2011 Substation Technical Guide Book

2011

Substation Technical Guide Book

IEC 61850-3 and IEEE 1588

in Smart Substations

- Substation Standards: IEC 61850 & IEEE 1588
- Moxa's Breakthrough in Smarter Substations
- Substation Structure and Case Studies
- The Way Forward

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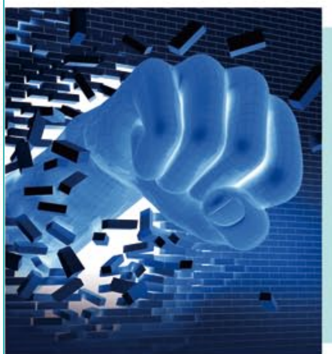

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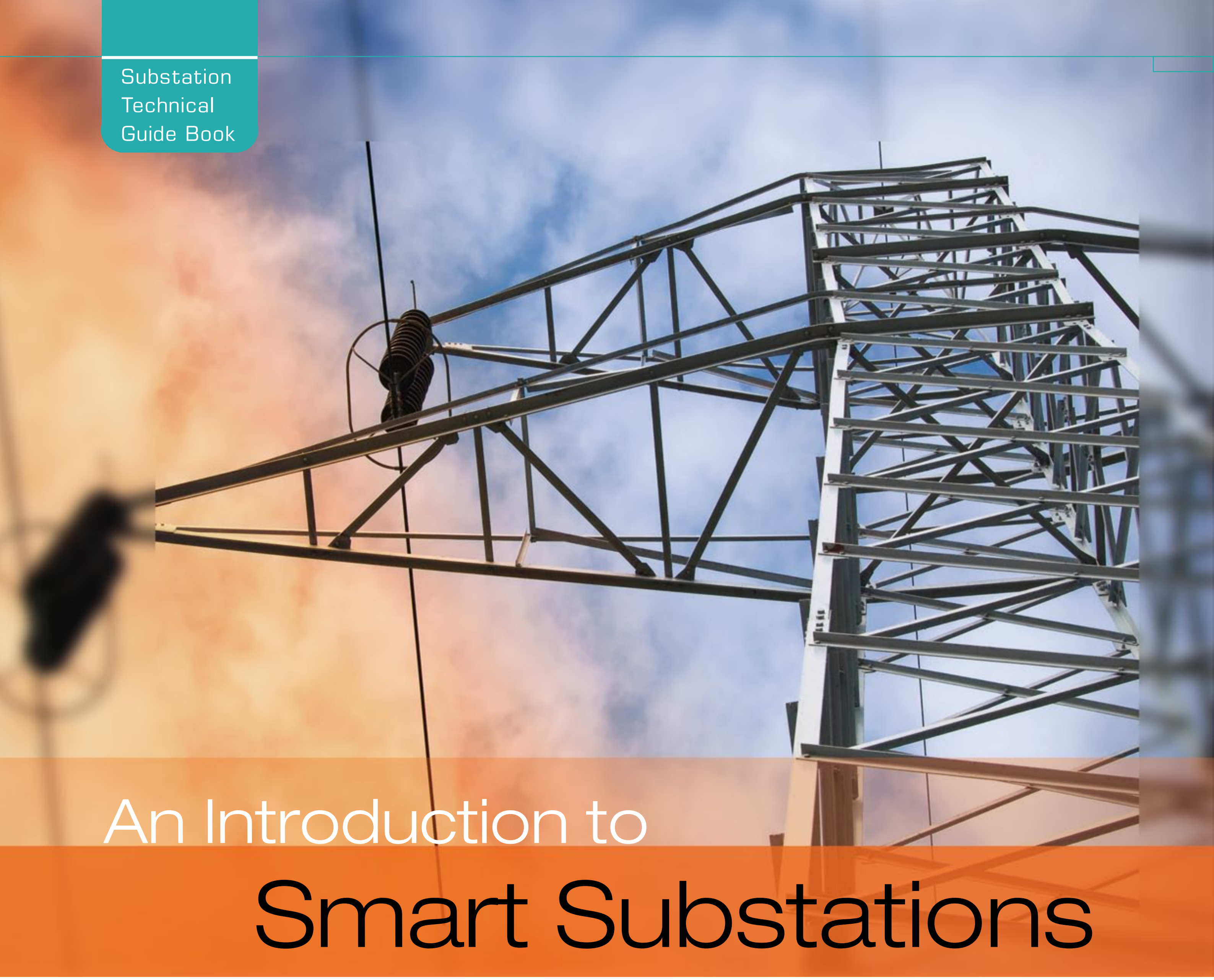
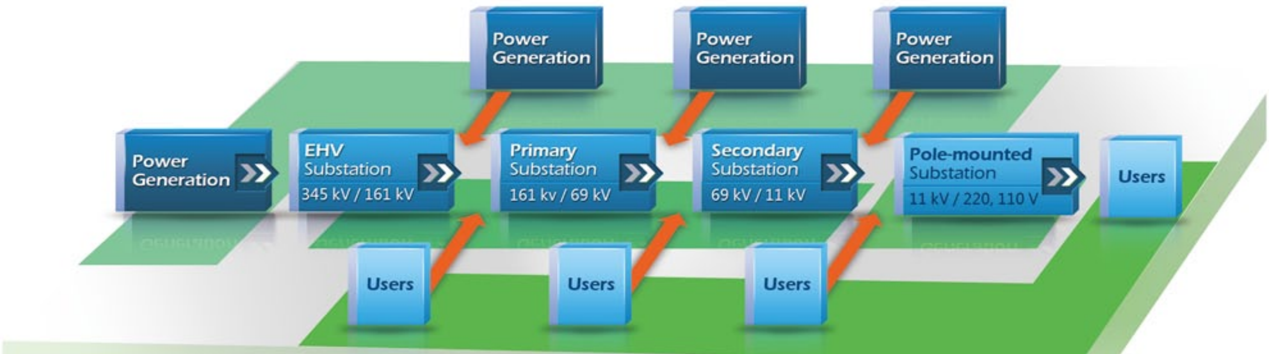


An Introduction to Smart Substations

Overview of an Electricity Substation

A substation is a part of the electricity generation, transmission, and distribution system. It transforms electricity voltages from high to low or low to high. Electricity is delivered through several transmission/distribution substations before reaching end users, such as factories, railway, MRT systems, or buildings.

