GRENZE Scientific Society

Proc. of Int. Conf. on Current Trends in Eng., Science and Technology, ICCTEST

Study of Substation Automation System using IEC 61850 Protocol

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***Abstract*— Thispaper discusses Substation automation using IEC61850 protocol. The IEC61850 is a part of International Electro-technical commission's Technical committee 57.(TC57) architecture of electric power systems. The protocol is able to overcome many technical limitations of the existing network technology. IEC61850 is an innovative approach that requires a new way of thinking with respect to substation automation that will result in improved performance and economic operation of power system.**

***Index Terms*—SAS-substation automation system, IEC-international electro-technical commission.**

I. Introduction

The power industry is engaged in the generation, transmission, and distribution of electrical energy which is obtained by conversion from other forms of energy such as coal, gas, oil, nuclear, water, or other renewable energy. These activities often include mining, rail transport, shipping, slurry pipelines, and storage of energy in many forms. Many electric utilities are also engaged in the transmission and distribution of gas.
In the first 90 years of its history, the industry expanded at a pace nearly twice that of the overall economy, doubling roughly every 10 years. During this period, real prices per kilowatt hour decreased steadily because of generation, transmission, distribution, technical improvements, productivity increases, and stable fuel prices. Throughout the 1970s, increased fuel costs, limits in economies of scale, diminishing returns in technology improvement, and increased regulation costs led to increased kilowatthour costs and reduced demand growth.
The political and economic response to increasing costs has been a movement to smaller generator sizes, minimization of capital investment, and attempts to control costs by fostering competition in generation supply. Incentives were also established to reduce demands and increase load factors. Today power supply is diversifying away from large central station technologies and toward increased use and availability of the transmission system.
In scheduling its day-to-day operation, and in planning for its future growth, the industry has made extensive use of analytical tools and mathematical models which, through optimization and simulation, help in the decision-making process. As a consequence, the industry has long been one of the largest users of computers and among the most sophisticated in its modeling and computational techniques. This use is quite understandable when one considers the high cost of power system equipment, the complexity of power systems, and the severe operational, reliability, andenvironmental requirements on the electricity supply.
Today the industry has reached a stage where computer systems are no longer merely an engineering tool.

Grenze ID: 02.ICCTEST.2017.1.190

The effectiveness of computer applications is one of the key elements in achieving the basic functions associated with the planning, designing, construction, operation, and maintenance of the power system. In fact, engineering and computers have been integrated. This integration may be viewed as tending toward the construction of a utility industry information system. Such a system is shown in Fig 1. It depicts a typical information system which may be viewed as a combination and integration of several functional information systems.

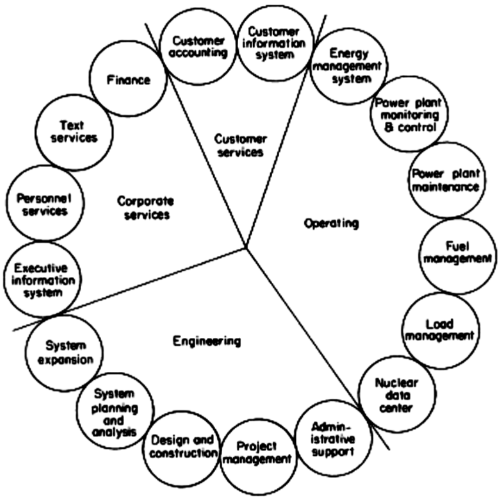

Fig 1.SCADA management

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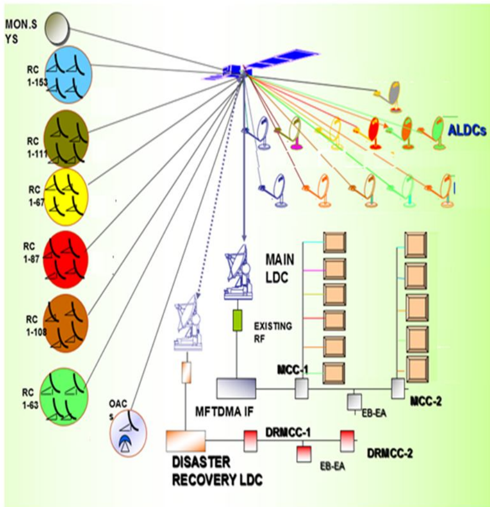

Fig 2.Typical SCADA system

Carrying out functions requires data acquisition and management systems. The function of this data acquisition systems is provide required information so that power system operation decisions can be appropriately taken.

