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Designing the Future Communication Architecture for High Voltage Substation

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Abstract- This paper presents the design of substation among new technology which increases the concert of substations. The effectiveness of this substation higher than in present substation. And also it reduces the maintenance cost as well as fault happening and also reduces the individual errors and labour cost. One of the important issues in a substation automation system is performance of the communication buses consist of station bus and process bus. The station bus provides communication between station level devices and bay level devices and the process bus provides communication between bay level devices and primary equipment as the substation communication world searches for the "Promised LAN", it would be helpful to have a roadmap to give direction to the search. Such expectations must be tempered with the cost and complexity of achieving them .In this paper describe a methodology that identified a set of Smart Distribution Grid use cases and utilized them to define an architecture based on Future Internet technologies.

Keywords:- Communication systems, Information Systems, Internet, Smart grids, IEC61850.

I. INTRODUCTION

High-speed peer-to-peer IEC 61850-8-1 GOOSE and IEC 61850-9-2 sampled values based information-exchange among IEDs in modern IEC 61850 substations have opened the opportunity for designing and developing innovative all-digital protection applications [7][1].

The transmission dependability and real-time presentation of these SVs and GOOSE messages, over the process-bus network, are critical to realize these all-digital IEC 61850 substation automation systems (SASs) protection applications. To address the reliability, accessibility, and Deterministic delay presentation needs of SAS, a novel IEC 61850-9-2 process-bus based substation communication network (SCN) architecture is proposed in this paper.

Future "smart" substations will be capable of providing such information. In the future power system electrical events affect not only the operation of the power system, but also operation of the electricity market. It can be conjectured that the importance of an electric event should consider the economic importance of the event, and the economic impact should be taken in consideration when electrical alarms occur.

Therefore, it is proposed that alarm issuance and alarm processing should include economic information in addition to the traditional alarms. In this section, an Intelligent Economic Alarm Processor (IEAP) structure that combines alarm processing techniques at both the substation and control centre level will be presented.[8] [12]

Reliability of the proposed as well as the traditional process-bus based SCN architectures is evaluated using the reliability block diagram (RBD) approach. Network components are modeled, and end-to-end (ETE) time-delay performance is also evaluated for all-digital protection applications running on the SCN architectures.

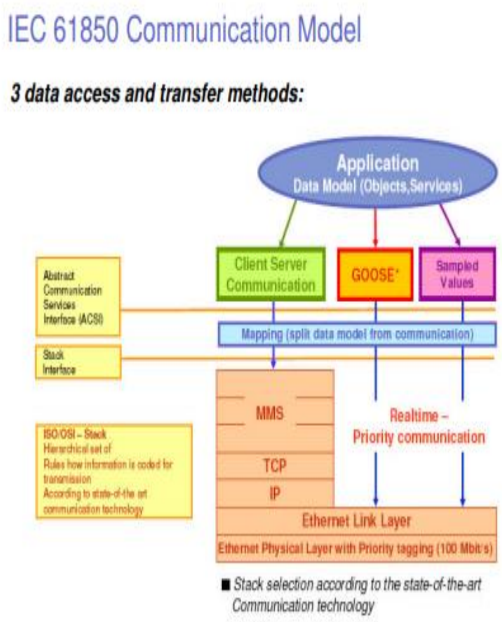

Fig 1. Future substation model.

II. OVERVIEW OF EXISTING SUBSTATION

Transmission substations consist of primary plant, such as transformers, switching equipment and instrument transformers and low voltage secondary equipment such as protection, monitoring and control equipment.

The secondary equipment is typically connected to the primary equipment via copper wire multi-core cables. The practice followed by Transmission Owners (TOs) for substation design, replacement and modernisation has evolved over years and has always been based on the best proven technology available at that point in time.

For example, substation automation systems (SAS) have evolved over the past 40-50 years from hard-wired mimic/control boards to mimic/control boards in conjunction with Remote Terminal Units (RTUs) to Substation Control Systems (SCS) with a substation computer. As the output of conventional CTs and VTs are analogue amperes and volts, the protection and control equipment to which they are connected are traditionally provided with analogue inputs. The functionality of protection relays has been greatly increased by the use of numeric microprocessor technology [4] [2].