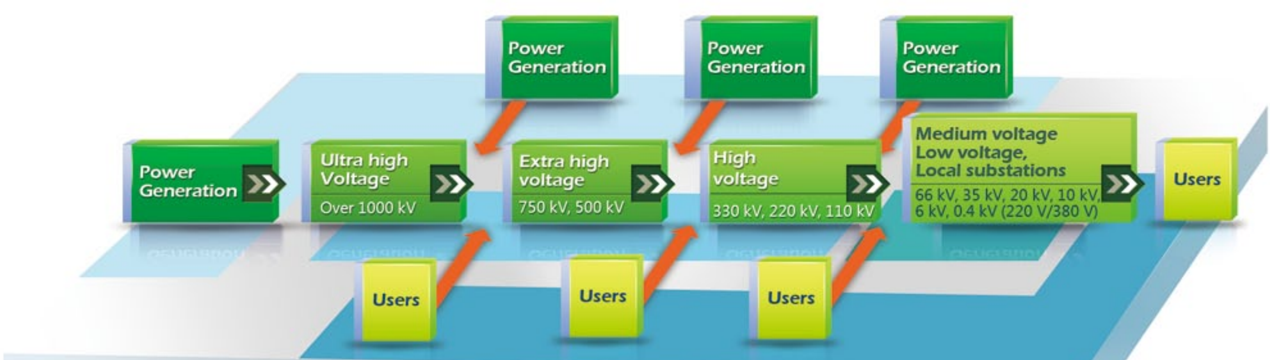
A substation transforms electricity voltages by step-up transformers and step-down transformers. A step-up transformer is used to transform the voltage from low to high. For example, the power grid in Taiwan generates power at a voltage of 11 to 28 kV. According to the formula P=I*IR, we know that the lower the current, the higher the energy transmission efficiency. Therefore, a step-up transformer within the substation will step up the voltage to 345 kV for better energy transmission efficiency, and then transmit electricity to EHV (Extra-high voltage) substations for further processing.



A Typical Substation Structure in Taiwan

On the other hand, the electricity needs to be at a low, consumer-friendly voltage once it reaches the end-user. Step-down transformers are responsible for converting the voltage back down. For example, the Taiwanese power grid lowers electric voltage to 161 kV for consumption by large-scale factories or the MRT system. Additional substations reduce the voltage further: primary substations reduce it to 69 kV, and secondary substations to 11 kV for use in smaller-scale applications, such as buildings or railway electrification. Pole-mounted transformers are the final stage, reducing voltage to 110/220 V, a level suitable for consumption by general household and commercial users.

However, in some area, such as China where the long-distance electricity transmission is required, higher voltage electricity will be generated. For example, the power plant will generate electricity with over 1000 kV voltage, and the voltage will be lowered down to 765 to 300 kV, and then 220 to 110 kV. In this scenario, more power substations are required for power transformation for the usage at the end user sites or the field sites.



A Typical Substation Structure in China

Small-Scaled Substations in End User Sites

Some user or field sites, such as factories, buildings, or transportation facilities, may build substations for optimal use. These substations perform the following tasks:

1.Transform voltage from high to low

Field site substations transform voltage from high to low for factories or other field site applications.

2.Provide flexible voltage for a variety of electric applications

Field sites may host many different electric-powered applications that all use different voltages. Field site substations should be able to transform the voltage necessary for each specific application.

3.Provide a reliable and stable power supply at the field sites

Field site substations should work independently to create a reliable and stable power supply system. If one substation should happen to experience a problem, the connection between it and the rest of the substations should be cut immediately to isolate the problem and prevent any damage to the broader power supply chain.

Substation Automation

Substation automation is the integration of existing substation devices and a new network infrastructure. By integrating primary devices with networked secondary devices, the substation can perform automatic industrial tasks such as data acquisition, device control, and event recording.

Substation automation has the following features:

1. Upgrades and optimizes the secondary equipment within the power system, such as measuring units, signals, relay controllers, automation units, and RTUs.
2. Combines electronic, telecommunication, and signal process technology to enable substation automation.
3. Integrates the automatic monitoring, measuring, controlling, and protection of the equipment used in power generation, distribution, and dispatch.
4. A complete intelligent system of function integration, structure computerization, display-based monitoring, and smart management.

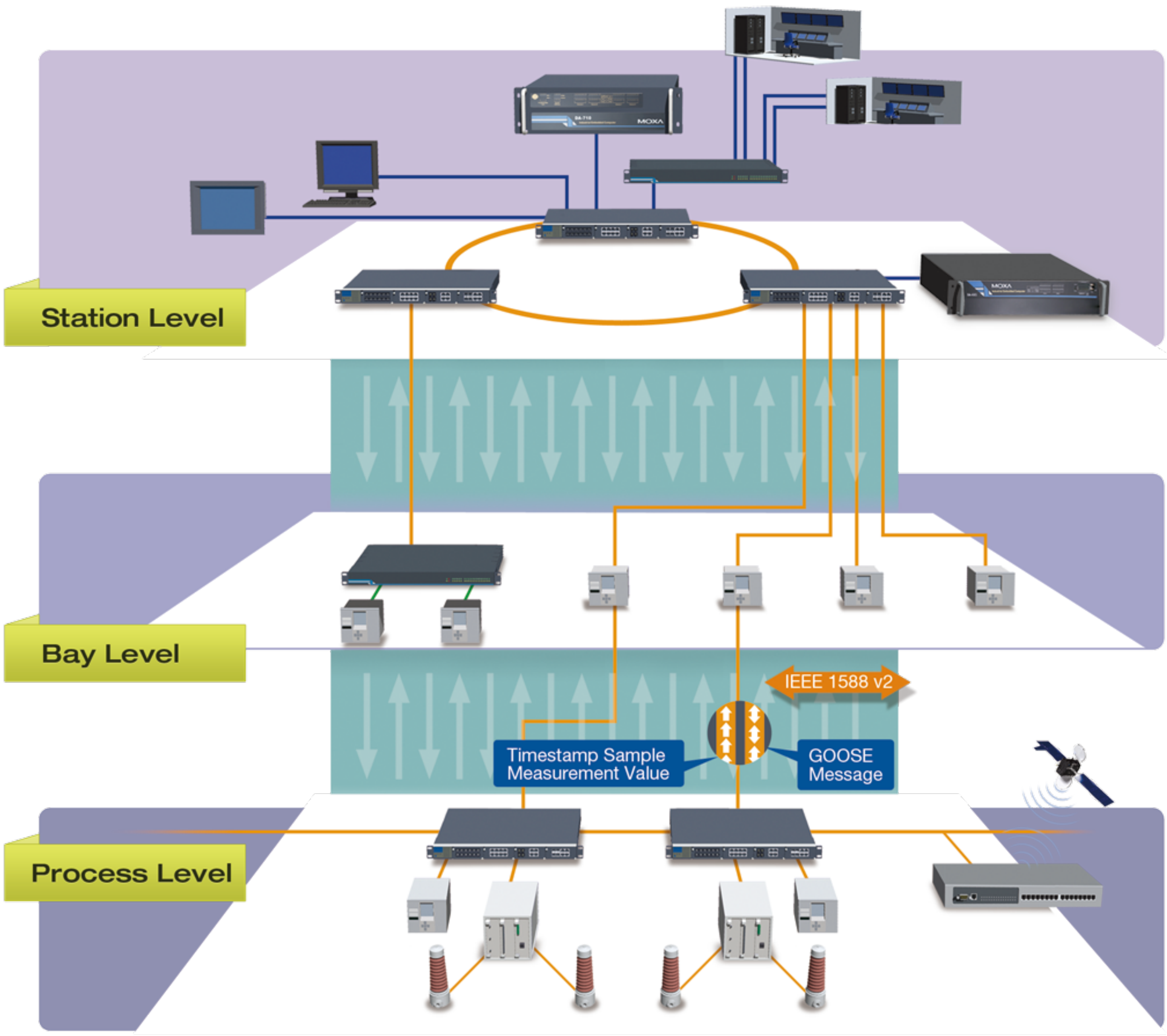
Smart Substations Factors Make a Substation Smarter

