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REVIEW ARTICLE

SUBSTATION AUTOMATION: A PERSPECTIVE (A LITERATURE SURVEY ON SUBSTATION AUTOMATION FOR POWER SYSTEM PROTECTION)

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ABSTRACT

Power System protection is a combination of Intelligent Electronic Devices, Digital Relays and other sophisticated equipment. It is an interconnected coordination between the smart devices. This paper gives the improved ideology of Substation Automation, which enables how the analog to digital signals are converted via fiber optics and sends the information to the neighboring devices. There are three major requirements for substation automation: Measurement, communication, Hardware and software. The SA is briefly explained by using one of the level i.e bay level process. Goose process also described in this review paper.

INTRODUCTION

The Substation-automation is processed in three parts mainly. First one is Input signal characterization based on Analog signal (continuous electrical signals such as active power, reactive power, frequency, Voltage etc.) or Digital signal (switching signals high or low, isolator open or brake etc.). The second one is processing the data like analog signal conversion to digital signal via fiber optics. This is to be carried out by a protocol sequence with a real time operating system (RTO) and lastly the output analyzing. The results are to be expressed in user friendly environment like displays. The data communication is done to substation via telephone lines, fiber optic cables, satellite, power lines, microwave lines. The Open Systems Interconnection model (OSI) is a conceptual model that characterizes and standardizes the internal functions of a communication system by partitioning it into abstraction layers. The OSI model works analogous to letter from sender to receiver. In the first level the sender written a letter, put it on envelope and drop it in letter box. In the second level of process the letter is carried out from mailbox to post-office. Later it was delivered to a carrier from the post office. It was travelled by certain transmission system and delivered to destination post office, reached to receiver via carrier, the receiver opens the envelope and reads the information.

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OSI Model

In signal transmission a powerful medium is to be used like Ethernet. Ethernet is one type of local area network (LAN) cabling system and is restricted to a limited area only, whereas router is meant for wide area. In the model groups communication functions into seven logical layers. A layer serves the layer above it and is served by the layer below it. For example, a layer that provides error-free communications across a network provides the path needed by applications above it, while it calls the next lower layer to send and receive packets that make up the contents of that path. Two instances at one layer are connected by a horizontal connection on that layer. The various layers in OSI model is shown in Fig 1.

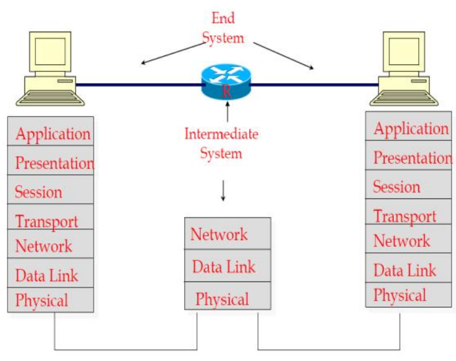

Fig.1. OSI model layers

In this model, a networking system was divided into several layers. Within each layer, one or more entities implement its functionality. Each entity interacted directly only with the layer immediately beneath it, and provided facilities for use by the layer above it. The data is formatting in the various headers in a sequential manner such as application header, presentation header, session header, transport header, network header, data link header & trailer and physical frame preamble. Protocols enabled an entity in one host to interact with a corresponding entity at the same layer in another host. Service definitions abstractly described the functionality provided to an (N)-layer by an (N-1) layer, where N was one of the seven layers of protocols operating in the local host. The application, presentation, session and transport layers are considered like host layers and rest of them are media layers.

The *application layer* is the OSI layer closest to the end user, which means both the OSI application layer and the user interact directly with the software application. This layer interacts with software applications that implement a communicating component. In synchronizing communication, all communication between applications requires cooperation that is managed by the application layer. Some examples of application-layer implementations include: *On OSI stack*: FTAM File Transfer and Access Management Protocol, X.400 Mail, Common Management Information Protocol (CMIP) *On TCP/IP stack:* Hypertext Transfer Protocol (HTTP), File Transfer Protocol (FTP), Simple Mail Transfer Protocol (SMTP), Simple Network Management Protocol (SNMP), etc. The *presentation layer* establishes context between application-layer entities, in which the application-layer entities may use different syntax and semantics if the presentation service provides a big mapping between them. If a mapping is available, presentation service data units are encapsulated into session protocol data units, and passed down the protocol stack. This layer provides independence from data representation (e.g., encryption) by translating between application and network formats. The presentation layer transforms data into the form that the application accepts. This layer formats and encrypts data to be sent across a network. It is sometimes called the syntax layer. The *session layer* controls the dialogues (connections) between computers.

