Substation Automation in Kerala: A Step Ahead

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Abstract: Substation automation deals with remotely monitoring, controlling and coordinating the various parameters in a substation. The communication protocol presently used for SCADA communications in Kerala is IEC 60870-5-101. Even though expansion of the system was done, no step was taken towards automating the system. As a result of these serious problems are being face such as the considerable time needed for restoration of power due tripping of feeder, due to instantaneous faults, operational errors, non-functioning of interlocks and human error. Kerala has understood that automation is the key to modernization, but however automation of electrical power transmission and distribution, still, remains a distant goal.

Thus, this project tries to attain, what is considered to be a distant goal for the state. It involves the usage of Intelligent Electronic Devices (IED's) over Remote Terminal Units (RTU's) as today, control, protection, metering and a wide range of other tasks can be performed by a single IED. As this then involves communication between IED's, industry standard, IEC 61850 is used. With the usage of advanced technology comes the need for advanced computing and database management. Hence a study on improving the present system to accommodate the fast paced technology is conducted.

Keywords: IEC 60870-5-101, IEC 61850, interoperability, XA/21, IED,reliability.

1. Introduction

Smart substations form the key building block of a smart grid. Smart substation implies, the creation of highly reliable power system, which rapidly responds to real time events, with appropriate action to ensure uninterrupted power services to end users. Substation automation lead to smart substations and Supervisory control and data acquisition (SCADA) forms the entry towards substation automation. SCADA was introduced in Indian substations in the year 2000. It followed the GE Harris Extended architecture for the 21st century (XA/21). Kerala started with 30 Remote Terminal Units (RTU's) and has at present 32 RTU's. Information is gathered from a series of RTU's, which are wired to substation equipments, such as isolators, CT's, PT's, transformers, etc. The communication protocols used is IEC 60870-5-101. The State Load Dispatch Centre is located at Kalamassery and is supported by three Sub Load Dispatch Centers at Thiruvananthapuram, Kalamassery and Kannur.

The system operation activities of the State are co-ordinated from the State Load Dispatch Centre. The Load Dispatch Control room is equipped with a full-fledged SCADA system acquiring real time data from all Generating Stations, 400kV, 220kV and major grid 110kV stations. The RTU Stations connects the generating stations, 400kV, 220kV substations and major 110kV substations to the SLDC via optical fiber, microwave and the PLCC Communication Network System. The data from these stations are made available on a real time basis through Data Networking. The GE Energy XA/21 software package is used for the SCADA/EMS system in all the control centers.

2. System Architecture

The substation structure can be divided into four levels: process level, bay level and a station level and network level

The process level forms the base, where the switchgear equipment is located. These are wired to the Bay Control Units (BUC) which form the bay level. The bay control unit performs (a) control in accordance with control commands from station level control equipment and (b) monitoring for the bay. The data transferred consists either an analog or binary input or output. Human Machine Interface (HMI) device, a monitoring and maintenance tool for bay control unit and data communication unit during commissioning or maintenance is placed at the bay level. At the station level, which forms the brain of the system, is located the Station Control Unit (SCU). Between the bay level and station level is present a Data Communication Unit (DCU), which serves as a communication interface between station level and bay level units.

At present, the process level is equipped with RTU's. Communication between the bay level and station level is through Power Line Carrier Communication (PLCC), Optical fiber communication or microwave communication following the IEC 60870-5-101 protocol (defines protocols for SCADA).Communication between control centers is through inter control center communication protocol.