The concept of a “smart substation” is to build a completely intelligent substation environment where all the devices can work and collaborate on the same network. With intelligent electronic devices (IED), it’s possible to add control and automation capability to the substation, and empower remote users to manage system devices using remote control commands.

An intelligent substation has the following features:

1. All primary devices have been upgraded as intelligent devices.
2. All secondary devices have been networked.
3. Substation operation and management have all been automated.

Moxa provides a suit of networking and computing solutions for constructing smart substations. The figure below illustrates a smart substation that implements IEC 61850 for common communication models and IEEE 1588 for precise time synchronization among smart devices.



In Chapter 2 of this guide book, we provide an overview of IEC 61850 and IEEE 1588 certifications for smart substations. Moxa substation solutions are introduced in Chapter 3 and some case studies are shared in Chapter 4. Finally, in Chapter 5, we present the conclusions and market insights for smart substations.

Substation Standards:
IEC 61850 & IEEE 1588

IEC 61850: A Communication Standard

IEC 61850 is a substation automation standard, and part of the International Electrotechnical Commission's (IEC) Technical Committee 57 (TC57) reference architecture for electric power systems. The abstract data models defined in IEC 61850 can be mapped to a number of protocols including MMS (Manufacturing Message Specification), GOOSE, and SMV. These protocols can run over high speed TCP/IP networks to gain a fast response time (< 4 ms) as needed for protective relays.

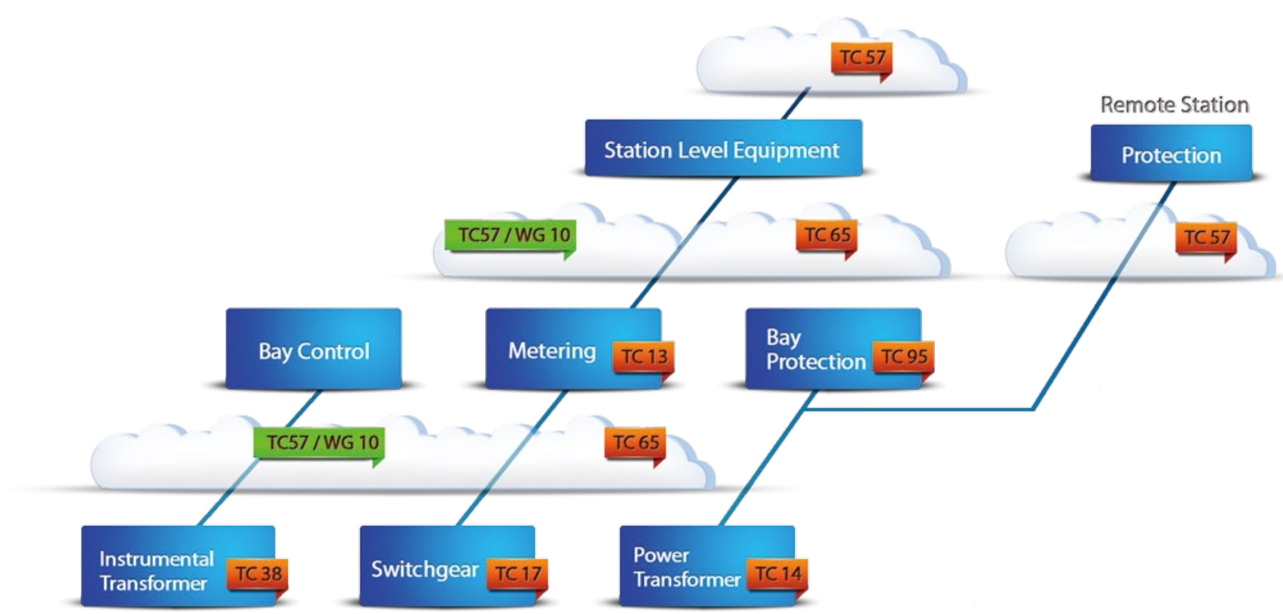
IEC 61850 standardization brings benefits to electric power systems.

- Interoperability and integration - All devices and systems that meet the IEC 61850 standard will interoperate when integrated together.
- Consistent device and data modeling and names - Device and data modeling and names will conform to the same IEC 61850 standard, helping users quickly distinguish their devices and data.
- Fast and convenient communication - IEC 61850-compliant devices quickly and efficiently establish communications with each other throughout a power automation system.
- Low cost for installation, configuration, and maintenance - When all devices in a network meet the same standard, there are fewer installation and maintenance complications and lower costs.

