernet by GPS system and IEEE 1588 standard.

At last with a lot of advantages of IEC 61850, it will be use in smart substation on smart grids [4, 17].

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