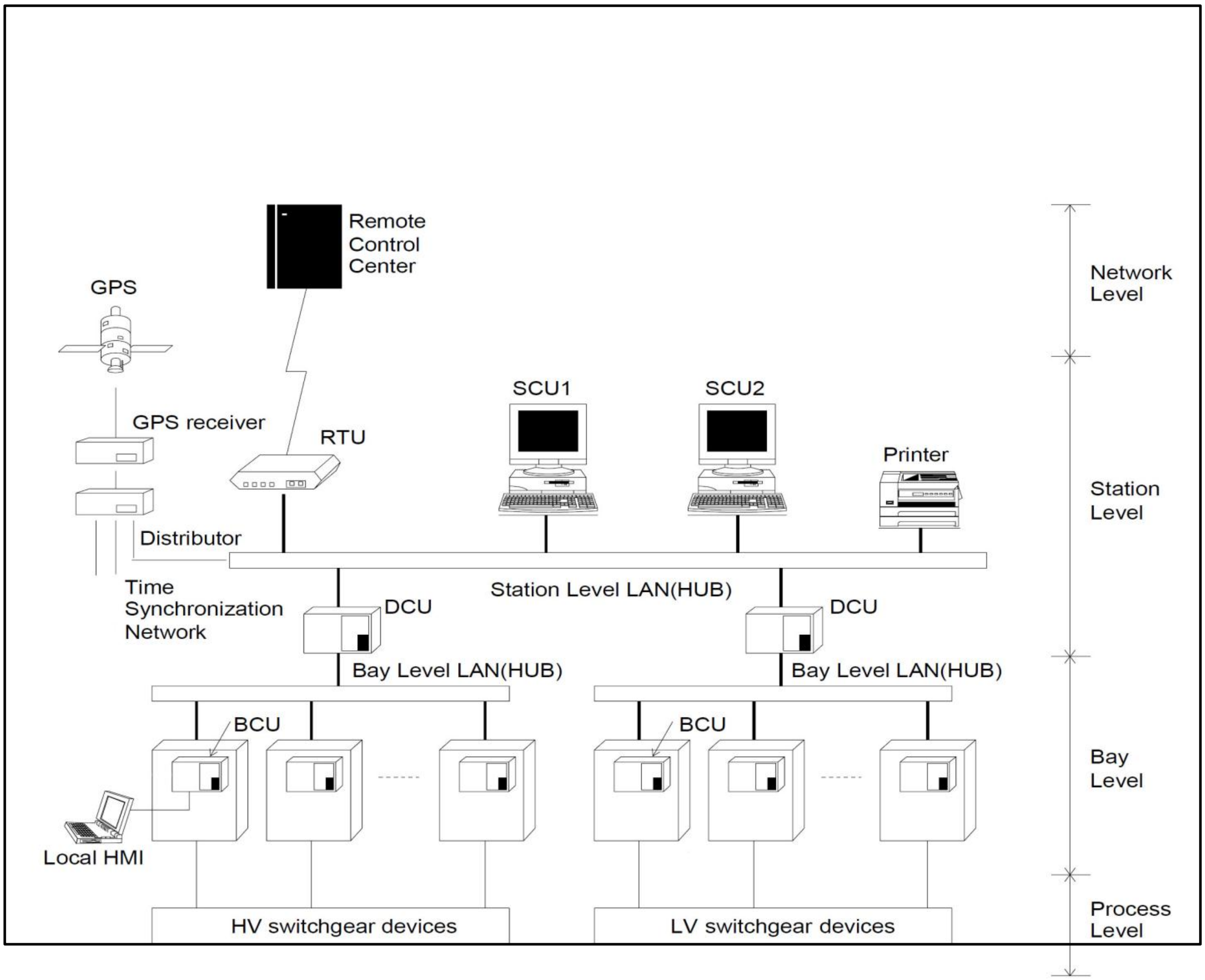

Fig1: System Architecture

To make the system reliable and intelligent, either the present RTU's are upgraded or replaced with IED's. As communication protocol defined for substation automation is IEC 61850 and IED's communicate following IEC 61850, communication takes place following IEC 61850 protocols.

Time Synchronization is done through a global positioning satellite (GPS). At present only the remote control centre is equipped with GPS. As time synchronization is an important element while establishing IEC61850, it is crucial that a GPS antenna is located both at the remote control centre and the substation

3. IEC 61850

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.
The result of this work was a profile of "recommended" protocols for the various layers of the International Standards Organization (ISO) Open System Interconnect (OSI) communication system model. The concepts and fundamental work done in UCA became the foundation for the work done in the IEC Technical Committee Number 57 (TC57) Working Group 10 (WG10), which resulted in the International Standard – IEC 61850 – Communication Networks and Systems in Substations

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).

