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The Era of Global Standard for SCADA Substation Automation

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Abstract

The IT revolution has encompassed within its realm the electrical power sector by the application of Intelligence in Metering, Protection, Monitoring and Control.

The amalgamation of communication and IT has made it possible for a Real time IT systems to monitor and control, from a central place, by SCADA for the operation of Power Generation, Transmission and Distribution.

A hierarchical structure exists in the transmission and distribution of power since the power is received at a high voltage level in a substation and delivered to a load center through another substation at reduced voltage level. These substations are being transformed from hardwired configurations to a networked platform by leveraging the technological advancements. The technological transformations have brought within its purview Comprehensive Automation of Substation.

This paper brings out the current trend in communication & systems in Substation Automation IEC61850 Standard along with its benefits for improving Quality and Reliability of the Power System. Also, this paper highlights the case study of a real time process control scheme.

Key words: Substation Automation, SCADA, IEC 61850 Standard, Intelligent Electronics devices.

Introduction

Substation equipments generally are categorized into two domains primary equipments and secondary equipments. Primary equipments include transformer, switchgear etc, while the secondary equipments include protection, control and communication equipments.

Levels of Sub-Station Automation: Sub-station Automation systems comprise three levels

The station level: It consists of the station computer with a database, operator's workplace, and interfaces for remote communication etc. Station Level functions refer to the substation as a whole.

There are two classes of station level functions namely the process related station level function and the interface related station level function.

The Process related functions act on the data from multiple bays or substation level database. These functions are used to submit the control commands for the primary equipment (Circuit breakers) and collect the substation data like voltage, current, power factor etc. from the bay level devices. As described above, each bay includes one primary equipment such as transformers, feeders etc. Interface related functions enable interactive interface of the substation automation system to the local station operator HMI (Human Machine Interface), to a remote control centre or to the remote monitoring centre for monitoring and maintenance.

The Bay level: It comprises of all the control and protection units and the process level with more or less intelligent process interfaces to the field equipments. Extended implementations show all three levels equipped with IEDs, There is not only vertical communication between the levels (e.g. between bay and station level), but also horizontal communication within the level (e.g. in the bay level between bay units for functions like interlocking).

Bay level functions are using mainly one bay and acting mainly on the primary equipment of one bay. The definition of bay level functions considers some kind of a meaningful substructure in the primary substation configuration and related to this substructure, some local functionality or autonomy in the secondary system. Examples for such functions are line protection or bay control. These functions communicate within the bay level and process level.

The Process Level Function: Its main task is to extract the information from switchgear / CTs / VTs in the substation and to send them to upper level device, called bay level device. The other major task of process level function is to receive the control command from bay level device and execute it at appropriate switch level.

The initial advent of digital substations was followed by a rapid evolution of software technology. Substation automation systems formed out of distributed components is a technological possibility made viable by the IEC 61850 standard "Communication Networks and Systems in Substations".

Substation automation basically consists of implementing intelligent electronic devices (IEDs) using microprocessors to monitor and control the physical power system devices. These IEDs can make more data available in digital format. However, these data can be turned into information that is available in the right form, at the right place, and at the right time through automation. It is this information that is the true benefit of substation automation.

Substation automation offers implementation benefits as enumerated below:-

(a) Reduced quantities of equipment, networks implemented with fiber-optic cable, industry standard interface technology – Ethernet, Data management, Metadata management, designing toward a seamless architecture, Integration of digital information and functionality, Gradual displacement of analog devices, new digital equipment capabilities and Station HMI consoles.

(b) Substation automation benefits the utility staff, Maintenance staff, Planner, Asset management personnel, Operators and operational planners, Protection engineers, Operations engineers, Data administrators,

(c) Substation automation benefits control center operations, SCADA/EMS systems, Contingency analysis (security analysis), Intelligent alarm processing, Emergency response etc.

Legacy System Architecture

The SCADA applications and individual device vendors share common tag database as shown in Figure 1. Each IED/RTD manufacturer had to develop & supply driver. Specialized point to point link to IEDs applications must deal with numerous Protocols, Data formats & Data addressing. There is virtually no link to other applications.

Communication path must be reconfigured, when new device and applications are added. The most recently widely used technology like OPC was mainly adopting this approach.

