Emergence Of IEC 61850 In Substation Automation & Its Applications In Making Of Smart Grid

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Abstract **-** Smart grid is an electricity network that copes with the power demand in a sustainable, reliable, and economic approach, which is based on state-of-the-art infrastructure and integrates the behaviour and actions of all users connected to it. Substation automation in power industry enables the development of remote monitoring, control and electronic devices coordination. The use of numerical relays in substation automation lays a great amount of prominence on the communication protocols. The conventional relay architectures and substation automation protocols do offer necessary functions for power system automation. However, they are deficient in crafting with respect to networking expertise. In recent period, there has been a enormous improvement in networking technology, like TCP/IP, Ethernet. This paper discusses the role of communication module for a Numerical Protection Relay, by referring to IEC61850, an important new international standard for substation automation along with some of its practical applications. This is a part of the IEC's Technical Committee 57 (TC57) architecture dedicated for power systems which enables to achieve a complete interoperability.

Keywords - *Smart grid; substation automation; protection relays; networking; IEC 61850.*

I. INTRODUCTION

The implementation of substation automation system has picked up at a brisk rate all over the world. But, one of the imposing challenges that substation engineers are facing is, justifying substation automation investments. Automation impacts positively on power quality, operating costs, and reduced outage response. But little attention is paid on the use of a communication standard and its impact on operation of the substation. Communication always performs a crucial role in the real-time operation of any power system. Fig.1 shows typical substation automation architecture[1].

The traditional communication protocols were developed with a aim of providing the vital functions required by the power systems as well as reducing the number of bytes used by the protocol, due to severe bandwidth limitations. But these protocols suffered from vulnerability to persistent failure, proprietary equipments and complex cabling. Also, a large number of standard communication protocols used by the IEDs have restricted the utilities from achieving a wholesum incorporation of protection, control and data acquisition functions. The foremost challenge, therefore has been achieving interoperability among an assorted group of IEDs and functionalities.

This objective of this paper is to review the fundamentals of a new emerging standard - IEC 61850 and to provide a framework for substation engineers to identify the benefits of using IEC 61850 technology for numerical protection relays by discussing on some practical applications.

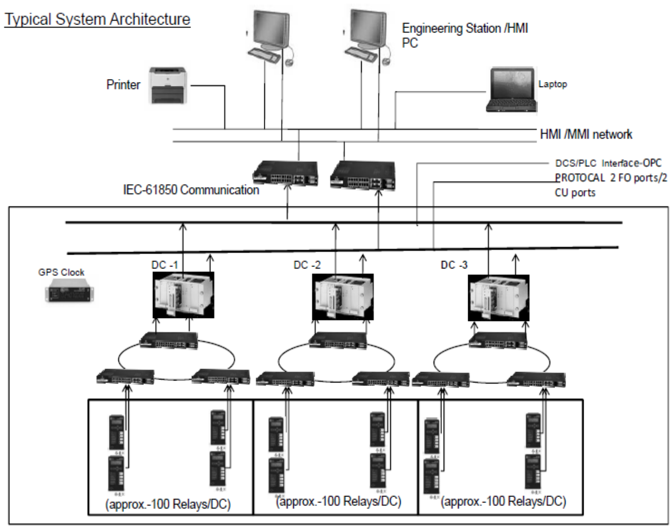

Fig. 1. Typical Substation Automation Architecture

II. LITERATURE REVIEW

As we move into the digital age, hundreds of analog and digital data pickup points are present in a relay and communication bandwidth is now, no longer a inhibiting factor. Substation to master communication data lines operating at 64 kb/s is now very common with an aim to achieve much higher rates. The key requirements of a communication system are[1][2][4]:

- Wide Networkability
- Guaranteed delivery times
- Standards based
- Multi-vendor interoperability and integration
- Support for Current and Voltage samples data
- File Transfer Support
- Auto-reconfigurable

- Security

Considering the above requirements, work on the next-gen communication architecture began with the development of Utility Communication Architecture in 1988. This architecture gave rise to definition of a profile of protocols, data representations and service definitions, and this was then, known as UCA. The concepts and paramount work done in UCA became the base for the task done in the IEC TC 57, Working Group 10, which resulted in the International Standard, "IEC 61850"[4]. IEC 61850 is the retort of existing standards limitations. It has brought many assets for technology development and implementation. The further sections of the paper emphasize on IEC 61850 as the, to go for protocol.

