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SUBSTATION AUTOMATION SYSTEM BASED 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. Substation Automation Systems (SASs) are widely used for the purpose of control, protection, monitoring, communication etc. in substations to improve the reliability of the power system. SASs adopting IT based solutions such as Ethernet LAN have recently become more common, although hardwired control has been used in the past in earlier versions of SAS utilizing simple communication methods. Moreover, the IEC61850 standard has been issued as the new global communication standard for substations. The standard consists of ten parts, the final part being issued in 2005. Subsequently IEC61850 has been applied widely in SASs around the world.

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.

I. INTRODUCTION

Interruption's cost in electricity supply is increasing and the electricity distribution company's wants reduce it and offer better quality electricity. Substation automation has a critical role for these matters.

Substation Automation Systems (SAS) are widely-used for the purpose of control, protection, monitoring, communication etc. in the substation to improve the reliability of the power system. SASs using IT, such as Ethernet LAN have recently become more common, although hardwired control has been used in the past in earlier versions of SAS utilising simple communication methods. Moreover, IEC 61850, which is the international standard for communications within substations, has been published, and the application of SASs based on IEC 61850 is increasing. [9, 15]

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

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

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 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.

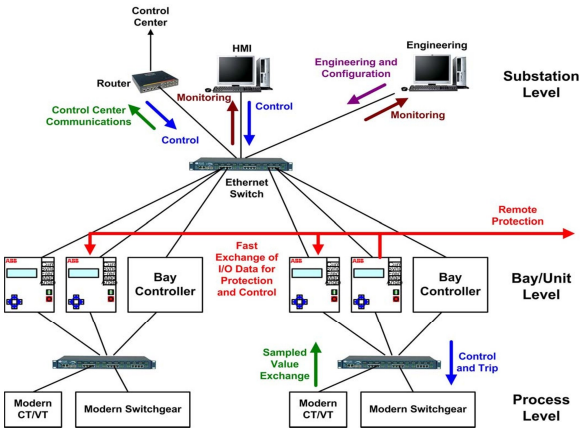

Fig 1 substation automation levels based IEC61850

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.

II. IEC61850 STANDARD

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]. It contain 10 part according to below Picture. See figure 2.

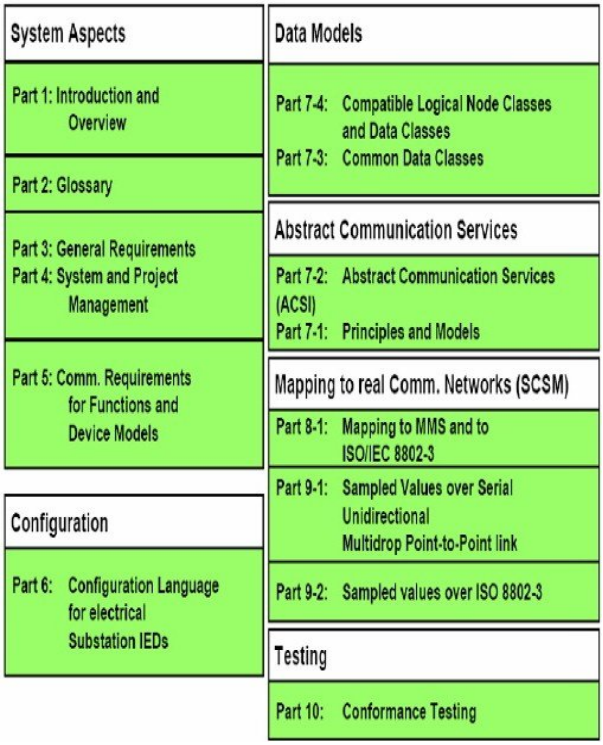

Fig 2 IEC 61850 standard

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, and 10]

- Interoperability by various manufacturer's IEDs as An integrated system
- peer to Peer communication model instead of master-slave Communication model in previewed protocols.
- Object-oriented Model which contains whole data specifications Instead of single-oriented model with each data Definition by numeric addresses.
- Supporting functionality of devices to provide better Communication.
- Communication extendibility and data integrity
- Providing integrated communication system.
- Accurate function by Time Synchronization
- 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 topology
- IEC 61850 offers a complete set of specifications covering all communication issues inside a substation.

A. 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. See figure 3.

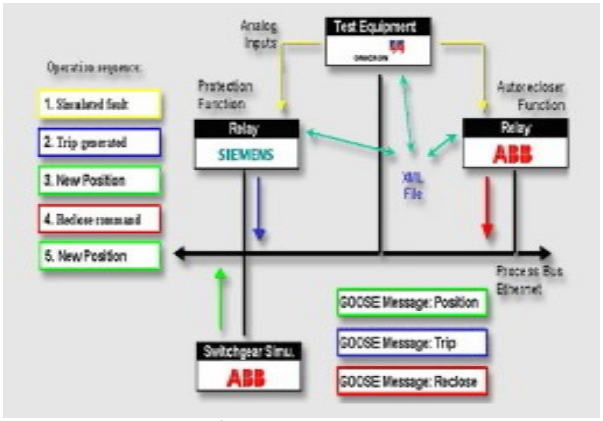

Fig 3 The New Standard of Interoperability

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 and 5]

Fig 4 IEC61850 International Standard

B. Peer to peer communication

One of the services for data exchange is horizontal communication, which can be best described as fast peer-to-peer communication between devices. The possible application of this communication can replace present solutions of protection and control realized by hardwired schemes. It is used to replace the hard wired control signals exchange between IEDs for protection and control purposes in IEC61850.

