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Role of IEC 61850 & GOOSE in Substation Automation: A Review

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Abstract:- There is increasing requirement to integrate a substation automation system (SAS) which provides high performance and flexibility. IEC 61850 is upshot of the hard work of IEC Technical Committee to fabricate a open standard for SAS. IEC 61850 has gained recognition in a very short span of time and is spreading throughout the world. Substations are getting increasingly dependent on IEDs / relays compatible with IEC 61850 standard. However, the compliance of a device with the standard does not guarantee interoperability with devices from different substation automation equipment vendors. Employing IEC 61850 compatible devices present a test to several system integrators, due to deficiency of knowledge, skills & expertise of Logical Nodes (LNs), Reporting (RCB), Generic Object Oriented Substation Event (GOOSE), Sample Measured Values (SMV) and system redundancy. To ease a smooth implementation, all the features and data exchanges between devices must be evaluated & validated to ensure that the system functions correctly. It is vital to establish the compatibility of the devices & products furnished by diverse manufacturers so as to establish a fruitful SAS.

Keywords:- *Protocol, Substation Automation, Relays, IEC 61850, LNs, GOOSE Message, Redundancy, IEDs, Inter-operability.*

I. INTRODUCTION

Legacy communication protocols were designed & developed with a aim to provide necessary functionalities needed by power systems, at the same time, to minimize the memory being used by the protocol because of stringent bandwidth limitations. As modern communication networking protocols such as TCP/IP started to become pre-dominant, this brought upon a need to modify the existing protocols to work over TCP/IP instead of serial links. This approach gave the benefits of modern networking technologies to the substation, but had a fundamental flaw. The existing protocols that were being used were still designed so as to minimize memory, but did not take complete benefit of huge bandwidth increase that modern networking technologies deliver by providing a high range of functionality that can largely reduce the implementation, operation & commissioning costs of SAS.

The key requirements of a communication system are: Networkability throughout the utility, Guaranteed delivery times, Multi-manufacturer interoperability and integration, Time Synchronisation on SNTP, Comtrade Files on FTP & security support. Considering these requirements, UCA was developed in 1988 to work on next-gen communication architecture. This architecture gave rise to the definition of a "profile" of protocols, data representations, & some service definitions. The concepts and paramount work done by the UCA became base for the work done in IEC TC 57, Working Group 10, resulting in the protocol, "IEC 61850".

The distinguished features of IEC 61850 bring a straight forward effect on the cost to design, install, commission & operate the power systems. While the existing Ethernet protocols enable the substation engineer to do exactly the same thing, IEC 61850 enables fundamental improvements in SAS that that could not have been possible with existing approaches, with or without TCP/IP-Ethernet. To put a light on these specific benefits, this paper examines the critical features of IEC 61850 and explains how these result in significant advantages that cannot be achieved with legacy approaches. [1][2][4][7][8]

This objective of this paper is to review the IEC 61850 protocol & GOOSE messaging and to provide a framework for substation engineers to identify the benefits of using IEC 61850 technology for SAS.

II. LITERATURE REVIEW

SAS in power sector demands remote monitoring & control of intelligent electronic devices (IEDs). However, the major challenges like power distribution reliability and efficiency are faced by SAS. Potential risk factors like lightning, accidents, system faults or financial efficiency lead to development of standard process. Standards & apt trends & technologies help to contribute to the various issues like[1][3]:

- Trim down settings & configuration efforts
- Generate more capability & flexibility
- Ensure interoperability & inter-changeability
- Reduce installation cost
- Diminish manual endeavours & errors

Communication protocols were introduced to industry in 1970s, & were soon adopted for the power sector. In the early 1990s, it was observed that speed of advances in communication technology was far greater than its power system counterpart, demanding more SAS adaptation & high independence from the underlying communication technologies. Therefore, the change-over phase in power sector from manufacturer dependent communication protocols to open standards was speedened up, directing towards more & more advanced products & solutions which could provide an interoperable and future proof environment [5].

Designed basically to ensure interoperability among multi-manufacturer systems, these protocols also ease commissioning & integration of communication networks, minimize installment costs, allowing independent testing, verification & validation, further leading to even more proficient designs. Furthermore, communication protocols designed according to these standards can be effortlessly upgraded or adapted in future. This is equally imperative, as the advancements & novelties in the area of communication networks outpace the modification frequency in power system infrastructure. Hence, the designed network architecture must be adaptable to new power system automation designs with minimum effort [6].

There are multiple ways by which a protocol controls transmission of messages. This can be done via Master / slave or token ring protocol. SCADA systems communicate with RTU, or outstation device using a protocol. Initially, relays or IEDs allowed remote communication via RS485 connection. Each protocol consists of 2 message sets: a master protocol, containing statements for master station initiation & a RTU protocol, containing statements an RTU can initiate. The SCADA protocol between master & RTU forms a model for IED-to-RTU communication.