It establishes, manages and terminates the connections between the local and remote application. It provides for full-duplex, half-duplex, or simplex operation, and establishes check pointing, adjournment, termination, and restart procedures. The OSI model made this layer responsible for graceful close of sessions, which is a property of the Transmission Control Protocol, and also for session check pointing and recovery, which is not usually used in the Internet Protocol Suite. The *transport layer* provides the functional and procedural means of transferring variable-length data sequences from a source to a destination host via one or more networks, while maintaining the quality of service functions. An example of a transport-layer protocol in the standard Internet stack is Transmission Control Protocol (TCP), usually built on top of the Internet Protocol (IP). The *network layer* provides the functional and procedural means of transferring variable length data sequences (called datagrams) from one node to another connected to the same network. A network is a medium to which many nodes can be connected, on which every node has an address and which permits nodes connected to it to transfer messages to other nodes connected to it by merely providing the content of a message and the address of the destination node and letting the network find the way to deliver ("route") the message to the destination node. In addition to message routing, the network may (or may not) implement message delivery by splitting the message into several fragments, delivering each fragment by a separate route and reassembling the fragments, report delivery errors, etc. The *data link layer* provides a reliable link between two directly connected nodes, by detecting and possibly correcting errors that may occur in the physical layer. The *physical layer* has lot of functions such as it defines the electrical and physical specifications of the data connection. It defines the relationship between a device and a physical transmission medium (e.g., a copper or fibre optical cable). This includes the layout of pins, voltages, ne impedance, cable specifications, signal timing, hubs, repeaters, network adapters, host bus adapters. The summary of OSI model is shown in Fig. 2.

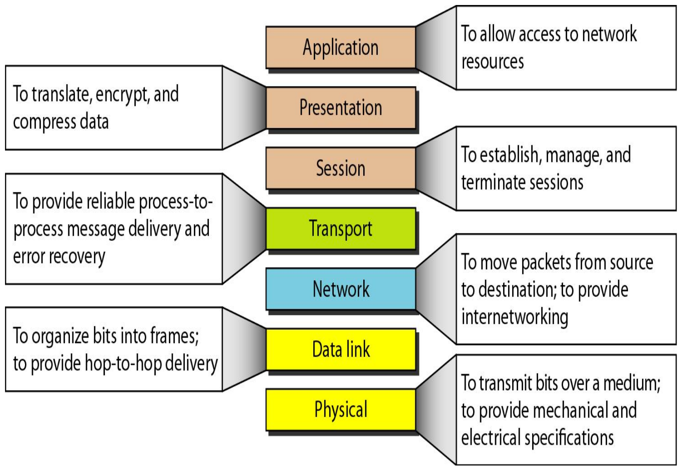

Fig.2. Summary of OSI Model

Intelligent Electronic Devices

General concept of packets serves as a prerequisite to the understanding of the ISO-OSI model. The data packet may consists of start information, receivers address, senders address, control data, data and error correction protocol. Packets must conform to a standard in order for the nodes in a network to be able to communicate with one another The International Standards Organization (ISO) has provided a reference model. Standards are established for operations at each layer of the ISO/OSI model in the form of protocols. When Intelligent Devices communicate with each other, there need to be a common set of rules and instructions that each device follows. A specific set of communication rules is called a protocol. A protocol should be used for Intelligent Electronic Devices (IEDs) to enable the interoperability. Interoperability means Applications and devices can exchange useful information across business functions without the user having to engineer it. IEC 61850 is to be followed by manufactures to enable the interoperability. Now a days all the relays used in power system protection are IEDs only because of their multi functionality and multi-tasking activities. IEDs can be defined as "Any device incorporating one or more processors with the capability to receive or send data/control from or to an external source." These are provided with various functions like remote I/O, remote metering, Power quality monitoring, deterministic programmable logic etc. some of the examples of IEDs are Programmable logic controllers (PLCs), Digital relays, digital fault recorders, sequence of event recorders, voltage regulators etc.

Role of Digital relays in Substation Automation

One bay, one unit the numerical relays offers fully integrated protection, control, monitoring and automation incorporated in a single device. They have the communication facility with PC. The relays have the communication facility station suitability and system integration. For every manufacturer will have their own software and protocols which should be inoperable with any other made IEDs. D e abbreviations in the title or heads unless they are unavoidable.

Role of multi device functionality

Single IED replaces multiple conventional instruments that were previously separate devices. It requires less panel space (fewer panels, smaller buildings) requires much less inter-device wiring, less complexity.

Some of the protective functions of Relays

The various functionalities are listed as follows. Phase time overcurrent, Phase instantaneous overcurrent, Ground overcurrent, Ground instantaneous overcurrent, Over/under voltage, Negative sequence overcurrent, Phase and ground directional overcurrent, Under frequency load shedding, Automatic reclosing, Adaptive relaying (e.g., cold load pickup). IEDs can perform sophisticated processing functions in addition to "standard" features *like* Determination of "derived" quantities (watts, vars, power factor, etc.) from basic ac inputs (CT and PT measurements), Harmonic Analysis, Digital fault recording and SOE analysis, Fault location.