III. OVERVIEW OF IEC 61850

A. *Scope Of IEC 61850*

The scope of IEC 61850 was stated for communication within the substation. IEC 61850 defines the following communication paths[3]:

- From the measurement process to the IED - known as the "Process Bus"
- IED to IED Communication through - known as the "Station Bus"
- Client (a Distributed Control System) to Server (IED) communications

The numerous aspects of the substation communication network divided in 10 major sections can be seen in the Table.

TABLE I. STRUCTURE OF THE IEC 61850 STANDARD

Part #	Title
1	Introduction
2	Glossary
3	General Requirements
4	System and Project Management
5	Communication Requirements for Device Modeling
6	Configuration Description Language for Communication in Substations Related to Relay Architectures
7	Basic Communication Structure for Substation
7.1	Principles and Models
7.2	Abstract Communication Service Interface (ACSI)
7.3	Common Data Classes (CDC)
7.4	Compatible logical node classes and data classes
8	Specific Communication Service Mapping (SCSM)
8.1	Mappings to MMS(ISO/IEC 9506 – Part 1 and Part 2) and to ISO/IEC 8802-3
9	Specific Communication Service Mapping (SCSM)
9.1	Sampled Values over Serial Unidirectional Multidrop Point-to-Point Link
9.2	Sampled Values over ISO/IEC 8802-3
10	Conformance Testing

IEC61850 defines data models and abstract services to access the data which can be mapped to a numerous protocols. Some current mappings in the standard are to Manufacturing Message Specification (MMS) and Generic Object Oriented Substation Event (GOOSE). IEC 61850 requires an Ethernet network and uses high-speed switches to provide network connectivity. Also, a method for the continuous transfer of data, like voltages, currents and distributing these digitized signals to manifold devices has been defined. Thus, IEC 61850 provides a widespread model for how the data in the power system devices should be organized, such that it is consistent across all types and manufacturers of devices.

The parts 3, 4, and 5 of the standard, analyze the general and specific requirements for communication in a substation, which are then used as forcing functions to assist in the description of the services and data representations needed, the protocol required, and the underlying layers that should meet the overall requisites[5].

The unique construct that 61850 adopts is, to abstract the definition of the data items and the services, i.e., creating data items and services which are independent of any protocol. These abstract definitions permit mapping of the services and the data objects to any other protocol which can meet the data and service requisites. Part 7.2 of the standard defines these abstract services and Part 7.4 defines abstraction of the data objects (Logical Nodes). Most of the data objects include similar Functional Constraints like Status, Control, Measurement, Substitution. Hence, a concept of "Common Data Classes" or "CDC" was developed which defined basic building blocks to create larger data objects. These elements are defined in Part 7.3 of the standard.

After having the data and services abstract definitions, the concluding step is the "mapping" the abstract services into an actual protocol. Part 8.1 of the standard defines the mapping of the abstract data objects and services onto the MMS, the Manufacturing Messaging Specification and the Parts 9.1 and 9.2 define the mapping of Sample Measured Values onto an Ethernet data frame. Part 9.2 of the standard defines the Process Bus[5].

From a system perspective, a significant amount of configuration is required to combine all the pieces together and have them in working condition. To expedite this process and to eradicate the human error component, an Substation Configuration Language (SCL), based on XML has been defined in Part 6. It describes the relation between substation and the substation automation system. At the application level, the substation topology itself and the relation of the substation structure to the logical nodes configured on the relay architecture can be described. Each device must possess an SCL file describing its configuration. Finally, Part 10 defines a test plan in order to determine conformance with the numerous protocol definitions and constraints[5].

IEC 61850 has been designed to operate for the modern networking technologies and delivers a remarkable amount of functionality which is not available in the existing communications protocols. These above mentioned characteristics of IEC 61850 have a great impact on the costing to design, build, install, commission, and finally operate, a substation automation system[1][5].