II. SUPERVISORY CONTROL AND DATA ACQUISITION SYSTEM

The electric utility SCADA (Supervisory Control and Data Acquisition) system is now a mainstay. Most electric utilities have means to monitor their power system activity and control substation equipment from a central location that would be classified as a SCADA system. The long sought improvements in efficiency promised by upgrading manned substations to monitored substations have been largely achieved. Typical SCADA system is shown in Fig 2.

It has taken many decades to get to this point. There has been a long evolution of technology and change that has brought SCADA technology this far. While substation automation is considered current technology, it is valuable to understand the steps in technological evolution and to recognize that some of that history is still in use in utilities today. The evolution in computer technology that helped drive the SCADA systems in their infancy has seen many significant changes. In the substation, microprocessor technology that gave birth to the intelligent electronic device (IED), opened the opportunity to combine functions and has significantly changed the landscape for the substation interface.

The SCADA system connects two distinctly different environments. The substation, where it measures, monitors, and digitizes; and the operations center, where it collects, stores, displays, and processes substation data. A communications pathway connects the two environments. Interfaces to substation equipment and conversations and communications resources complete the system. The substation terminus for traditional SCADA system is the remote terminal unit (RTU) where the communications and substation interface interconnect.

SCADA system RTUs collect measurements of power system parameters and transport them to an operations center where the SCADA master presents them to system operators. Predominantly, there are real and reactive power flow (watts and vars) voltages and currents. But other measurement slike tank levels—

pressures and tap positions are common to SCADA systems. These belong to the class of measurements termed analogs. Almost anything that can be viewed as a continuous variable over a range fits this category. Analog data is refreshed periodically so that the operator can be assured that data on this screen is relevant. The refresh rate is often dependent on the characteristics of the data being viewed and the communications resources available.

SCADA master stations monitor the incoming stream of analog variables and flag values that are outside prescribed limits with warnings and alarms to alert the system operator to potential problems. Data are screened for "bad" (i.e., out of reasonability limits) data as well.

SCADA systems also collect the state of power equipment such as circuit breakers and switches. These data are presented to the system operator, usually on graphical displays, to give the operatora view of the connectivity of the power system at any given moment. Various state change-reporting techniques have been used to report such changes for the system operator. These include flagging momentary changes, counting changes and time tagging them with varying degrees of resolution(sometimes as short as one millisecond).

SCADA systems almost always provide a means for the system operator to control power equipment. This includes circuit breakers, switches, tap changers, and generators. It may include some peripheral equipment in the substation as well.

In the operation center, a SCADA system has at least one computer, communicating to substations and/or generating stations collecting data, issuing control commands, and storing the incoming data. The system operator views data and messages through a set of displays on "view stations." The displays allow the operator to control power equipment and make system changes through a screen dialog.

Besides these basic functions, the operations center computer archives data and displays selected data sets, such as trends and logs in special ways for the operators. More modern systems providedata to other areas of the utility enterprise in any number of different forms and services.

III. IEC 61850 PROTOCOL

Communication plays an important role in the real time operation of a power system. In the beginning, telephone was used to communicate line loadings back to the control center as well as to dispatch operators to perform switching operations at substations. With the entry into a digital age, we needed the technology to cater to the hot requirements, which are;

- High-speed IED to IED communication
- Multi-vendor interoperability
- Support for File Transfer
- Auto-configurable / configuration support
- Support for security

Given these requirements, work on next generation communication architecture began with the development of the Utility Communication Architecture (UCA) in 1988.

Today, IEC 61850 is a standard for the design of electrical substation automation and it has been defined in cooperation with manufacturers and users to create a uniform, future-proof basis for the protection, communication and control of substations. IEC 61850 meets the requirements for an integrated Information Management, providing the user with consistent Knowledge of the System on-line rather than just Gigabytes of raw data values. IEC 61850 defines standardized Information Models across vendors and a comprehensive configuration standard (SCL – System Configuration Language).