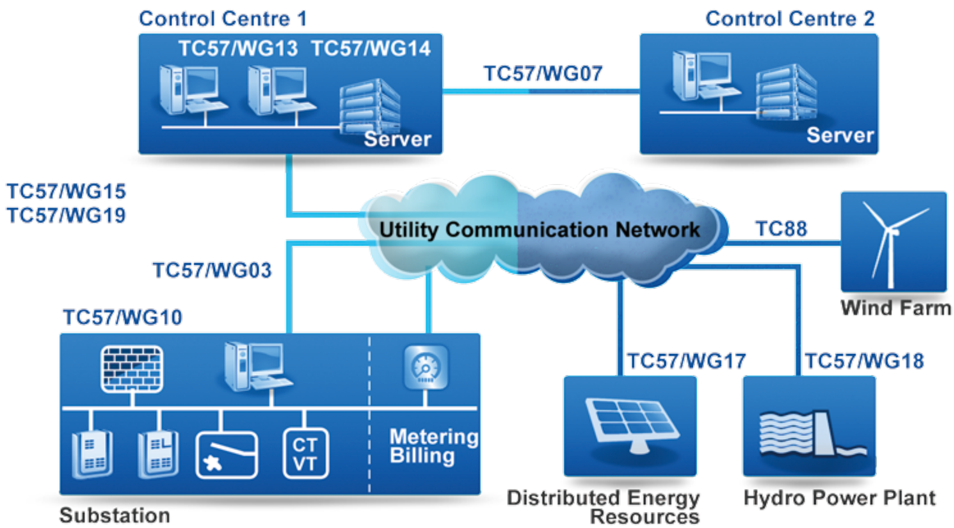
In short, IEC 61850 standardizes technical and mechanical operations in power automation systems to achieve more consistent and reliable communications. Due to its standardization, IEC 61850 has been adopted in the Smart Grid standardization roadmap used by NIST, IEC and the German Strategy Group.

IEC Substation Committees

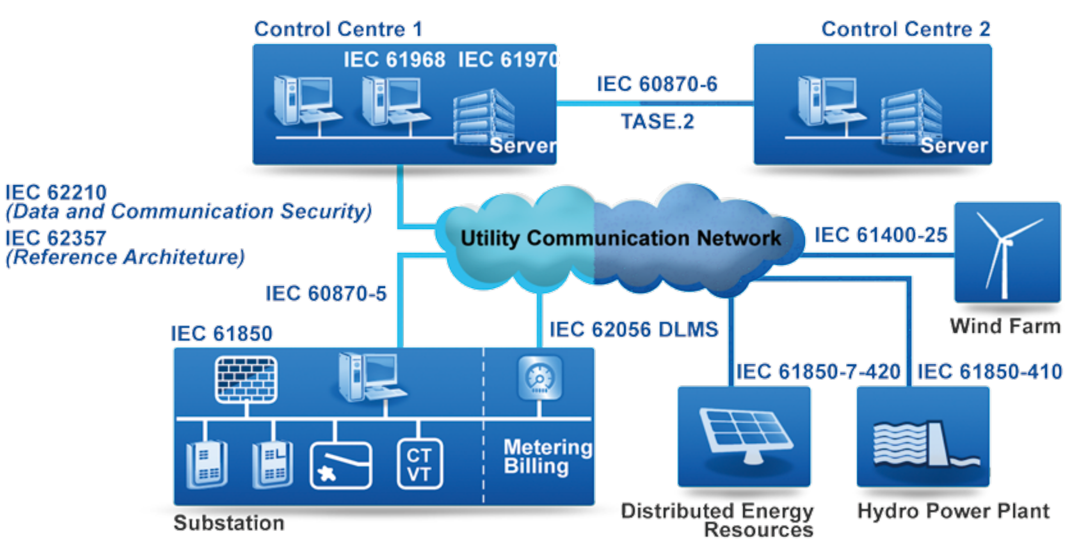
As shown below, there are specific IEC committees assigned to each category of substation device. For example, TC38 is responsible for instrumental transformers, TC17 for switch gears and TC14 for power transformers.



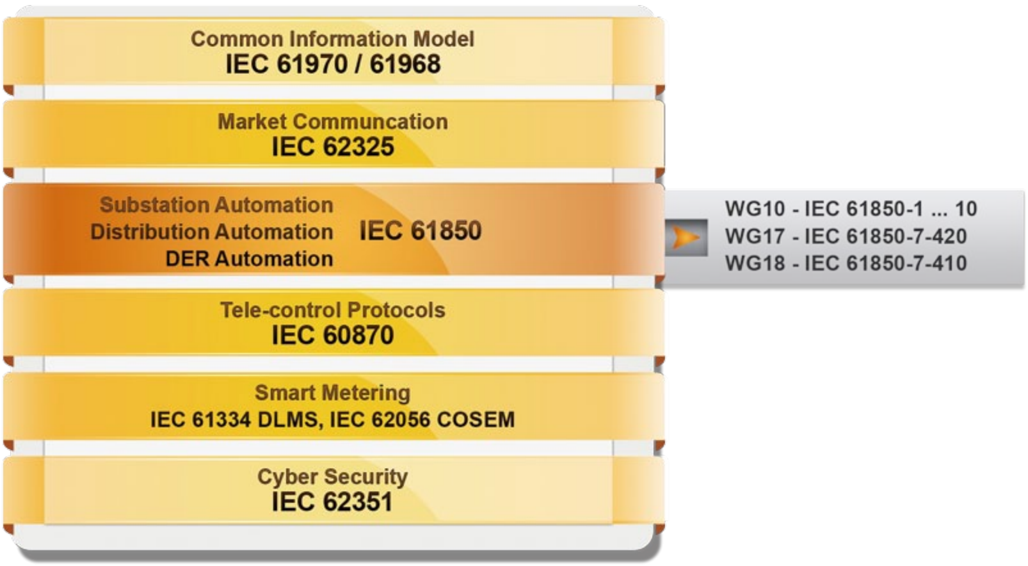
Under each IEC committee, working groups are organized to define functions in a power automation system. TC57/WG13 and TC57/WG14 cover the communication within a control center, and TC17/WG07 will be responsible for communication between control centers. The figure below shows a more detailed breakdown of each working group's area of responsibility.



