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Power System Automation Using Ethernet

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Abstract – Ethernet is widely used technique for mission critical real time applications because of limitations associated with collision based access techniques. Ethernet technology is finding wide acceptance and exponential growth from its inception. Ethernet has now evolved into a highly predictable and reliable real time network technology.

This paper contains various application examples which describes the use of Ethernet in distribution substation. And industrial plant automation like fast bus trip, breaker failure protection.

Keywords— Power System, Smart Grid. Monitoring and Control.

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INTRODUCTION

Digital communication is one of the most important part of electric network. Eventhough it is not directly involved in bulk power transfer but large interconnected power system cannote operate without digital communication infrastructure.

Blackout happened on august 14, 2003 realizes need for improved data collection and real time situational awareness.impetus. This disaster created path towards the development of new technologies such as application of GPS based golbal time dissemination, substation ethernet, and better use of existing microprocessor based relay's or intelligent electronics devices(IED's). Because of the improved digital commuincations it is difficult to distinguish the SCADA remote terminal unit (RTU) functionality from a commuinication processor, protective relay etc. Technology is developing in such a way that in the near future all the above devices could merge into a single multifuntion unit of performing any subset of power system automation and conrol function. This merging process is being set by international standard IEC61850. This standard intentinally separates application data, data transfer services and communication protocols so that functions can be merged or distributed among any number of devies[1].

IEC 61850 standards is currently being extended to include communications between substation and control center, thus becomes real SCADA protocol. IEC 61850 also includes four real time mechanism aimed at time critical protective relay communications. IEC 61850 has managed to span much of the application space, which provides solid base for building reliable and interoperable substation control or protection systems. This standard is also necessary for file transfer, engineering access, diagnosis, video etc.

IEC 61850 real time communication mechanisms are: GSSE- Generic substation state event, GOOSE- Generic object oriented substation event. etc.

These mechanisms are very powerful and also supports for some of the most demanding substation applications such as precision time synchronization, bus differential protection etc.

It is also expected that these application related issues will be resolved in near future. In this paper attempt is made to explain some of the consequences of using communicated data for power system protection.

Now a day's Ethernet technology was widely used for mission critical real time applications. Because of pressure from consumer driven web based technologies Ethernet eas enhanced to become a highly predictable real time network technology. Key mechanisms behind the predictable real time Ethernet technology to avoid existing shortcomings are as fallows. 100 Mbps port speed, full duplex port operation, collision free environment, collision free environment, priority queuing support, loss of link management etc original 10 Mbps Ethernet has been virtually replaced by upgraded 100 Mbps line interface. Modern switches offer a full duplex interface which is capable of transmitting and receiving data simultaneously. This capability virtually doubles the available bandwidth (200 Mbps), while eliminating the possibility of local packet collisions.

The primary function of an ethernet switch is to establish a direct connection between the sender and receiver based on the individual device media access controller (MAC). Individual packets are forwarded only between the two communicating ports without affecting the bandwidth available to other ports. By taking power system substation application where mission critical IEC GOOSE traffic must coexist with SCADA or device management type traffic. It is obvious that different messages have different time requirements which create separate incoming traffic into different priority queues. The priority queuing mechanism is described in the IEEE 802.1p standard. Priority is accomplished by inserting a four bit tag into the standard Ethernet frame header. Actual tag is shown in fig 1.

Destination address	Source address	Tag	Type	Data

TPID = 0x8100	x	x	x	0	0xXXX

Fig1. Tagged Ethernet MAC header

The number of priority queues varies among switches, with the minimum of two needed to claim IEEE 802.1p. Because of the high reliability expected from power system automation devices, virtually all manufacturers have equipped their products with a redundant Ethernet port interface. This interface normally provides a stand by channel capable of taking over the network functions in case of the primary port failure.

II. POWER SYSTEM PROTECTION, AUTOMATION AND ETHERNET LIMITATIONS

In power system protection it is very important to have look at the issues and requirements associated with Ethernet network technology. Very high availability through network equipment is associated with several undesirable side effects such as possibility of delayed frame reception and engineering/planning mistakes etc. To avoid problems related to unreliable communication channels we must carefully design Ethernet based conventional automation and protection system based on locally measured voltage and current values.

To provide basic system protection standard over current elements, time current coordination techniques, distance protection, harmonic restraint etc should be used. Once system is protected using locally measured data, it is desirable to use communicated data form remote nodes to improve full selectivity, increase speed of operation or add additional intelligence made possible by global situation awareness.