B. *GOOSE Messaging*

Generic Object Oriented Substation Event message is a user-defined dataset that is "Published" only when, a change is detected in any of the data items. Any device on the LAN interested in this published data can "Subscribe" to the

Publisher's GOOSE message and can subsequently use any of the data items in the message as desired. Hence, GOOSE is also known as a Publish-Subscribe message. For the analog measurements, a deadband is defined wherein, if the analog value becomes larger than the deadband value, the GOOSE message is sent with the changed analog value. For the binary values, change detect may be a True-to-False or a False-to-True transition[3].

C. Integrating The IEDs

To accomplish a complete interoperability, the IEDs are integrated to the bus using IEC 61850. IEDs with different makes, as well as IEDs having similar makes but different configurations can be integrated in the network. In the IEC 61850 environment, the protection, control and monitoring functions are divided into smaller units, known as Logical Nodes (LN). These LNs are nothing but the objects defined in the standard. In all, there are 92 LNs defined in IEC 61850 corresponding to various protection, controlling, and metering functions, and some physical components like the breakers. Each LN may have up to 30 data objects, each of which, belong to a Common Data Class (CDC). Each Data Object (DO) has a few Data Attributes (DAs). These nodes can be on any of the three levels defined for substation automation. Each physical device / IED can host numerous LNs depending on its functionality. These LNs are grouped into what are known as logical devices (LD) which are defined in the context of the physical device, where each physical device contains at least one LD. Figure 2 shows two different logical nodes for an IED[4].

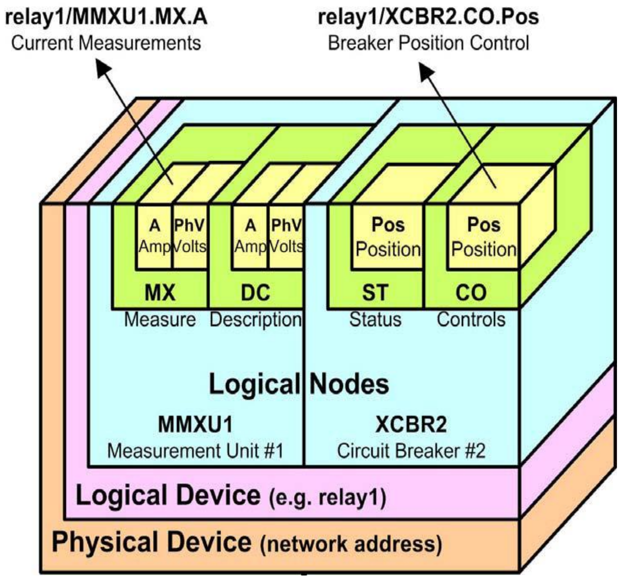

Fig. 2. A Logical Node

Figure 3 shows further breakdown of the logical node for a protection function into various Functional Constraints (FC). Each FC includes data corresponding to that in the device. Description (DC) gives description related to the protection function. Configuration (CF) gives the range and step size for the parameters related to the protection function. Setpoint (SP) gives the values of the set thresholds. Status (ST) gives the status on pickup or trip of a protection function. All of this data includes three fields: the actual data, the time at which data is recorded, and the quality of the data.