Features of IEC 61850:

1. *Data Modeling*: Primary process objects as well as protection and control functionality in 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*).
2. *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.
3. *Fast Transfer of events:* Generic Substation Events (*GSE*) are defined for fast transfer of event data for a peer-to-peer communication mode. This is again subdivided into *GOOSE* & *GSSE*.
4. *Setting Groups:* The setting group control Blocks (*SGCB*) is defined to handle the setting groups so that user can switch to any active group according to the requirement.
5. *Sampled Data Transfer:* Schemes are also defined to handle transfer of sampled

values using Sampled Value Control blocks (*SVCB*)

6. *Commands:* Various command types are also supported by IEC 61850 which include direct & select before operate (SBO) commands with normal and enhanced securities.
7. *Data Storage:* Substation Configuration Language (*SCL*) is defined for complete storage of configured data of the substation in a specific format.

The main advantages of using IEC61850 include:

- Offering a complete set of specifications covering all communication issues inside a substation.
- Meeting the requirement for an integrated information management providing the user with consistent knowledge of the system on line, rather than just gigabytes of raw data.
- Inter-operability between various manufacturers' IED's, thus forming an integrated system.
- Substation Configuration Language(SCL)
- Lowering installation and maintenance costs, with self-describing devices that reduce manual configuration.
- Support for functions difficult to implement otherwise.

4. Communication

Communication involves exchange of information, and it takes places through one of the following ways

- Power Line Carrier Communication (PLCC)
- Microwave Communication
- Fiber Optic Communication

for various functions, which include voice communication, teleprotection, telemetering and telecontrol.

PLCC is an approach to utilize the existing power lines for the transmission of information.

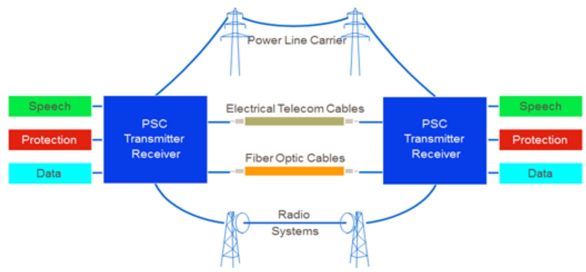

Fig2: Forms of communication

A Power line modem is used for communications over power lines. It works as both transmitter and receiver, i.e., it transmits and receives data over the power lines. There are two different ways by which we can connect a PLC unit with the power lines – capacitive coupling and inductive coupling. In capacitive coupling, a capacitor is used to superimpose the modulated signal on to the network's voltage waveform. Another way is inductive coupling which employs an inductor to couple the signal with the network's waveform

Limitations of PLCC are

- Limited carrier frequency spectrum (50 - 495 KHz)
- Noise and radio interference
  - -Due to irregular discharges across the insulators
  - -Due to Impulse Noise
  - -Due to neighboring systems, like RADARs, International distress signals, etc.
- Low speed data transmission to a max of 600 baud with speech and 1200 baud without speech

Due to the limitations of PLCC for carrying large quantity of data over long distance and at high speed, Wideband Systems came into Power System Communications. Due to the rapid growth of Power System and poor Grid management the following problems originated.

- Wide frequency fluctuations
- Frequent grid disturbances, Generator trippings, supply interruptions & inability to serve loads, cascading & grid disintegration
- Grid indiscipline
- Uneconomic operation

To overcome this crisis, Unified Load Despatch and Communication (ULDC) project commissioned in 2002 by PGCIL with the participation of EBs. It forms the Communication Systems for carrying required Real time data and voice for LD operations.