The basic requirements of Substation automation is purely based on Modularity. It enables the plug and play. Fig 3 shows the modularity of the bay level.

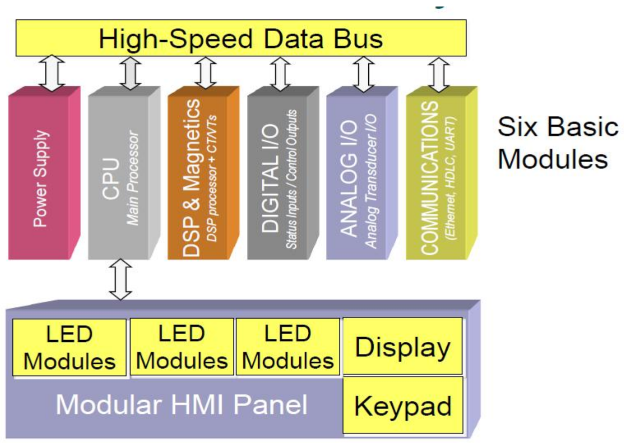

Fig. 3. Modularity

Basic principles of automation

The general principles of the substation operation have not changed. The control and protection tasks remain the same. The objective of modern substation automation (SA) is to solve these tasks in a more efficient and economical way by using state of the art Information Technologies (IT) and to provide to work plant and systems harder. The Integration of All substation Equipment and bring the data to one place for Control, Monitoring and analyzing the data.

Major Components at Station level is station Computer, HMI Workstation, Engineering Workstation Station Switch, GPS Receiver etc. Components at Bay level is bay control Unit (BCU), Protection Unit (BPU) Monitoring Unit (BMU), Energy Meter Unit (EM), Bay Switch etc. The Components at Station and bay level are inter connected by the station LAN.

Various levels

SAS: The SAS comprises of Station level, Bay level and Field level components and are integrated as depicted in the system Architecture.. *BCU* is fully self-sufficient control and monitoring system with non-volatile storage of all Bay unit parameters. BCU comprise of I/O cards for field equipment's and LCD screen for Mimics BCU in conjunction with Numerical Relays/IEDs of each Bay form integrated system for Control, Monitoring and Protection. *AC Kiosk Model*: BCU with associated BPUs/IEDs/Numerical Protection Relays housed in AC Kiosk. *Processing Interface:* The Bay Units (BCU/BPU/IEDs) are interfaced directly to the HV Equipment by traditional I/O cards. *BAY Interfacing*: At Bay level, All BCU/BPU/IEDs are interconnected to Bay Ethernet Switches. *Station/bay Interfacing:* The Station level and the BU are the station LAN. *Goose Interfacing* inter connected by Interlocking functions, Start-up and signaling functions *Remote centering Interfacing:* Through Gate way function in the Station Computer and the protocols IEC60870-5-104 and IEC60870-5-101. Fig 4 shows the various components at bay level for bus-bar in a substation. Fig 5 shows the various components at bay level for energy meter. Fig 6 shows the various components at bay level for station level.