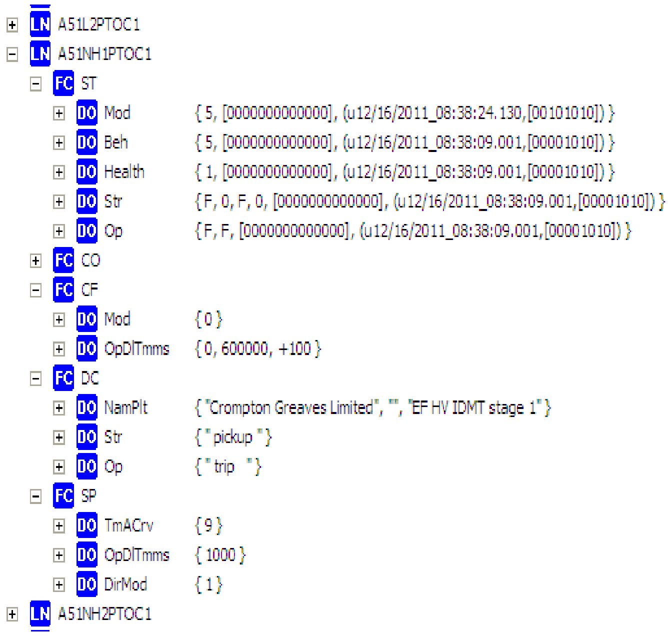

Fig. 3. Fuctional Constraints in a Logical Node

IV. PRACTICAL APPLICATIONS OF IEC 61850

A. Switchgear Interlocking

A high speed communication employed directly between bay control units and the protection devices can be used to implement switchgear interlocking across the bays. The IED Configuration Tool provides a view across the devices, which makes simple engineering of the substation interlocking possible, independent from the station level. The example in figure 4 shows a coupler and feeders of a busbar system which exchange the information necessary for substation interlocking.

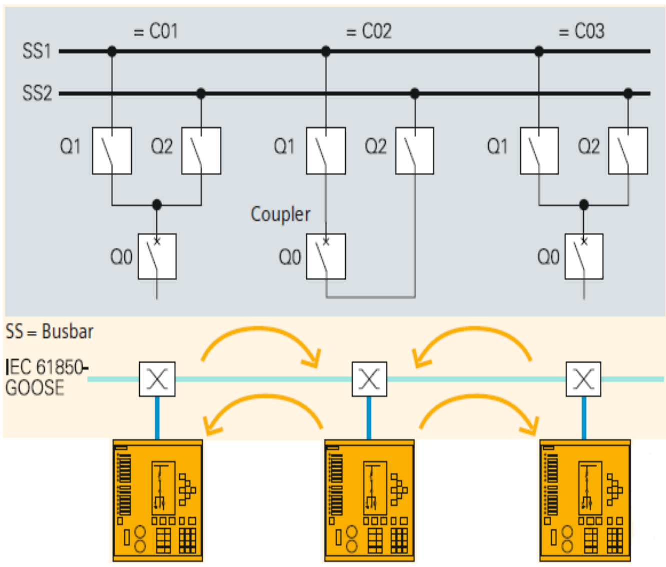

Fig. 4. Switchgear Interlocking

The following information may be exchanged for substation interlocking: Coupler conveys the information to the feeders, that it is closed. If this situation is met, the disconnectors will always operate in the feeder bays even if the CBs of the feeders are closed. Also, feeders convey the information to the coupler, that the busbars are connected via the disconnectors. As soon as these disconnectors get closed in one of the bays, the coupler C02 cannot be opened, else, it will not be permissible to operate the disconnectors in the feeders. This is called a coupler switch blocking and each feeder conveys this information to the coupler bay.

The use of IEC 61850-GOOSE enables implementation of "substation wide switchgear interlocking" as a distributed application and has the advantage of increased availability and being independent from the centralized station controller.

B. Reverse Interlocking

Reverse interlocking provides a feasible method to implement busbar protection in conjunction with over current protection devices as they have the required performance to perform time-constrained protection applications using GOOSE messaging. The busbar is powered via a transformer feeder and the other feeders go to the loads as shown in figure 5.