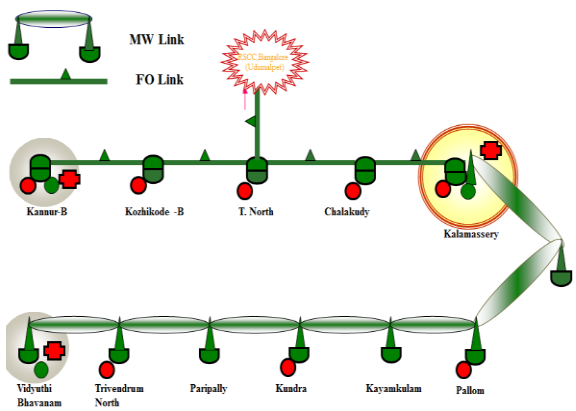

Fig3: Communication between various substations in Kerala

Microwave communication is the transmission of signals via radio using a series of microwave towers. They have an operating range of 50 Kms to 100 Kms and frequency range 300 Mhz to 30 Ghz

Their advantages include

- Reliable
- Multiple voice and data channel capabilities
- Last Mile Access
- Right of way
- Enables communication where wired networks are difficult to install.
- Wider bandwidth

With the development of satellite and cellular technologies, microwave has become less widely used in the telecommunications industry. Fiber optic communication is now the dominant data transmission method. Depending upon applications, the choices of cables are

- OPGW (Optical ground wire): During initial construction of new transmission lines. Techniques have also been developed to install OPGW by substituting the conventional Ground wire on existing lines
    - ADSS (All Dielectric Self Supporting cable): To be erected on existing Towers by stringing the cable at electromagnetic null points on the power lines.
    - Wrap Around: Specially suited for existing transmission lines where installation of ADSS cable is not possible due to inadequate ground clearance or excessive wind loading.

Advantages of using fibre optic communication

- High quality transmission
- Not susceptible to noise, ground potential or EMI
- Very high bandwidth
- Immune to cross-talk (light radiated from neighbor cable do not Interfere)
- Secure (cannot be tapped)
- Long life span

Inspite of all these advantages, they suffer from certain disadvantages, like

- Expensive
- Right of way
- Maintenance is costly and tedious (damaged fiber cable requires skilled technician with proper equipment)

5. Software

KSEB uses XA/21 version 4.3.2 for its SCADA/EMS applications. XA/21 was chosen as GE quoted the lowest tender among the rest of its competitors in the tendering process. Some of its competitors are Toshiba's-TOSCAN-3500, Siemens'-WIN CC.

XA/21 is a field proven, scalable and feature-rich Supervisory Control and Data Acquisition (SCADA) / Energy Management System (EMS) solution that is specifically designed to meet the needs of electric utilities.

XA/21 has several features and advantages, which include:

- Presenting a consistent real-time view of the entire electrical network to operators.

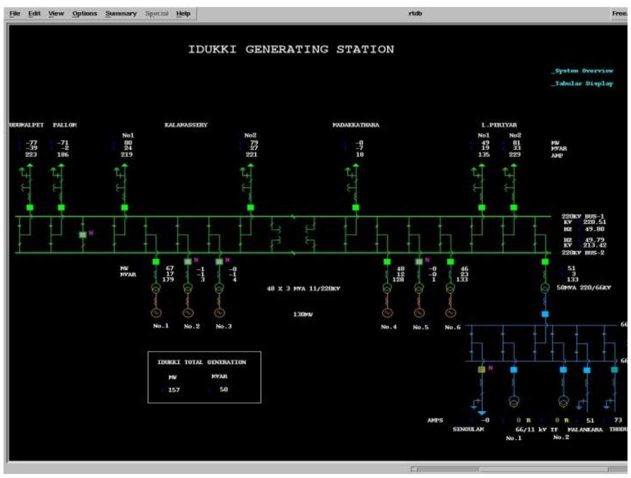

Fig4: Real time view

- Reducing costs of ownership, operating and maintenance costs.
- Next generation Java™-based, full graphic user interface.
- Facility to add, modify or delete database entries online, without interruption of online operations.
- Advanced security measures including centralized management of end users, user authentication, data/communication encryption, and file tampering detection.