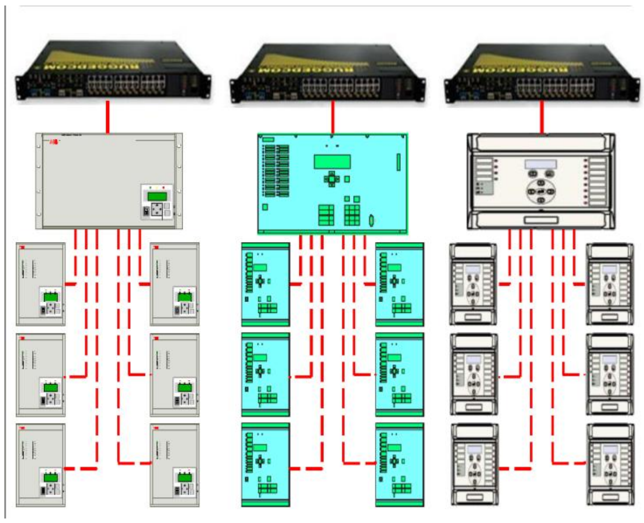

Fig. 4. Components at bay level for bus bar

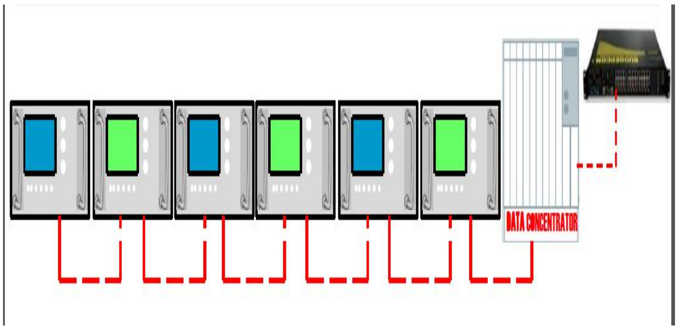

Fig. 5. Components at bay level for energy meter

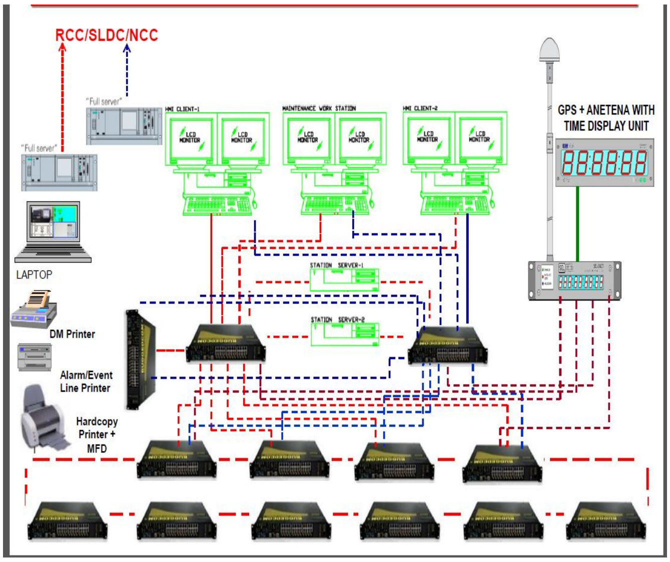

Fig.6. components at bay level for station level

GOOSE (Generic Object Oriented Substation Event) is a mechanism for the fast transmission of substation events, such as commands, alarms, indications, as messages. A single GOOSE message sent by an IED can be received and used by Several receivers. GOOSE takes advantage of the powerful Ethernet and supports real-time behaviour it is used for e.g. tripping of switchgear, starting of disturbance recorder, providing position indication for interlocking. Fig 7 shows the Goose concept which is used for independent multifunctional activities. Fig 8 shows the typical line constructed with hard brick redundant architecture.

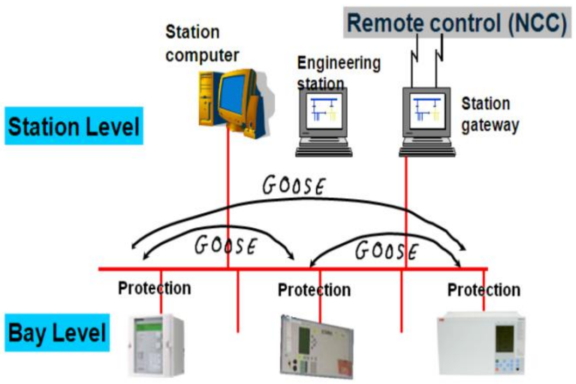

Fig. 7. Goose Technology

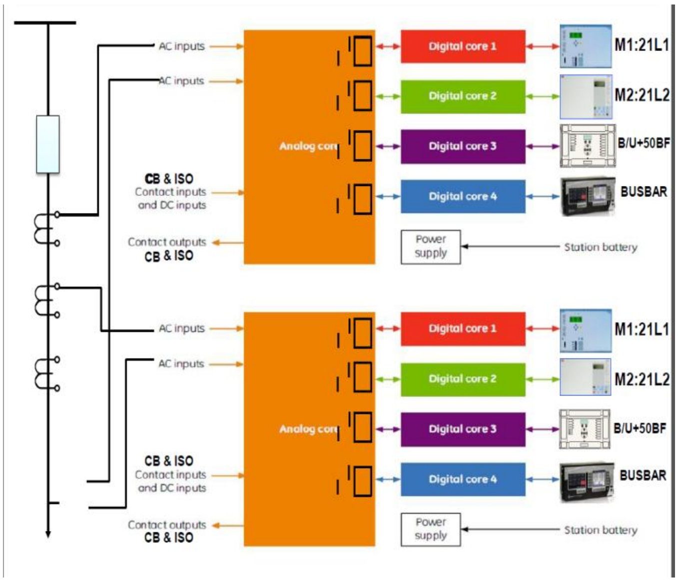

Fig. 8. Hard brick redundant architecture

Conclusion

The SA gives more effective long term planning loading decisions. Also provides real-time analysis that avoids interruptions. SA reduces the need for Costly Field Visits. It gives the precise and confident operator decision in Restoring Service. In future the cloud computing is provided with other devices to enable the & fast operation and control from remote area to all other devices.

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