A. Interoperability of 61850

- Each of these companies will implement IEC61850 in its power automation products and systems.
- A roadmap for the staged implementation of IEC 61850 has been defined in line with the progress of the standard.
- To verify the implementation of IEC61850 of all three suppliers, joint interoperability tests have been specified.
- Interoperability is the ability of two or more IEDs from the same vendor, or different vendors, to exchange information and uses that information for correct co-operation.
- Interchangeability is the ability to replace a device supplied by one manufacturer with a device supplied by another manufacturer, without making change to the other elements in the system

B. Intelligent electronic device

- Microprocessor-based controllers of power system equipment –e.g. circuit breaker, protective relay
- Receive digitalized data from sensors and power equipment, Issue control commands in case of maintain the desired status of power grid–e.g. tripping circuit breaker

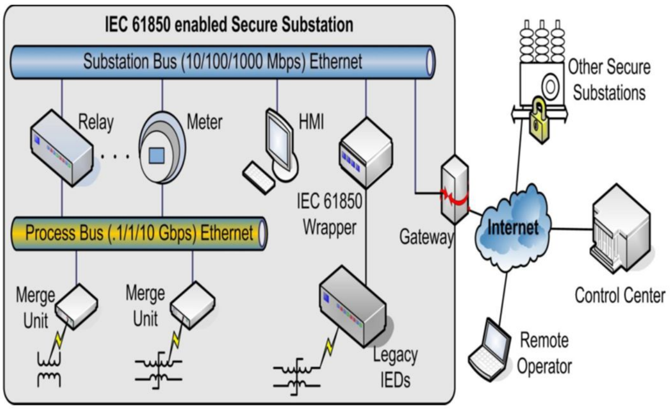

Fig.3 SCADA architecture

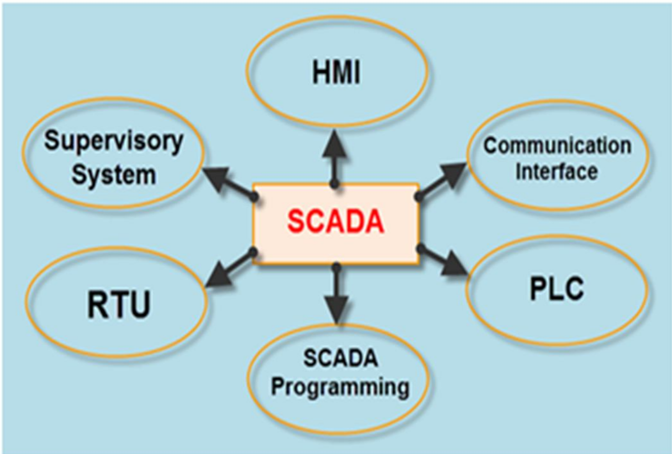

Fig .4 Basic scada

- IEC61850-enabled IEDs get digitalized power grid condition data via process bus and merge units
- IEDs communicate with each other using substation buses
- Legacy devices use IEC61850 wrapper
  - Substation bus is realized as a medium bandwidth Ethernet network, which carries all ACSI(absolute communication system interface) requests/responses and generic substation events messages(GSE, including GOOSE and GSSE).
  - Process bus connects the IEDs to the traditional dumb devices (merge units, etc.) and is realized as a high bandwidth Ethernet network
  - ACSI:ACSI is the primary interface in the IEC 61850 standard. ACSI defines the semantics of the data exchanged between applications and servers.

C. Function Hierarchy and Interfaces of IEC 61850

The three levels in the functional hierarchy are shown

Process level:
This level includes switchyard equipmentssuch as CTs / PTs, Remote I/O, actuators, etc.

Bay level:
Bay level includes protection and control IEDs of different bays.

Station level:
The functions requiring data from more thanone bay are implemented at this level.

Process bus:
This facilitates the time critical communication between protection and control IED to the process (the primary equipment in the substation), such as sampled values, binary status signals or binary control signals.

Station bus:
It facilitates communication between station level and bay level. It also allows communication among different bays.

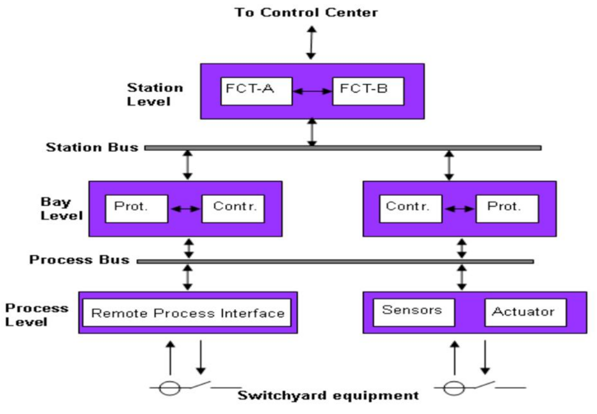

Fig5.Interface model of a substation automation system.