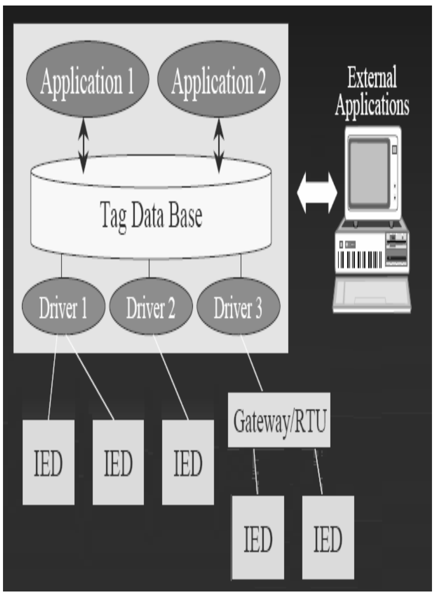

Figure 1: Legacy System Architecture.

Legacy sub-station to control center

The major draw back of the above scheme is that every substation must have separate access & every application & node must be configured for access. This has low speed modem links to RTUs in sub-station as shown in figure 2.

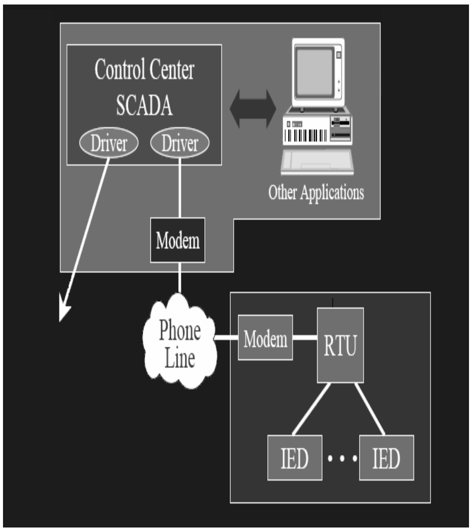

Figure 2: Legacy System Architecture.

Relay to Relay Legacy communication Architecture

Each relay to relay requires a dedicated link and change in relay behavior requires rewiring as shown in figure 3. Also, one can not know the status of the links if it is working or not unless it is used. The dedicated application can only access data from the IEDs. Addition of new device needs modification in the common data path such as need to add driver specific to the new device, add an entry into tag database and to modify the application if required.

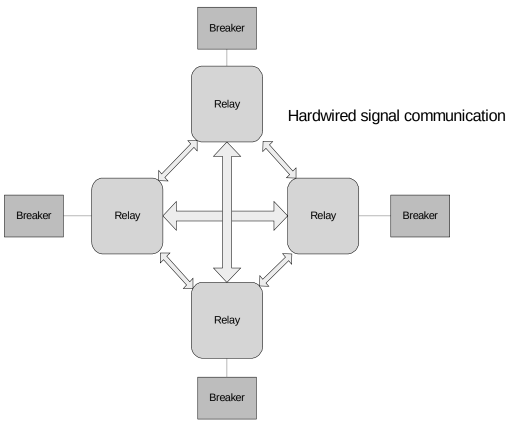

Figure 3: Relay to Relay Legacy communication Architecture.

IEC 61850 Substation Communication Architecture

Standard defines two separate LANs. Station LAN or Bus and Process LAN or bus as shown in figure 4.

Station LAN connects all of the IEDs to one another and to a router or other device for communicating outside the substation with wide area network (WAN).

Process LAN conveys unprocessed power system information - voltage and current samples and apparatus status from switchyard source devices to the relays or IEDs. It is also possible to merge the station and process LANs into one physical communication network**.**

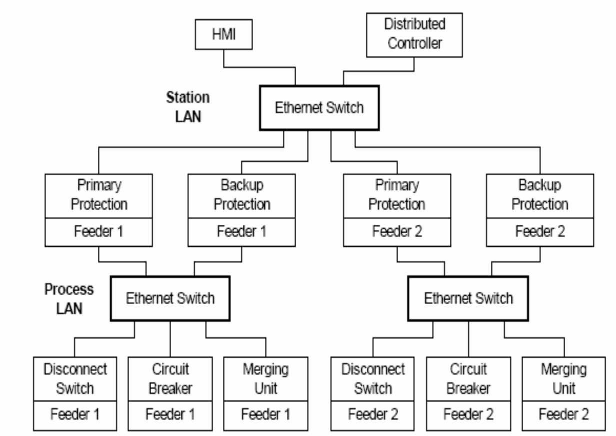

Figure 4: IEC 61850 Substation Communication Architecture.