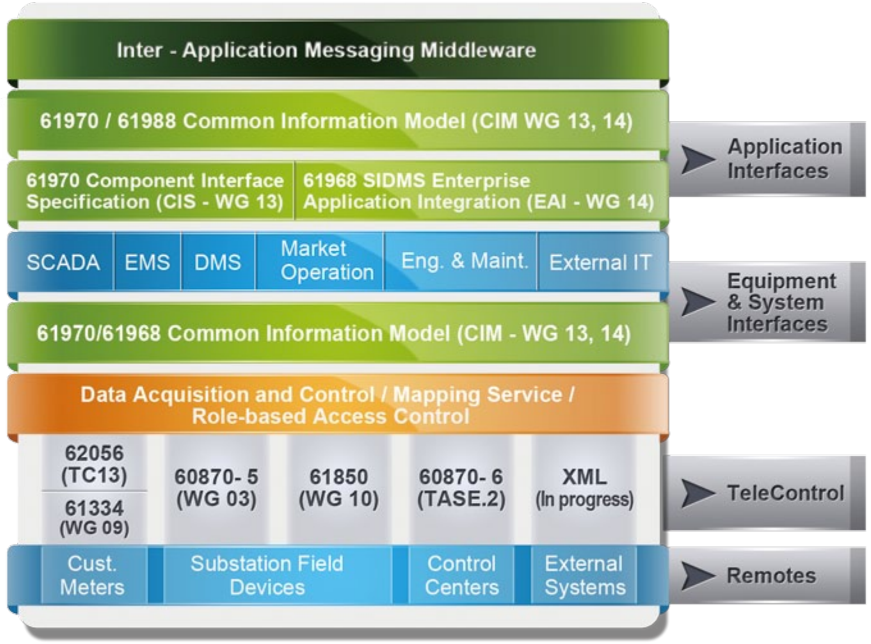
As shown below, these working groups have created various standards respectively used in different segments. These standards include IEC 61968 and IEC 61970 for communications within a control center, and IEC 60870-6 for communications between control centers.



TC 57 Architecture for the Smart Grid

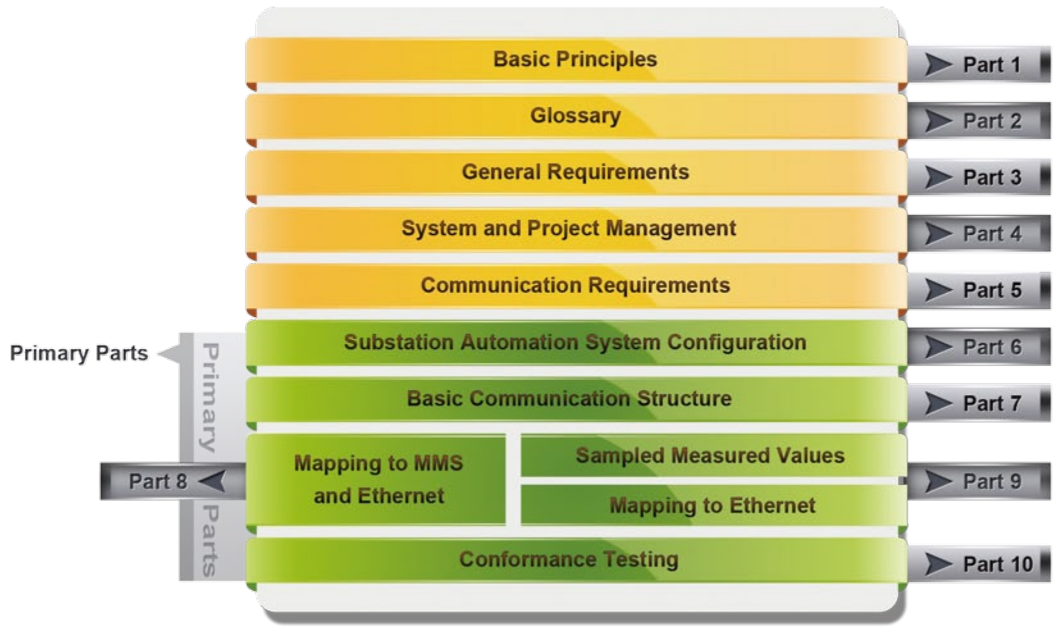


The IEC Technical Committee 57 (TC57) sets standards for substation automation. Three working groups have been formed for different tasks: WG10 is responsible for the IEC 61850-1 to IEC 61850-10 standards; WG17 for the IEC 61850-7-420 standard; and WG18 for the IEC 61850-7-410 standard.



IEC 61850 Standards Document

IEC 61850 Edition 1 was titled “Communications Networks and Systems in Substations,” but Edition 2 was given a new title to reflect its increased scope: “Communication Networks and Systems for Power Utility Automation.”



For more detailed categorizations, see the following table:

System Aspects

- Part 1: Introduction and Overview
- Part 2: Glossary
- Part 3: General Requirements
- Part 4: System and Project Management
- Part 5: Communication Requirements for Functions and Device Models

Configuration

- Part 6: Configuration Language for Electrical Substation IED's

Testing

- Part 10: Conformance Testing

Data Models

Basic Communication Structure for Substations and Feeder Equipment
- Part 7-4: Compatible Logical Node Classes and Data Classes
- Part 7-3: Common Data Classes

Abstract Comm. Services

Basic Communication Structure for Substations and Feeder Equipment
- Part 7-2: Abstract Communication Servces (ACSI)

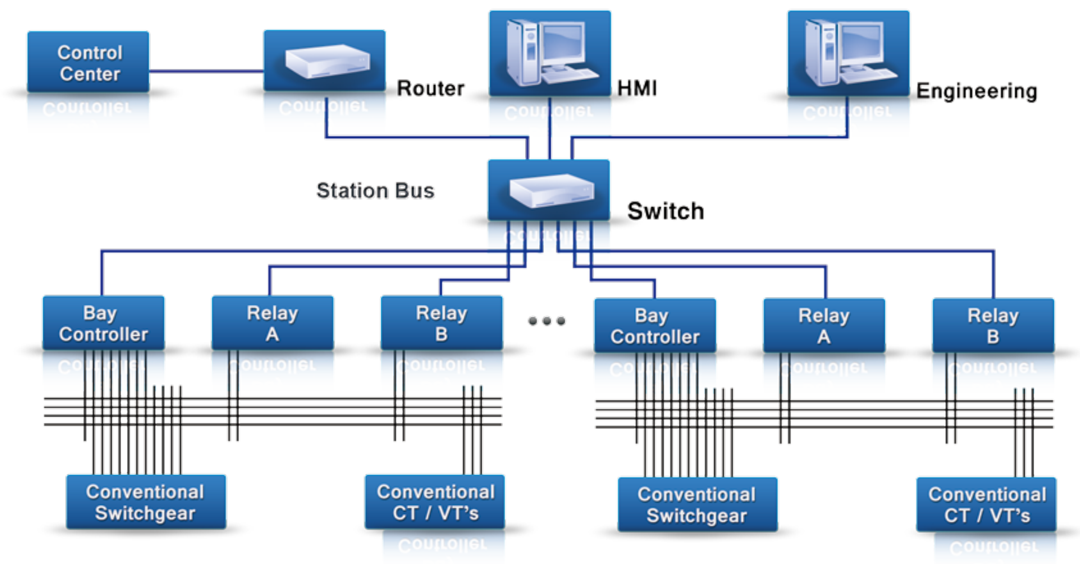
Mapping to real Comm. Networks (SCSM)