However, to allow connection to conventional CTs and VTs, each numeric protection relay is provided with interposing transformers and Analogue to Digital Converters (ADC). Circuit breaker trip coils require a DC voltage for operation.

Even the latest numeric protection relays, when issuing a trip command, usually operate a trip contact in the relay to switch the DC voltage on to the circuit breaker trip coil. Copper wire multicore cables are therefore also used for this function.

In addition to the copper wire multicore cables required for CT and VT analogue inputs and circuit breaker control, copper wire connections are required for status and alarm signals.

The current design of substations, based on conventional CTs and VTs, have been optimised for the latest numeric multifunction protection relays and substation control equipment with copper wire connections.

III. FUTURE COMMUNICATION ARCHITECTURE

Design of the future communication for high voltage substation .The reliability of the process-bus network has a tough contact on the dependability of these all-digital protection applications in IEC 61850 SAS.

Also, there are some real-time performance requirements for IEC 61850 SVs/GOOSE messages on the process-bus for implementing SAS applications. The most critical information exchange is related to the protection function, i.e., the transmission of the SVs from the Conventional or NCITs/merging units (MUs) at the process level to the protection IEDs on the bay level. It also involves the transmission of GOOSE trip commands from the protection IEDs to the circuit breaker IEDs or the transmission of interlocking data between IEDs.

Thus, the reliability and performance of a process-bus network is critical and presents one of the most challenging issues to the substation communication network (SCN) design engineer.

This feature accelerates the transmission of time-critical GOOSE and SVs messages but adversely affects their transmission reliability. Moreover, the use of switched Ethernet technology with quality of service features allows the efficient use of available network bandwidth and minimizes the delays by segregating and prioritizing the network traffic.

However, these features do not ensure the deterministic delivery of these real-time messages over the process-bus network during worst-case scenarios, [6] [9] i.e., the arrival of high-priority SVs/GOOSE messages during the transmission of the lower-priority client-server traffic with large packet size. In this situation, the higher-priority packets will have to wait in a queue until the lower-priority packets are transmitted.

The worst-case scenario also depends on the packet size and traffic on SCN. Unlike conventional hardwired schemes, the performance of IEC 61850 communications-based protection applications are influenced primarily by the SCN topology along with communication network parameters, network load conditions, and the processing capabilities of the devices used.

For this, the transmission time performance requirements of SVs/GOOSE messages as per IEC 61850-5 standard must be ensured under any network operating conditions. [8][10][1][6]

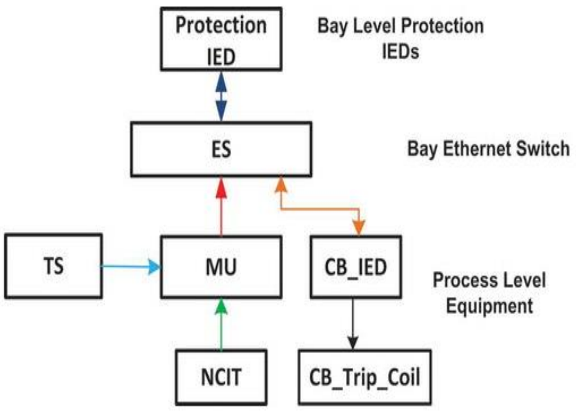

Fig 2. Traditional IEC 61850 intra-bay SCN architecture.

Fig.2 shows traditional IEC 61850 intra-bay SCN architecture, which is prone to single point of failures, first, from a communication point of view as ES provides the only link for connecting the process level and the bay level equipment, and second, from the communication path point of view as there exists only one path for accessing primary equipment by protection IED through MU IED.

Moreover, this architecture consists of only single critically important protection IED whose nonavailability directly affects the performance of the protection function.