IEC 61850 Object Model

One or more logical nodes builds a logical device as shown in figure 5. Logical devices are implemented in IED. Logical Node contains a list of data specific to functionality with dedicated data attributes. The logical nodes and the data contained in the logical device are crucial for the description and information exchange for substation automation systems to reach interoperability as shown in figure 6.

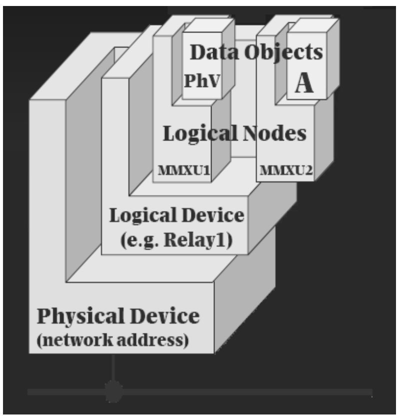

Figure 5: IEC 61850 Object Model.

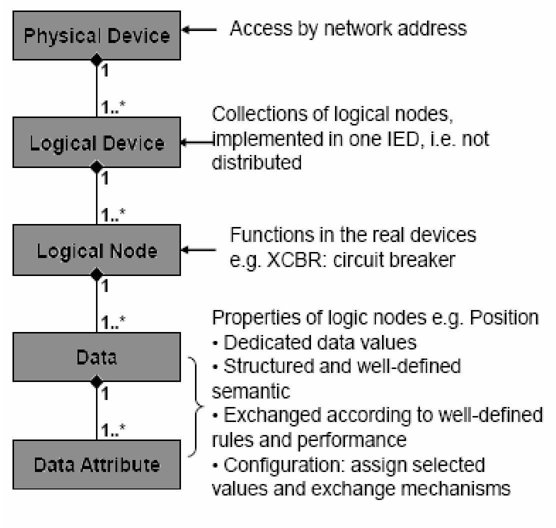

Figure 6: Logical flow diagram.

In addition, application change will have impact on the devices it communicates & dedicated application can only retrieve the sub-station data. The scheme has higher wiring cost, equipment migration from one manufacture to another is not easy, link status between the devices can not be known before the use, less flexible for expandability due to hardwired connections, each device needs to be configured individually, inflexible interoperability between the devices & makes, different system integrators will have different approach for planning ,operation & maintenance. It is not so easy for integration of equipment & systems for controlling the Power.

History of IEC 61850

Introduction of IT base is vital to determine the true benefits of substation automation to all stakeholders. All may not be cost justified; nevertheless, many benefits that were not initially obvious have become increasingly cost-justified, as automation has ushered in interaction among the process as against replacement. It is possible to add on new functions to enhance the scope of a running system. Standards based security, no conversion protocols or converters in a substation environment. The various equipments that are integrated to put in place the substation automation system in a given substation had to exchange enormous information to deliver the desired performance. This required considerable customization through protocol converters that were proprietary (Manufacturer Specific) in nature, but that was not compatible with a multi vendor environment. Therefore, professionals opted for Open protocols viz. IEC 60870-5 101/103/104,

MODBUS, DNP3.0. This allows future modifications to the system without having to re-engineer the entire system. Even though many protocols are used for, but none of them completely support the interoperability among devices supplied by different vendors. There need to be a protocol which is flexible and meets many of market requirement and to achieve interoperability.

The need for a standard interface to the new IED's that were being developed by different vendors was acknowledged by IEC. IEC TC57 and IEC TC95 set up a joint working group, which developed a standard for the "Informative interface of protection equipments". During the same time the Electric Power research Institute (EPRI) of the USA initiated the Utility Communication Architecture (UCA) to add specifications detailing the object models of the field devices and definitions of the communication behavior and this was published as the UCA ver. 2.0.

In 1995 the need for a much more general standard covering communication networks and systems in substations was acknowledged by the IEC. In 1997, the two groups agreed to work together to define a common international standard that would combine the work of both groups. As a result a common International Standard IEC 61850 published in 2003.