- Part 7-1: Principles and Models
- Part 8-1: Mapping to MMS and ISO / IEC 8802-3
- Part 9-1: Sampled Values over Serial Unidirectional Multidrop Point-to-Point Link
- Part 9-2: Sampled Values over ISO / IEC 8802-3

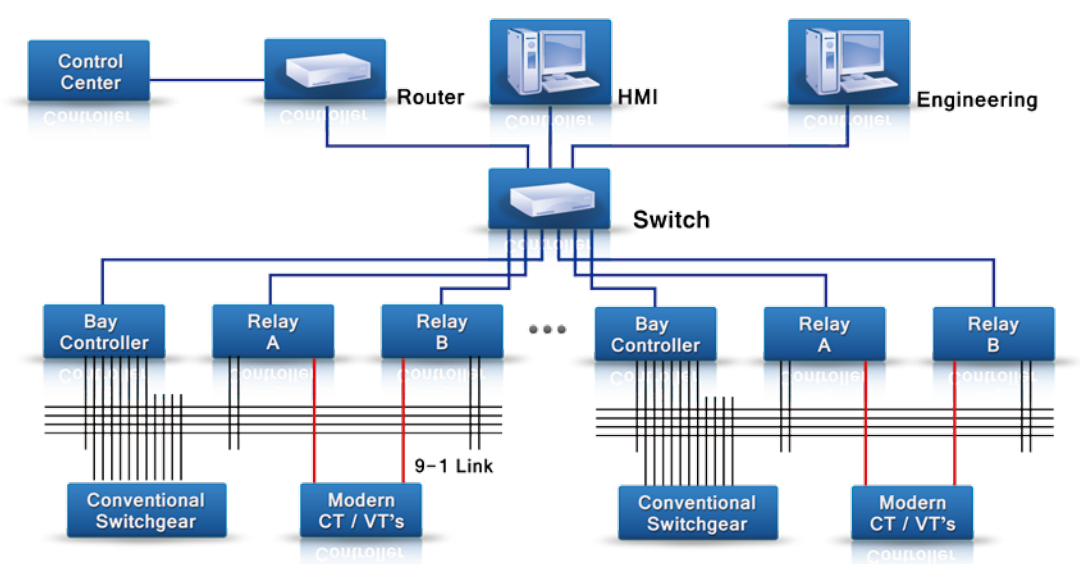
- **IEC/TR 61850-1: Introduction and overview**
- **IEC/TS 61850-2: Glossary**
- **IEC/IS 61850-3: General requirements**
- **IEC/IS 61850-4: System and project management**
- **IEC/IS 61850-5: Communication requirements for functions and device models**
- **IEC/IS 61850-6: Configuration description language for communication in electrical substations related to IEDs**
- **IEC 61850-7: Basic communication structure for substation and feeder equipments**
  - IEC/IS 61850-7-1: Principles and models
  - IEC/IS 61850-7-2: Abstract communication service interface (ACSI)
  - IEC/IS 61850-7-3: Common data classes
  - IEC/IS 61850-7-4: Compatible logical node classes and data classes
- **IEC 61850-8: Specific communication service mapping (SCSM)**
  - IEC/IS 61850-8-1: Mappings to MMS (ISO/IEC 9506-1 and ISO/IEC 9506-2) and to ISC/IEC 8802-3
- **IEC 61850-9: Specific communication service mapping (SCSM)**
  - IEC/IS 61850-9-1: Sampled values over serial unidirectional multidrop point to pint link
  - IEC/IS 61850-9-2: Sampled values over ISO/IEC 8802-3
- **IEC/IS 61850-10: Conformance testing**

IEC 61850 System Architecture

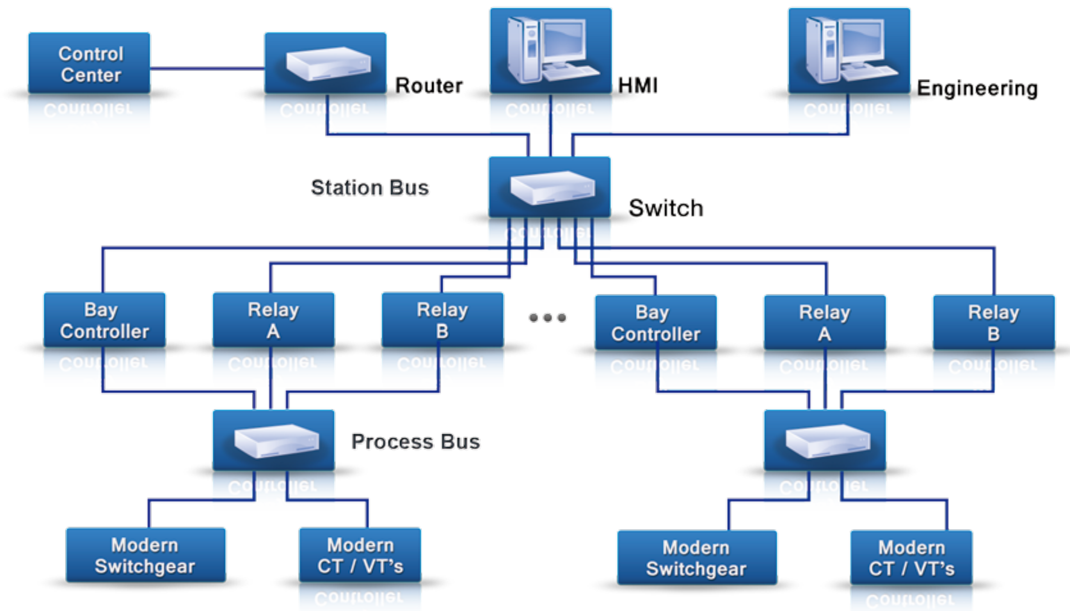
This section depicts three different system architectures in a substation: traditional, IEC 61850-9-1, and IEC 61850-9-2.