To supplement the high performance communication network based functionality an Ethernet based locally derived conventional protection becomes reliable back up. When this backup is properly combined with communication enhanced protection then resulting system offers exceptional availability and resiliency to multiple system failures. This new network environment allows for continuous communication system monitoring i.e it is possible to optimize the protection device decision making process based on the actual amount of data available at any given time.

For example two IED's protecting a transmission line by exchanging directional data at a rate of 4 ms can track the arrival of remote end messages. In case of communication disruption, communicating devices can instantaneously switch over to reliable distance based backup. The above guidelines for the design of Ethernet based network protection system can be summarized as follows.

a) Network enhanced protection systems must be built on the top of local back up.

b) Any loss of communication capability must be reliably detected and addressed, resulting in predictable and coordinated performance degradation.

c) Message error detection and control must be rigorous and capable of detecting all possible message corruptions.

d) Network based communications must be continuously monitored.

e) Continuous data exchange is preferred over the event driven model.

f) Multiple messages may be exchanged in order to guarantee operational correctness and to avoid complex conditions.

The biggest problem with the event driven model is its inability to detect the message loss. When it comes to power system protection, it is required to reserve bandwidth ahead of time. And to use this bandwidth continuously provides real time system monitoring and instantaneously failure detection.

In order to support real time protection over Ethernet, substation network infrastructure needs to satisfy the following minimum requirements.

a) Ethernet hubs should not be used and they should be replaced by Ethernet switches.

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b) All Ethernet switches need to managed.

c) Every switch must support 10 0Mbps full duplex port operation.

d) Priority queuing, virtual LAN functionality should be supported

e) High priority network traffic should be allocated to power system protection and high speed automation.

f) Redundant network architecture is highly encouraged.

g) All Ethernet switches must be rated for operation in the substation environment

III. SUBSTATION AUTOMATION

Substation automation with an emphasis on power system protection has evolved significantly and this provides the context for the development of the IEC 61850 family of standards. Due to its flexibility, scalability and robustness, Ethernet networking has gained significant ground in utility applications. The parts of the IEC 61850 standard are dedicated to process bus applications in the substation. But this type of networking brings several challenges that need to be addressed. And which are still acting as significant factor tp the wider acceptance of packet switched networking in electric power system protection and control. One of the main drawback of data packet based communication is the inherent variable transmission time that is difficult to overcome with widely used digital relaying algorithms.

A. Protective relaying

Protective relays have been used for more than 100 years to protect electrical equipment from damage when fault occur. The technology used for relaying evolved significantly throughout the twentieth century. The first electromechanical relays protected against over current and reverse current in generators, but before long were providing distance protection and differential protection. Microprocessor based protection relays now support digital communications and integrate the functions of what were separated devices into a single device.

B. Non-Conventional Instrument transformers

The term Non-Conventional Instrument transformer (NCIT) is used to describe any measurement transformer that does not use magnetic induction and iron cores. NCIT's have been adopted in power systems due to their compact size, wide frequency response and excellent linearity.

C. Real time data networks

Horizontal communication in substations is the communication between protection relays or within a bay. Vertical communication is the control of substation equipment through a local operator interface, or from a remote control centre. Communication networks are critical for smart grid applications, and the benefits of a smart grid will not be realized if the performance of these networks is inadequate. Much of the focus is on smart grid communications has been on distribution networks or synchrophasors, both of which are wide area networks. Industrial networks are moving from proprietary networks, which are often in compatible with one another, to shared ethernet networks. Some industrial protocols use vanilla Ethernet, while others modify the standard to include guaranteed bandwidth and time slots. Applications with high performance requirement tht use standard Ethernet tend to communicate with raw Ethernet frames, rather than use more complex protocols such as internet protocol (IP).

Ethernet has evolved significantly since its introduction as a shared network with carrier sense multiple access with collision detection(CSMA/CD) access arbitration. The speed of Ethernet networks has steadily increased from the original 3Mb/sec to 1Gb/sec in common use.

To test the performance of protective functions the process bus is integrated into power system model as shown below.