IEC 61850 – An overview

IEC 61850 standards "Communication Networks and Systems in Substation" is, by and large adopted by many utilities by framing the desired requirements or functions. The basic functionality of Substation Automation is given by its requirements and is not altered by IEC 61850. The standard retains the system architecture but embraces Object oriented data model, the selection of mainstream communication technology (Ethernet) , standardized rules for exchange of routine or vital information among equipments, interoperability and many more. These features support designing optimized systems which not only includes overall functional performance but also economic aspects like investment, availability, expandability and maintainability, i.e. all life cycle costs.

The objectives that set for the making the standard was:

(a) A single protocol for complete substation considering modeling of different data required for substation.
(b) Definition of basic services required to transfer data so that the entire mapping to communication protocol can be made future proof.
(c) Promotion of high interoperability between systems from different vendor.
(d) A common method or format for storing complete data.
(e) Define complete testing required for the equipments that confirms to the standard.

Features of the IEC 61850 Standard 3.41Data Modeling -Complete functionality of the substation is modeled into different standard logical nodes which can be grouped under different logical devices. There are logical nodes for data/functions related to the logical device (LLN0) and physical device (LPHD).

Reporting Schemes -- There are various reporting schemes (BRCB & URCB) for reporting data from server through a server-client relationship which can be triggered based on pre-defined trigger conditions.

Fast Transfer of events -- Generic Substation Event (GSE) is defined for fast transfer of event data for a peer-to-peer communication mode. This is again subdivided into GOOSE & GSSE.

Setting Groups -- The setting group control Blocks (SGCB) are defined to handle the setting groups so that user can switch to any active group according to the requirement.

Sampled Data Transfer -- Schemes are also defined to handle transfer of sampled values using Sampled Value Control blocks (SVCB)

Commands -- Various command types are also supported by IEC 61850 which include direct & SBO commands with normal and enhanced securities.

Data Storage—SCL (Substation Configuration Language) is defined for complete storage of configured data of the substation in a specific format.

Benefits of the Standard

(1) IEC 61850 is a global System Standard for inter compatibility between devices from various suppliers that are installed in Substation. This allows optimizing the selection of devices for dedicated applications and will improve competition.

(2) In conventional Substation a bunch of Hard Control Wire used to come to the Control Room, But IEC 61850 replace it with a single Ethernet Cable, so Reduction in hard control wirings.

(3) IEC 61850 is a future proof Standard because of the split between the application model and communication. This allows modifying and extending the application without touching the communication Stack.

(4) IEC 61850 is a standard with a comprehensive standardized Substation Configuration Language (SCL).This allows for easy Engineering and Maintenance of Substation Automation System. Efficient system operation using computer aided control decision.

(5) The information model uses concept of Virtualization for the information exchange so that the information is independent of implementation. Virtualization provides a view of those aspects of a real device that are of interest for the information exchange with other devices. Device application functions are decomposed into the smallest entities which are then used for information exchange. The decomposition of these entities are to dedicated devices (IEDs) These entities are called Logical Nodes.

(6) All major equipment manufactures are contributing & adopting this standard.IEC 61850 provides a comprehensive set of definitions that are expected to reduce the total cost of ownership of future substation automation and asset management systems. IEC 61850 will become the protocol of choice as utilities migrate to network solutions for the substations and beyond.

(7) Eliminate Procurement Ambiguity.
(8) Lower Installation Cost
(9) Lower Transducer Costs.
(10) Lower Commissioning Costs.
(11) Lower Equipment Migration Costs.
(12) Lower Extension Costs.
(13) Lower Integration Costs
(14) Implement New Capabilities.

A Case of real time multitasking Process control application using makes of various venders with IEC 61850 standard

General description: Sodium processing system.

Tank T_1 is filled with Sodium and heated by heater H. The temperature inside the tank is sensed by 3 sensors t_1, $t_2$and t_3 as shown in figure 7**.** Readings of temperature are taken every second.

The effective temperature of the liquid in the tank is calculated by the formula: Te=k1t1+k2t2+k3t3.

Where,

k1, k2and k3 are inputted by the user.

The user also inputs the set temperature Ts.

L_1 and L_2 are level sensors which give an output of 1 if liquid reaches it or exceeds its level and 0 if liquid is below this level.

V_1 to V_7 are valves which open if 1 is given as input and close if 0 is given as input.

C_1 is an input which will close the relay (put the heater ON) if input to it is 1 or open it (put heater OFF) if 0 is given as input.