This is an extremely important and very time critical function that must be highly reliable. It is defined as GSE (Generic Substation Event) in IEC 61850 and is based on a multicast asynchronous reporting of an IEDs digital outputs status to other peer devices enrolled to receive it during the configuration stages of the substation integration process.

IEC 61850 has two forms of GSE:

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

Some examples of the use of GOOSE messages include sending a high-speed message for Breaker Failure Protection to trip the adjacent breakers or to provide distribution or sub-transmission bus protection based on GOOSE messages from the feeder protection IEDs. GOOSE messages can also be used for distributed recording applications.[16]

C. Object Oriented model

In the IEC 61850 environment, protection and control functions are broken into smaller units called Logical Nodes(LN). These virtual units are in fact the objects defined in the object oriented context of the standard, and present one of the most important advantages of the standard over legacy protocols. There are a total of 92 LNs defined in IEC 61850 that correspond to various protection, protection related, control, metering, and monitoring functions as well as the physical components such as the transformers and breakers.

Each LN can have a few or up to 30 data objects, each of which belonging to a Common Data Class (CDC). Each data object in turn has a few or more than 20 data attributes. The LNs can be on any of the three levels defined for substation automation. It should be noted that each physical device such as an IED can host several logical nodes depending on its functionality. These LNs are grouped into logical devices (LD) which are defined in the context of the physical device with each physical device containing at least one logical device.[2, 3and 7]

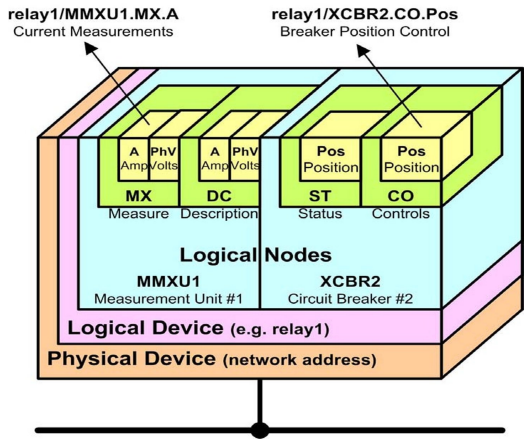

Fig 5 Object Oriented model in IEC61850

IEC 61850 defines an abundance of services that act upon the data objects of the LNs. These services not only cover the traditional control/read/write commands, but they also cover new and expanded services for grouping the data objects, reporting and logging, as well as transmitting the fast messages between devices.

D. 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].

E. Disturbance recordings

The IEC 61850 international standard enables the development of different distributed waveform recording systems. It allows a new approach to recording of transients, faults or other abnormal conditions with sampling rate of 256 samples/cycle. Sampled Analog Values from multiple interface units are multicast and used by a central recording unit for waveform recording.
The distributed waveform recording system architecture includes three types of devices: [15]

- Recording device
- Interface device
- Synchronization device

F. 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 [13].

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].

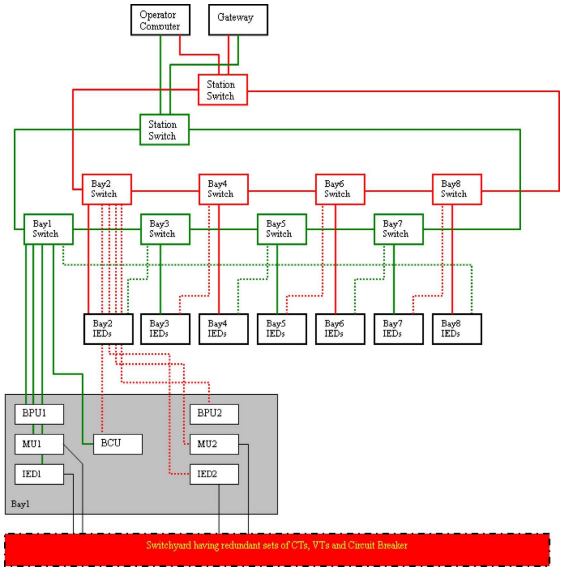

Fig 6 proposed structure [1]

III. CONCLUSIONS

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 and it is now being applied widely in substations.

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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BIOGRAPHIES

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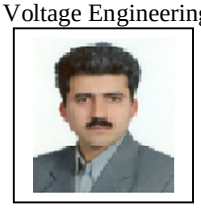

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