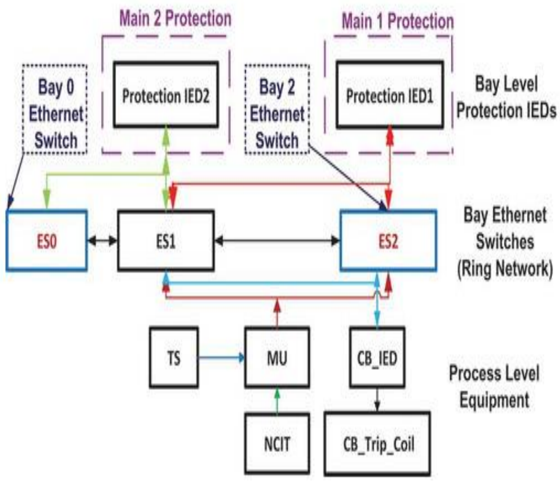

Fig 3. The proposed future communication architecture for high voltage substation.

Here the protection system consists of two redundant and independent protection IEDs (main1 and main2), i.e., protection IED1 and protection IED2 per bay, from different manufacturers operating with the different protection principles.

Moreover, only one protection IED, i.e., primary, out of redundant protection IEDs, i.e., protection IED1 and protection IED2, works at a time to clear the fault. Each dual-port protection IED, MU IED and CB_IED, are connected to two different Ethernet switches, i.e., with its own bay Ethernet switch and to the adjacent bay Ethernet switch.

In fig. 3, it is illustrated that the Ethernet switches ES0, ES1, and ES2 correspond to bay 0, bay 1, and bay 2, respectively. Here the protection IED1 is connected to ES1 and ES2, i.e., Ethernet switch of its bay (ES1) and adjacent bay (ES2).

Similarly, protection IED2 is connected to ES1 and ES0, i.e., Ethernet switch of its bay (ES1) and adjacent bay (ES0). In case of failure in the communication network of a protection system, e.g., main1, i.e., protection IED1, transfers the control to the redundant port through dual homing protocol (DHP) port switchover mechanism and uses the alternate communication path for further communication.

Thus, only single Ethernet switch and protection IED per bay is utilized effectively in the protection function implementation at a time.

From the introduction of processor based devices, we have had the ability to communicate with these devices. The ability to communicate gives added value to the IED and as such, has hastened their implementation. Another aspect is that revisions and generations of new IED's have become a frequent occurrence demanding constant "stone cutting" and "chipping" of translation communication software.

Newer IED designs implement faster communication rates, have more data to communicate, and are capable of performing some programmable logic functions. In view of future capabilities and a continuing proliferation of IED's in the substation, a cry has come from the utility community to create a framework for not only common communication but an architecture that will provide for interoperation.

Interoperation implies the ability to "plug and play" and also to be able to "share" data and functions. As an example, a protective relay may be required to provide a "check synchronism" function which requires the magnitude and phase angle comparison of two voltages.

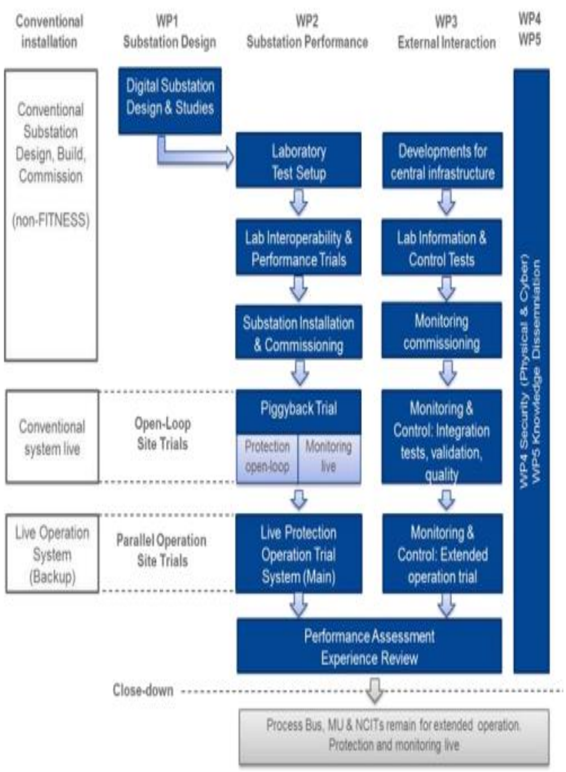

Fig 4. Demonstration Methods proving Substation Architecture and Integration.