Traditional System Architecture



System Architecture Using IEC 61850-9-1



System Architecture Using IEC 61850-9-2

Details on IEC 61850-3 and EMC Level 4

IEC 61850-3

IEC 61850-3 covers the general requirements for many standards. Two parts of IEC 61850-3 have been defined, each for a different purpose:

IEC TS 61000-6-5 deals with electromagnetic compatibility issues, clearly setting the benchmark for resilience against different environmental challenges, such as ESD, surge, and voltage.

IEC 61850-3

Communications Networks and Systems in Substations - Part 3: General Requirement

IEC TS 61000-6-5

Electromagnetic Compatibility (EMC) –
Part 6-5: Generic Standards – Immunity for
Power Station and Substation Environments

IEC 61000-4-x Series
Basic Immunity Standards

61000-4-2 (ESD)
61000-4-3 (Radiated RFI)
61000-4-4 (Electrical Burst Fast Transients)
61000-4-5 (Surge)
61000-4-6 (Conducted RFI)
61000-4-8 (Power Frequency Magnetic Field)
61000-4-11 (Voltage Dips – a.c. Power Supplies)
61000-4-12 (Damped Oscillatory Transients)
61000-4-16 (Mains Frequency Voltage)
61000-4-17 (Ripple on d.c. Power Supplies)
61000-4-29 (Voltage Dips – d.c. Power Supplies)

IEC 870-2-2

Telecontrol Equipment and Systems –
Part 2: Operating Conditions –
Section 2: Environmental Conditions

Class A: Air-conditioned locations (indoor)
Class B: Heated and/or cooled enclosed conditions
Class C: Sheltered locations
Class D: Outdoor locations

Class C1: -5 to 45°C
Class C2: -25 to 55°C
Class C3: -40 to 70°C
Class Cx: Special

IEC 870-2-2 categories the operating conditions, including environmental conditions and mechanical influences. Several classes have been defined to describe each dimension of the system environment. For example, Class A through Class D defines where the device is used, while Class C1 through Class Cx defines the operating temperature range. Vibration and shock conditions are defined under Class Cm.

The benchmarks for basic electromagnetic susceptibility (EMS) immunity are clearly defined under **IEC 61000-4-x**. There are five immunity levels, each for a different range of EMS resistance.

IEC 61000-4			General EPC		Moxa DA-683	
Test Items		**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
IEC 61000-4-2	Electrostatic Discharge	2 KV 2 KV	4 KV 4 KV	6 KV 8 KV	8 KV 15 KV	
IEC 61000-4-3	Radiated, radio-frequency, electromagnetic field immunity	1 Vm	3 Vm	10 Vm	*	
IEC 61000-4-4	Electrical fast transient/burst immunity	0.5 KV (5 kHz) 0.25 KV (5 kHz)	1KV (5 kHz) 0.5KV (5 kHz)	2KV (5 kHz) 1KV (5 kHz)	4KV (5 kHz) 2KV (5 kHz)	
IEC 61000-4-5	Surge immunity	0.5 KV	0.5 KV 1 KV	1 KV 2 KV	2 KV 4 KV	*
IEC 61000-4-6	Conducted disturbances, induced by radio-frequency fields	1 V	3 V	10 V	*	
IEC 61000-4-2-8	Power frequency magnetic field immunity	1 A/m	3 A/m	10 A/m	30 A/m	100 A/m
IEC 61000-4-11	Voltage dips, short interruptions and voltage variations					
IEC 61000-4-9	Pulse magnetic field immunity	--	--	100 A/m	300 A/m	1000 A/m
IEC 61000-4-10	Damped oscillatory magnetic field	--	--	10 A/m	30 A/m	100 A/m

EMC Level 4

A crucial mission of constructing a networking/computing automated substation is to prevent circuits and components from internal and external electricity disturbances.

Electromagnetic interference (EMI) disturbance is created by the product itself internally. The cause is from either electromagnetic induction or electromagnetic radiation emitted from the product. EMI can be classified to two levels: class A and class B. The former is addressed in the industrial segment and the latter is addressed in the commercial segment.

Electromagnetic susceptibility (EMS) disturbance is created by external sources. Some external sources include a momentary lighting spark and an incidental huge current inducted by a contact of an electricity object.

For fulfilling different environmental needs illustrated in the following table, IEC 61000-4-x level 4 has been attracting a great deal of attention in China substations.

IEC61000 & China National Standard -GB/T17626-1999 5 Levels	
Level 1	Protected environment
Level 2	Protected environment
Level 3	Typical industrial environment
Level 4	Harsh industrial environment
Level 5	Special environment that needs to be analyzed

These environmental needs indicate the tolerance levels of circuits and components to all external sources of interfering electromagnetic energy.

IEEE 1588: Precision Time Synchronization

IEEE 1588 is a precision time synchronization standard that delivers more accurate timekeeping. Precise timekeeping is very useful in substations, which often need to rely on reliable clocks in order to perform complex coordinated applications. When timestamps are accurate to a nano-second level, it's possible to achieve accurate sequential events.

Precision time synchronization has includes multiple technologies, including NTP (Network Time Protocol), SNTP (Simple Network Time Protocol), and PTP (Precision Time Protocol). Version two of the IEEE 1588 PTP standard specifies accuracy between 1 nanosecond and 100 microseconds.

- **NTP - Network Time Protocol (Version 3)**
- **SNTP - Simple NTP (Version 4)**
- **PTP - Precision Time Protocol (Version 2)**

Specification	RFC / IEEE	Accuracy
SNTP	RFC 2030	50-150 msec
NTP	RFC 1305	500 μsec-50 msec
PTP	IEEE 1588	1 nsec-100 μsec*