The temperature sensors t_1, t_2 and t_3 give the analog outputs proportional to the temperature sensed and these are fed to a single ADC through a multiplexer and the ADC gives a 12 bit digital output. S_1 and s_2 are select inputs to the multiplexer. Selection is done as follows:-

S_1S_2 Result

t_1 is selected as input to the ADC

t_2 is selected as input to the ADC

t_3 is selected as input to the ADC

The ADC gives an EOC pulse if a conversion is completed. The conversion time of the ADC is 100 microseconds and this will not affect the program as we need only one conversion of each t_1, t_2 and t_3 every second.

Once the temperature of the molten sodium reaches the required value, on a command from the user, the sodium in Tank 1 is transferred to Tank 3 and also a small quantity of special liquid is transferred from Tank 2 to Tank 3.

D_1 and D_2 are Sodium leak detectors. Further, S_1, S_2 and S_3 are smoke detectors.

In case of emergencies all the sodium in Tanks 1 and 3 are dumped into Tank 4 known as dump tank.

List of tasks

(a) Temperature out of limits task

Temperature control task to run every 5 sec

(Run the temperature control algorithm every 5 seconds: To control the temperature to be within 1% of the user set value Ts, and to give an alarm message if temperature value differs by 10%)

Wait for L2 to be on. Wait for data logging task to finish its cycles of updating the temperature.

Read the temperatures of t1, t2 and t3 from the buffer of data logging task.

Calculate the effective temperature

Te =k1t1+k2t2+k3t3.

If (Te-Ts) > 0.01* Ts,

Put off heater (by sending an output 0 to C1).

If (Ts-Te) > 0.01* Ts put on the heater.

Send 1 output to C1; else do not disturb the settings.

If (Te-Ts) > 0.1* Ts (OR).

If (Ts-Te) > 0.1* Ts display alarm message on screen then rest for 5 seconds.

(b) Transfer task

To wait for user command and the temperature to reach the set value and transfer the Sodium from Tank 1 to Tank 3 and also to transfer a small quantity of special liquid into tank 3 from Tank 2.

Wait for command from the user for transfer.

Wait for |(Ts-Te)| < 0.01* Ts ,

Open valve 2 for 7 seconds to allow special liquid from tank 2 to tank3.

Open valve V1.Wait until the level in tank T1 goes below level L1.

Close valve V1. Open valve V3.Wait till L3 and L4 are off showing that Tank T3 is drained.

Open valve V4 Wait until level in tank T1 is up to L2.Close valve V4.

(c) User interface task

Interrupts: Fire alarm interrupt, Sodium leakage interrupts to indicate if fire or Sodium leak is detected)

S1, S2 and S3 are smoke detectors giving output 1 if smoke is detected. Else output is 0.

If smoke or sodium leaks are detected by the sensors.

Put off heater H.

Open V5 and V6 to dump all sodium to an underground tank T4

If L1 to L2 interrupts are received.

Do synchronization actions.

(d) User task:

To give the temperature parameters and commands to transfer or to print logged data.

If command is to set temperature:

Wait for logging task to complete a scan

Sets k1, k2and k3 and Ts as given by the user.
If command is to transfer Sodium:
Wait for transfer if any to complete. Start Sodium transfer operation.