The major issue in this area is the truth that most protocols and developed systems are manufacturer dependent and cannot be adopted as a complicated solution.

III. IEC 61850 PROTOCOL & SUBSTATION AUTOMATION

One of the building blocks of modern utility protection and control systems is SAS, which is associated with primary substation equipments like breakers, transformers and distribution feeders. Systems put in to supply measurements & status information to the higher layers of system. Additionally, SAS sense any unusual condition and execute the essential feat to avoid more damage to equipment. A composite substation protection, control & monitoring system has a hierarchical formation which has differed communication levels. Substation automation & integration can be segregated into 5 levels as revealed in figure 1.

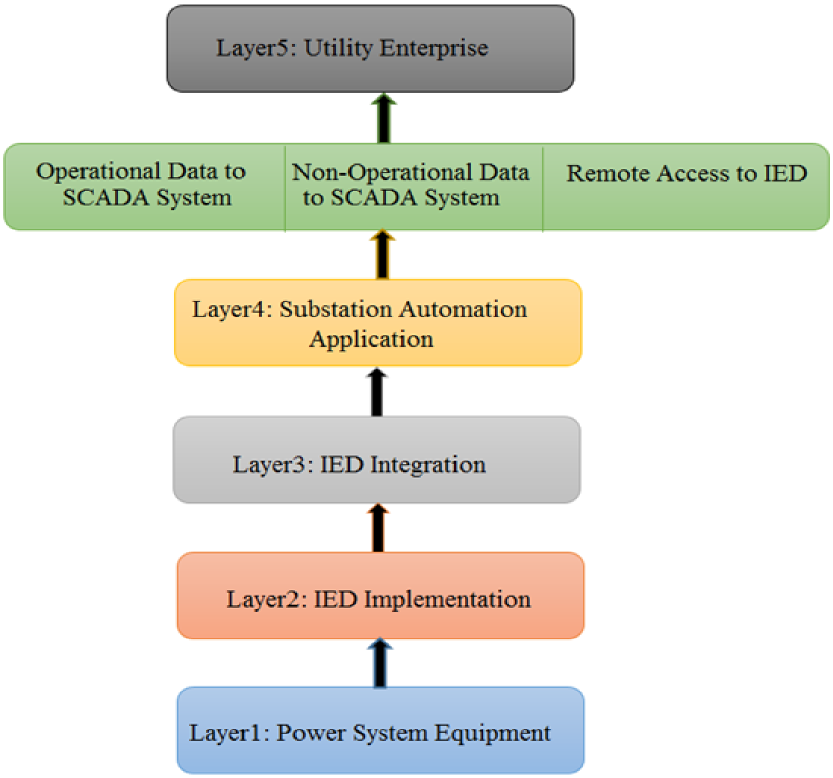

Fig. 1:- Layers of SAS

The lowest level of primary power system equipment is an integral part of the substation. It includes power system field equipment in the switch yard. The functions of this level are analog signals like measurements and binary status / control signals like the current breaker or isolator position.

Second and most important part is the IED / Relay implementation. These IEDs have ability to exchange data and fire control commands.

Third level is the IED integration. IEDs have allowed integration of protection, control, and data acquisition functions into a single platform, resulting in reduction of capital and operating costs of CRP.

Fourth stage is substation automation applications in which the intelligent alarm processing or adaptive relay coordination is implemented.

Fifth level is the utility enterprise that consists the 3rd-party softwares, in which, both, the operational and non-operational data is analysed. Also, the analysed historical data contributes for the predictive maintenance, reducing the maintenance expenditure. Transmitting data from substation to utility enterprise can be achieved by 3 paths. 1st is that of transmitting the operational data to the SCADA system. While the 2nd data path is that of transmitting the non-operational data to the data warehouse, 3rd one being the remote access to IEDs.

A. Introduction to IEC 61850 Protocol

IEC 61850 is an international standard recommended by IEC for Ethernet-based communication in substations. This is part of IEC's TC57 architecture dedicated for power system protection which enables to achieve complete interoperability. It helps the substation automation engineers to achieve a complete integration of all the protection, control, metering and monitoring functions within a substation, furthermore providing means for interlocking & inter-tripping. It combines the expediency of Ethernet alongwith security which is critical in modern substations. It divides inter-substation communication into 4 levels [8]:

- Process level: I/O devices, sensors and actuators, switchgear
- Bay level: Relays / IEDs
- Substation level: Substation PC & interfaces with outside world.
- Control Centre Level: SCADA HMI