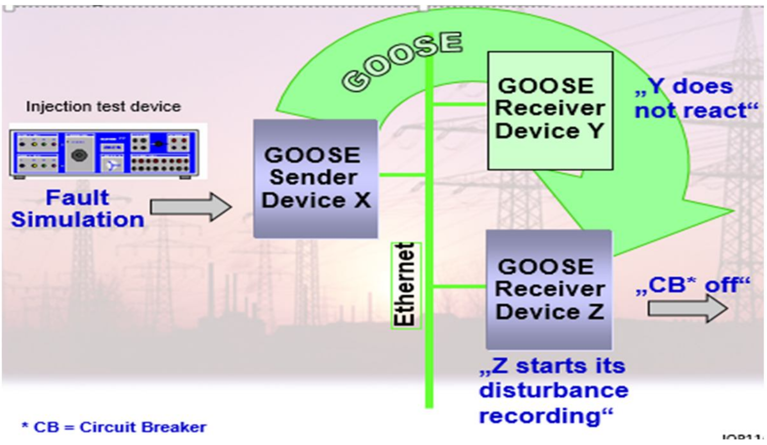

Fig6. IEC61850 principle

D. Goose

- GOOSE (Generic Object Oriented Substation Event)
- It 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

Tripping via goose

GOOSE message with commands for CB* tripping and disturbance recorder starting
Configuration: sender X --> receiver Z

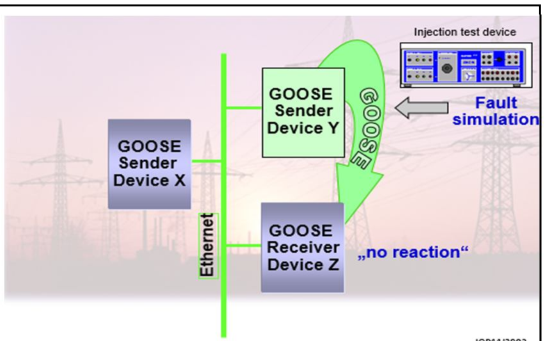

Fig.7 negative test

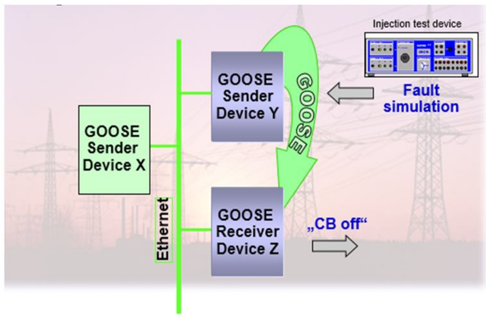

Fig.8 positive test

Negative tests

GOOSE message with commands for CB tripping and

- disturbance recorder starting
  Configuration: sender Y –> receiver Z not configured

Positive tests

- GOOSE message with commands for CB tripping and
- disturbance recorder starting
  Configuration: sender Y --> receiver Z

E. Benefits of IEC 61850

IEC 61850 is unique. IEC 61850 is not a former serial link protocol recast onto TCP/IP-Ethernet. IEC 61850 was designed from the ground up to operate over modern networking technologies and delivers an unprecedented amount of functionality that is simply not available from legacy communications protocols. These unique characteristics of IEC 61850 have a direct and positive impact on the cost to design, build, install, commission, and operate power systems. Whilelegacy protocols on Ethernet enable thesubstation engineer to do exactly the same thing that w
as done 10-15 years ago using Ethernet, IEC 61850 enables fundamental improvements in the substation automation process that is simply not possible with a legacy approach, with or without TCP/IP-Ethernet. To better understand the specific benefits we will first examine some of the key features and capabilities of IEC 61850 and then explain how these result in significant benefits that cannot be achieved with the legacy approach.

IV. Conclusion

The introduction of the standard IEC 61850 to the SA systems is a positive measure. The standard does not impose restrictive rules over many aspects because of which there is still a large functional freedom for each vendor to explore. It's a future-proof solution as it takes into consideration the progress of technology and is able to follow it. As it implements interoperability advantage, it is no doubt the technology to substation automation. Thus SCADA systems built with the latest RTU technologies can deliver the optimal reliability, efficiency, and cost-effectiveness that today's complex infrastructure and industrial processes require.

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