The relay performing the function may have intrinsic access to only one voltage. The other voltage may be available from another device in the substation. An interoperable system could then negotiate for access to the other voltage and as such, avoid all the overhead involved in direct wiring. The interaction between the substation and external systems is enabled by communication protocols.

The use of internationally accepted non-proprietary standards enables modularity between the provision of data and the functions depending on them.

IEC 61850 8-1 Defines 'Station Bus' for information exchange within the substation,• as shown in the structure in Figure 4.

- GOOSE for control values and trip commands;
- IEEE C37.118-2011 standard for synchrophasors;
- IEC 60870-5-104 for SCADA data; Common Information Model (CIM) for consistency between referencing elements, between substation and EMS/Wide Area Management System (WAMS);
- IEEE C37.111-2013 COMTRADE for transient data exchange.

Though, IEC 61850 is used for applications at the substation level. However, some features of IEC 61850 can also be utilized equally well for various applications outside the substation such as in distribution and feeder automation, distributed generation and to communicate with the control centre.

It is possible to manage and control variable energy supplies efficiently through IEC 61850 substation automation utilizing Ethernet and router based communication network devices.

IEC 61850 enable the seamless integration of various automation technologies in the transmission and distribution systems and support.

IV. BENEFITS OF THE FUTURE SUBSTATION DESIGN

In this part, a vision about future substation design of 20 years, 50 years or even more has been proposed. In a near future, there is no feasible technology that can replace AIS or GIS totally.

The vision of GIS will keep changing to meet the criteria of green field substation more fully. Some of desirable changes in GIS technology will appear in the near future.

The appearance of fault current limiter will reduce the number of circuit breakers and short circuit current to clear.

Thus, a simpler breaker scheme will lead to lower cost. Solid state breaker if available could eliminate the mechanical drive and simplify the geometry so that GIS could be designed in a much simpler and cost effective way. A distributed superconducting substation is feasible.

Superconducting substation containing HTS transformer as the main transformer, HTS cable for conducting, SFCL for fault current limiter and SMES for voltage stability and quality problem are envisioned.

The substation uses one cryogenic refrigerator system to provide liquid helium for every HTS device. This would be more economical than using one cryogenic refrigerator for each HTS device. With the new generation of superconducting cables, the power flow is increased 2 to 3 times from that of the existing right of way. Economic losses from outage or quality disturbance are rare.

Importantly, the environmental impacts are reduced significantly. HTS substation is expected to come to market in 20 to 30 years. SiC technology definitely will take an important part in the advancement of power electronics in transmission and distribution systems.

High voltage power electronics devices will have higher efficiency, less complexity, smaller size at affordable cost, challenging the conventional AC devices. Superconducting substation will be able to deliver large amount of energy over a long distance into load area.

V. FUTURE RESEARCH

- A number of issues are addressed but not explored in our research. Future work may include .Software retrofits in the retrofit part.
- This effort should figure out the requirements of the software retrofit to satisfy the future needs and requirements. Cyber security model, detection and test
- Plan for the new design. This effort should study the cyber security model for the specific proposed designs, the cyber security detection method and test plan for validating and certifying the design. Different data communication bus system Design.
- This effort needs more detailed information of real operation conditions in the future to better define requirements for the IEAP.

VI. CONCLUSION

This paper presents a novel IEC 61850-9-2 process-bus based SCN architecture that fulfils the transmission dependability and the real-time presentation and requirements of time-critical SVs and GOOSE messages for all-digital protection functions of the substation. Reliability block diagrams have been demonstrated intended for the proposed and traditional Ethernet SCN architectures, considering inter-bay communication among IEDs in substations, the IEC 61850 communication needs under normal network traffic.

Though, none of them achieves the strict presentation requirements of the standard beneath critical components/ communication path failure and worst network traffic scenario. Thus it is discovered that the proposed architecture achieves the highest reliability and performance, amongst all previous process-bus based SCN architectures.

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