XA/21(ver 4.3.2), was no doubt, the best when introduced. But with the advancement in technology, i.e with the change in protocol, ver 4.3.2 becomes incapable. Some drawbacks are,

- IEC 61850 communications have a refreshing rate of 2ms, while XA/21 refreshes in 4ms.
- Serial communications become obsolete, as IEC 61850 would require faster packet data communication.
- Modern peripheral equipment's become incompatible.
- With the passage of time, the system becomes matured, making service and updating troublesome.

The improved versions of XA/21 are updated and fixed ones, that overcomes the mentioned drawbacks.GE has now introduced the 7th version of XA/21.

6. Server

While a desktop system is optimized to run a user-friendly operating system, desktop applications, and facilitate other desktop oriented tasks, a server is engineered to manage, store, send and process data, 24 hours a day, 7 days a week, 356 days a year. For these reasons, servers need to be hugely reliable. The KSEB currently uses 6 IBM 43-P series server to meet the computational demands

Certain feature that makes IBM 43-P servers apt are:

- Affordable and powerful e-business server
- Network-ready, with 10/100Mbps Ethernet built in
- Powered by award-winning IBM AIX®
- Choice of two processor speeds to meet performance needs (i.e. choice of 250 or 375MHz PowerPC 604e processors)
- Up to 1GB system memory
- Mirrored RAID solution to prevent critical data loss due to disk failure

But, upgrading to IEC 61850 would require enhanced server capabilities. The IEC 61850

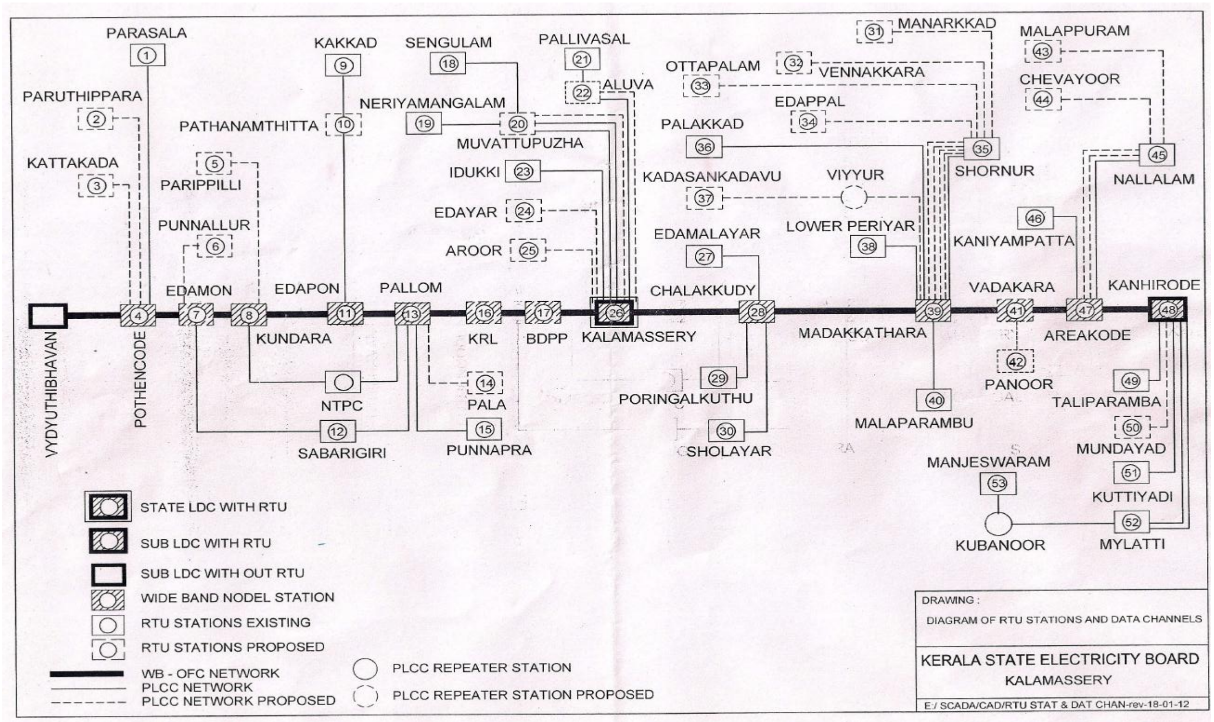

Fig5: Data Channel Routing of the EB

OPC Servers from MatrikonOPC provides connectivity to any IEC 61850 compliant RTU, IED (Intelligent Electronic Device), PLC, meter, transducer, relay, etc.