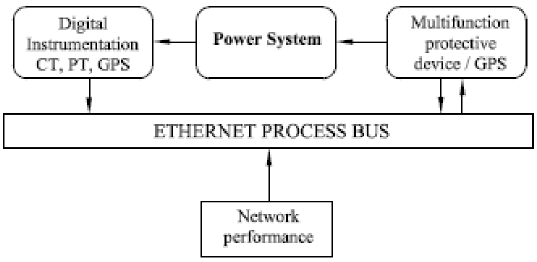

Fig 2: Network performance model.

The digital instrumentation samples the electrical values from the power system and streams the instantaneous measured data into process bus. The multifunction protective device receives the data and extracts the phasor information for each measured value. Under normal operating conditions, there are few delayed packets in the data stream. To test the performance of the protective functions normal distributions of data packet delays are considered[8].

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IV. APPLICATION EXAMPLES

A. Fast bus trip

Substation bus protection is most often accomplished by using dedicated differential protection. This approach offers exceptional speed and very high selectivity, but is associated with relatively high cost. While cost may not be an issue for high voltage switching and generator substations with multiple sources attached to the same bus, it may become prohibitive in cases of simple distribution voltage substations with one source and radially fed loads. It is in these lower voltage distribution substations that communications assisted fast bus trip often replaces the bus differential.

Typical distribution substation layout is shown in figure below. The substation has three radially fed feeders And one source breaker. Fast bus trip protection is accomplished by bringing he feeder relay status back to the min bus relay i.e in charge of the source side breaker. In case of feeder fault both the affected feeder relay and the bus relay will detect the overcurrent condition. Based on the fault indication supplied by the feeder relay, the bus relay will back off, allowing the feeder relay to clear fault based on previously set protection strategy[1].

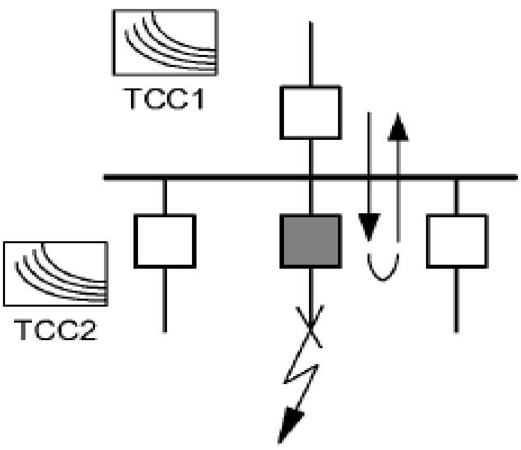

Fig 3: Feeder fault scenario

The bus fault clearing scenario is as shown below. The fault is seen only by the bus relay. The bus relay must be able to verify that none of the feeder relays is able to see the fault before issuing the trip command. The fast bus tripping scheme is initially dependent on the method used to bring the feeder relay over current element status information to the bus relay. But in conventional installations this is accomplished by hand wiring a set of output contacts or by contact state mirroring through dedicated serial communication channels.

When fast bus trip is implemented using IEC GSSE messages, it is necessary to note that this message conveys only status change. The simple state change communication approach cannot distinguish legitimate trip situation from Ethernet communication system failure.

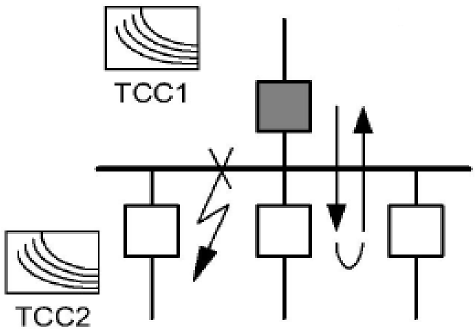

Fig 4. Bus fault scenario

B. Breaker failure protection

Breaker failure protection is timer driven scheme intended to coordinate upstream device operation necessary to clear a fault in situations when downstream protection device issues a trip command, but its associated breaker fails to clear the fault within a prescribed breaker failure time interval. Usually breaker failure function is distributed among multiple IED's[1].

V. CONCLUSION

This paper explains the latest international standards and mechanisms available to power system engineers. Also it describes the opportunities for enhancing power system automation using Ethernet. It should be noted that none of the applications presented in the paper may individually be able to justify the investment of equipping the substation with Ethernet network capability. And different messages offer an exchange of real time status information among multiple protection devices. These messages cab ne used to simplify substation wiring reduce installation cost and enhance overall protection system performance. Digital instrumentation in the substation is capable of streaming sampled current and voltage values into an ethernet based process bus.

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