Smoke detector S1
Smoke detector S2
Smoke detector S3

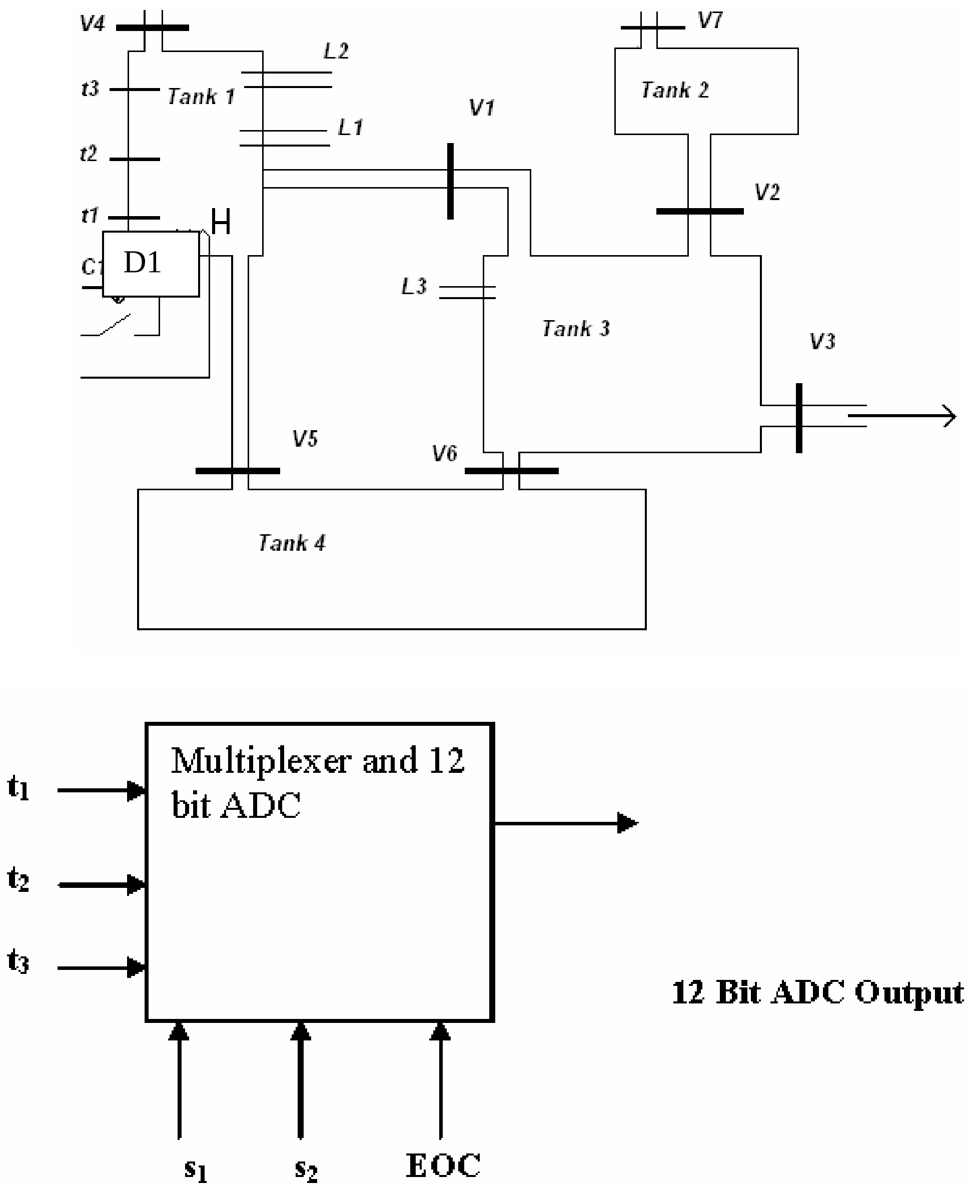

Figure 7: Real time multitasking Process control application using makes of various venders with IEC 61850 standards for Sodium processing system.

Discussion

The case described a typical application involving a distributed SCADA of different vendors and how the operating system primitive help in synchronization and communication in real time kernel to ease the overloads of programming and make it easier to develop, debug and deploy in the system. Further, this approach helps in solving considerable amount of money as fully developed software is very expensive to buy and maintain since the most of the components are readily available and it is easy to buy and integrate with in house developed software for specific application.

Saving potential of Distribution Automation

(a) Design and modification flexibility,
(b) Improving predictive maintenance,
(c) Trouble analysis.
(d) Reducing relay/control-house space requirements,
(e) Lowering engineering costs,

Besides the lower investment cost, the user gets a reduction of the operation cost due to the inherent self-monitoring capability and the possible remote operation and diagnosis. Thus, following benefits are achieved:-

(1) Improving quality and reliability of the power supply.
(2) Improving the operational capabilities of the staff.
(3) Reducing operation and maintenance cost by upgrading older generation protection and control systems with modular ER Automation system.

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Conclusion

The scope of IEC 61850 covers design, implementation of digital substation that can be expanded and augmented with additional functions. In addition, applications are in service that uses various components of IEC 61850 for wide area substation to substation communication. Customer’s network model database undergoes constant network topology changes throughout the life of the system. The changes are due to the natural evolution of the physical power system. In such a scenario IEC 61850 Standard can be implemented successfully for distribution automation application in future.

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