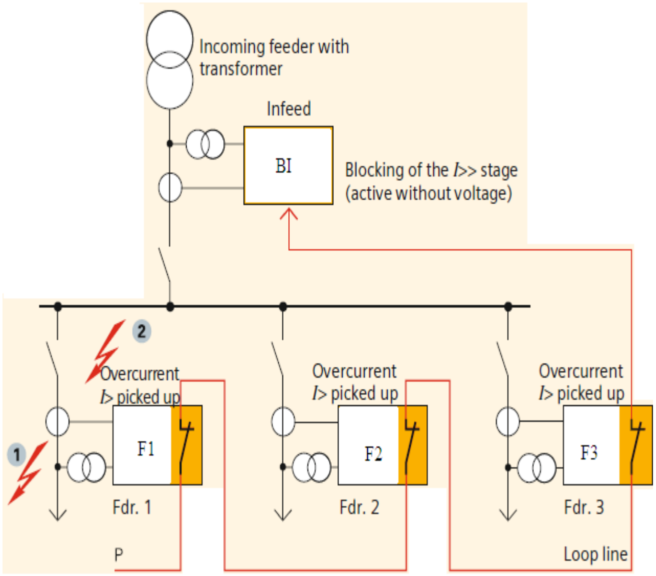

Fig. 5. Busbar Protection Using Reverse Interlocking

In IEC 61850, over current protection is described by the logical node "Protection Time Over current" (PTOC). On pick-up of the over current protection stage *I*> in feeders F1 – F3, the high set overcurrent stage *I*>> of the incoming feeder is blocked by a binary input(BI) . The BI is routed in such a way that this blocking is active in absence of voltage. The high set *I*>> stage of the incoming feeder is given a delay, so that a reliable blocking is safeguarded by a pick-up in the feeders before the time delay of this stage elapses in the incoming feeder. During normal operation, a voltage is applied to the BI via a loop line through the closed contacts, which means that the high-set *I*>> stage is not blocked and trips after the defined delay on pick-up of the *I*>> stage.

An external short circuit at location 1 results in pick-up of the *I*> stage on F1. This pick-up is routed to a NC contact and blocks the high set *I*>> stage of the incoming feeder via the BI because the BI gets de-energized when the contact opens. The short circuit is cleared by the relay of the short-circuited feeder when its delay time has elapsed.

The high set I>> stage of the incoming feeder is set to pick up value responding to a busbar short-circuit. A busbar short-circuit at location 2 does not result into a pick-up by the I> stages of the devices in F1-F3. After the set delay has elapsed, a trip command is issued and the short circuit gets cleared.

If the over current signal I> is picked up and configured in a GOOSE message, the unit transmits this message with high priority over the Ethernet network. The contents of this message communicate the state of pick-up (Yes or No) to the GOOSE message subscribers. The cyclic transmission of this message enable the subscribers to detect a failure using a logic block when a transmitter fails or, on interruption in the communications channel. This provides continuous monitoring of the transmission line as the subscriber expects to receive a message at short and fixed intervals. On a pick-up, a GOOSE message is transmitted spontaneously. If the pick-up drops off again within this time, spontaneous transmission is repeated. Fig. 6 shows the methodolgy applied to the pick-up signal. Each unit in the feeder transmits its GOOSE message to the unit in the incoming feeder.

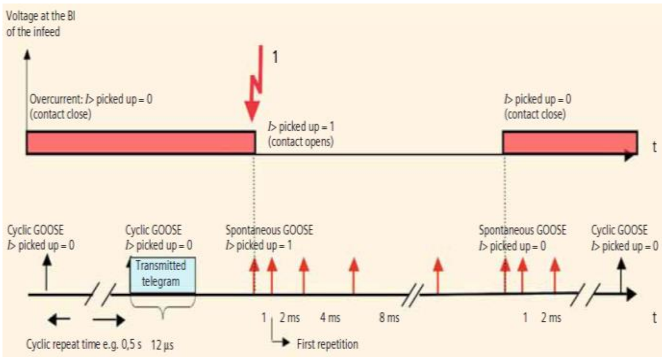

Fig. 6. Goose Message Transmission

V. CONCLUSION

IEC 61850 has been now released to the industry which addresses most of the issues that entail to migration to the digital world, especially, data names standardization, creating all-inclusive set of services, and implementing over standardized protocols and hardware. The IEC 61850 substation architectures are providing significant benefits in the power sector. The key feature is the flexibility to accomplish new objectives that were too costly or almost impossible using the legacy protocols. Multi-vendor interoperability has been manifested and compliance certification process is being established with the existing relay architectures. Discussions are underway to implement edition 2 for IEC 61850 protocol, to be known as IEC 61850-9-2 Process Bus, and the library providers are also updating their libraries for the same. Thus, the IEC 61850 protocol is bound to become the protocol of prime preference in terms of providing network solutions for the substation automation systems.

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