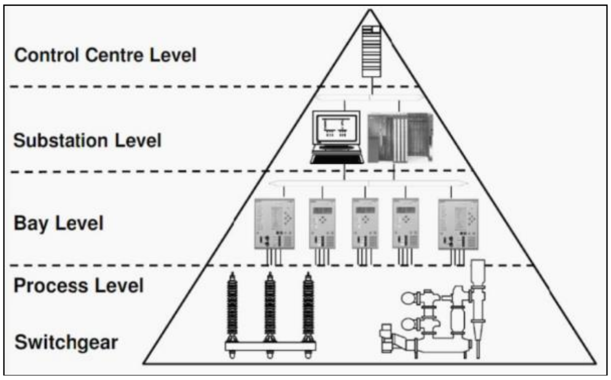

Fig. 2:- Levels of Communication

The IEC 61850 scope was stated for inter-substation communication. IEC 61850 defines the following communication pathways:

- From measurement process to IED, defined as Process Bus
- IED to IED Communication, defined as the Station Bus
- Client (DCS) to Server (IED) communications

B. GOOSE Messaging

Generic Object Oriented Substation Event (GOOSE) message is a user-defined dataset which is published only when, a data change is detected in any of the data items. Any IED on the network interested in this data can subscribe to Publishers' GOOSE message and can use any of the data items in the message as required. Hence, GOOSE is also called as Publish-Subscribe message. For analog measurements, a deadband is defined wherein, if analog value exceeds this deadband value, a GOOSE message is sent with the altered analog value. For the binary values, change may be a True-to-False or a False-to-True transition.

Figure below presents a GOOSE application in a substation protection scheme. IEC 61850 replaces & replicates hardwiring between IEDs. It is observed that implementation with GOOSE works in the same way and gives superior timing performance than copper links.

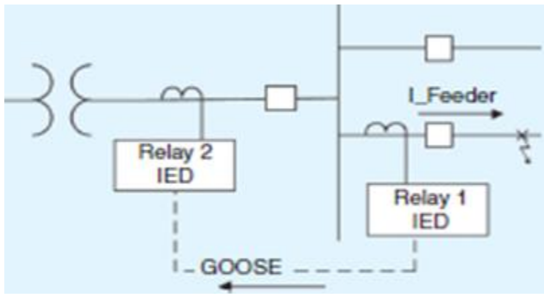

Fig 3:- CB Fail Application

For a feeder CB failure, SAS uses GOOSE to issue a trip command to the power transformers secondary CB. IEC 61850 system is further safe and sound since conventional copper cable links fail with no indication; on the other hand, if an IEC 61850 communication falters, the system instantaneously sends alerts due to failure of GOOSE system health messages.

GOOSE message with an event is shown in figure below:

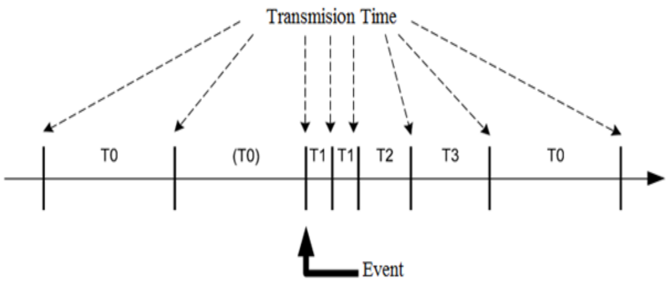

Fig. 4:- GOOSE Frame

The transmission times from above figure are:

1. T0: GOOSE retransmission phase under steady state;
2. T (0): instant at which GOOSE retransmission is intermittent by an event;
3. T1: retransmission of event in short interval;
4. T2 & T3: retransmission of event in short intervals until steadiness is reached.

GOOSE uses the data published in data sets. Analog, binary or integer values, i.e. the data attributes, and their quality attributes compose of a dataset.

The chief characteristics of the GOOSE messaging are:

1. Publish / subscribe;
2. Multiple clients require multicast MAC addresses;
3. is non-routable;
4. Multicast for many clients within LAN only.

IV. ADVANTAGES & APPLICATIONS

A. Advantages

- High Speed Inter-IED communication
- Networkable throughout the utility enterprises
- Multi-vendor Interoperability
- File Transfer Protocol (FTP) Support
- Support for Current and Voltage Data
- Support For Cyber Security

B. Applications

- Real time data exchange on high speed Ethernet ports
- Control- Switching ON/OFF switchgear
- Standardization of Protocols across the world
- WEB server
- FTP server
- GPS/SNTP for Time Synchronization

V. CONCLUSION

IEC 61850 has been now released to the industry which addresses multiple issues that entail to migration to digital world, specially, data names standardization, creating all-inclusive set of services, and implementing over standardized protocols & 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. Inter-operability has been manifested and compliance certification process has been established with the existing relay architectures. Industry is now focusing on bringing up novel substation network interconnection schemes like HSR & PRP so as to cope up with network redundancy in substation automation systems.

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