The OPC Server for IEC 61850 supports:

- The ability to control remote device operations by performing Structured Writes to Control Blocks. XML technology for saving configuration files
- Channel redundancy with multiple devices.
- Multiple communication channels at the same time for IEC 61850 Ethernet access (TCP/IP).
- Client-Server Architecture using MMS over TCP/IP.

7. RTU & IED

RTUs are intelligent microprocessor based units which are used to monitor and control the operation of equipment at a remote site.

Certain essential requirements of an RTU are

- Rugged construction to withstand extreme environmental conditions
- Multiple communication ports to keep the RTU online even whenever the primary communication fails.
- Watchdog timer to ensure equipment is back online after a power failure is resolved.
- Provides accurate date/time stamping of COS alarms.

The various components of an RTU are

- D20 processor
- Status card
- Control card
- Analog card

  -Analog Input Card: This card is used to sense analog parameters, e.g., Pressure, temperature etc. A transducer installed in the field converts the process parameter into electrical signal. The electrical signal is then converted to digital form using A/D converter and the digital value communicated to the CPU.

-Analog Input Card: This card is used to output analog data in form of electrical signals. The CPU communicates 12/16 bit digital values per AO channel to the AO card. The AO card then outputs these values as electrical signals after conversion using D/A converter.

-Digital Input card: This card is used to output analog data in form of electrical signals. The CPU communicates 12/16 bit digital values per AO channel to the AO card. The AO card then outputs these values as electrical signals after conversion using D/A converter.

-Digital Output Card: This card is used to drive external machinery. Typically the card receives the state (1 or 0 corresponding to ON or OFF state) of the DO channel from CPU. Based on this state the DO channel is triggered ON or OFF. Each DO channel is either a relay or a transistor

- Memory Modules
- Modem
- Communication Interface

  - Master Station Communication interface.

  - Local User Maintenance computer Interface.

RTU communicates in the vertical direction, as per the communication protocol IEC 60870. But with the need for advanced reliability, there arises a need that RTU's communicate with each other. Thus in order to enhance reliability and intelligence, an IED is used. IED's are capable of communicating in the horizontal direction thus enabling exchange of data from one IED directly to another. This feature is useful for example for station interlocking' between different bays or for complex distributed functions that demand a coordinated action of different IEDs.

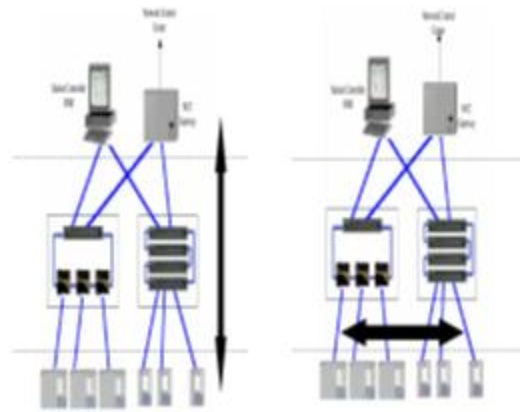

Fig6: Horizontal & Vertical communication

8. Cost Justification

Cost incurred is defined by Equipment, Installation, Engineering, Commissioning, Utilization Costs and maintenance cost. When SCADA system was first set up in Kerala, the installation cost was about 60 crores (INR). When seen from an engineer's point of view, the new system adds quality and reliability to the existing ailing system, but from a financier's point of view, the existing system seems perfect. But at the end, there are no benefits without any cost.

9. 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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