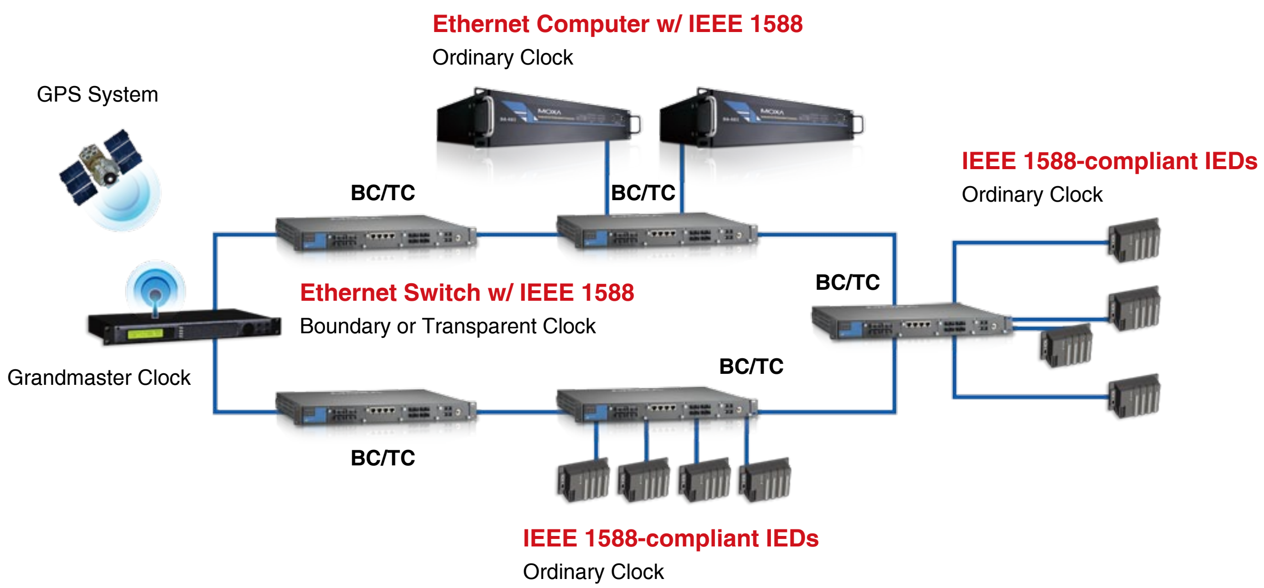
*Variance between hardware based and software based PTP implementation

Each performance class has a different accuracy target, as illustrated in the following table:

Performance Class	Accuracy	Application
T1	± 1 ms	Events
T2	± 0.1 ms	Synchrocheck
T3	± 25 μs	Sampled Values
T4	± 4 μs	Sampled Values
T5	± 1 μs	Sampled Values

T5 is the highest standard for the accuracy and used in the application for sampled values.

For the industrial computing network, IEEE 1588v2-compliant computers can work as the ordinary clock that connects with Ethernet switches to receive and synchronize timekeeping data. This timekeeping can be precise to even the nanosecond level, considerably enhancing the reliability of power substation systems.



The Breakthrough in Smarter Substation

Breakthrough in Network Redundancy

- Turbo Ring and Turbo Chain
- IEC 62430 PRP & HSR Protocol

Breakthrough in Secondary System Networking

Breakthrough in Embedded Computing

- Technology Breakthroughs for Substation Automation
- Moxa Substation Computing Solutions

Overview

The previous chapter reviewed the standards and requirements of IEC 61850-3 for substation automation and of IEEE 1588 for Precision Time Synchronization Protocol. In this chapter, we will introduce Moxa's breakthrough solutions for the IEC 61850-3 and IEEE 1588 standards in several segments, such as networking redundancy, secondary system networking and embedded computing systems.

Network Redundancy

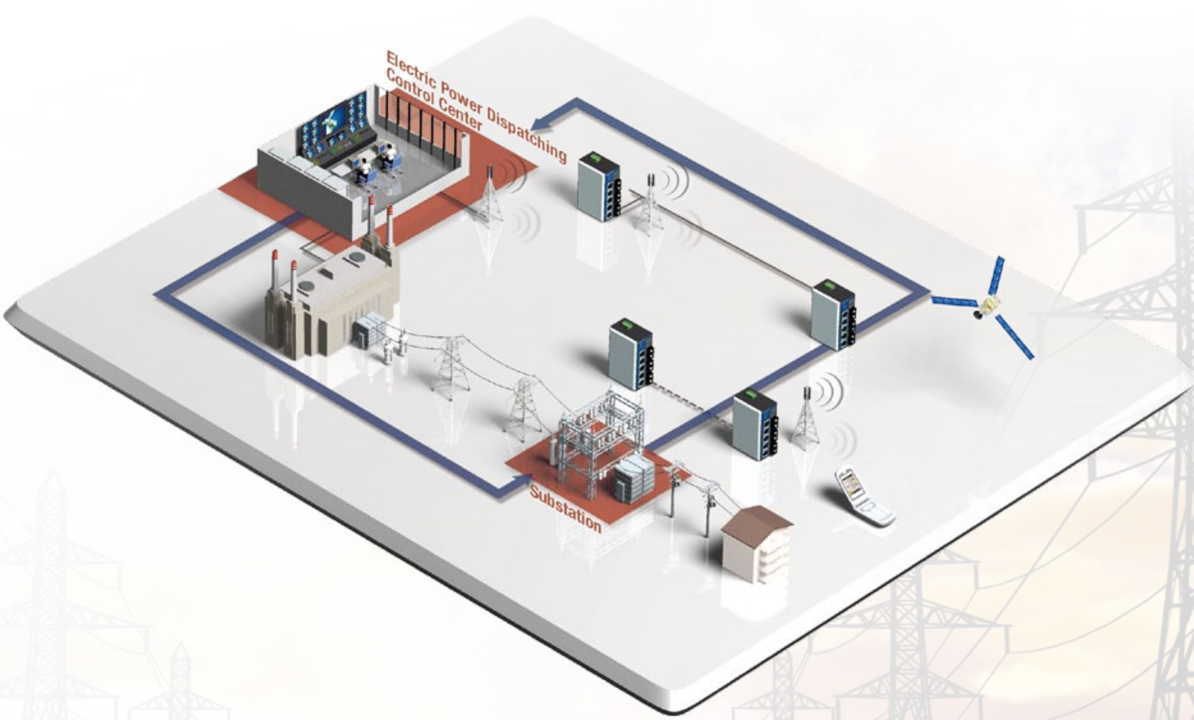
In this section, we introduce Moxa's Turbo Ring and Turbo Chain technologies, which offer extremely fast system recovery time. We also present the IEC 62430 PRP & HSR Protocol as an ideal network redundancy solution.

Secondary System Networking

In this section, we explain how the secondary networking system within a substation can be made smarter. Readers will learn about networking secondary systems and constructing an Ethernet-networking environment.

Embedded Computing

In this section, we address how embedded computing technology can be used in constructing a smart substation at three different layers: station level, bay level, and process level. We discuss how IEC 61580-3 computers that endure strong electromagnetic interference ensure high system reliability for smart substations. We also discuss IEEE 1588v2 technology for Precision Time Synchronization Protocol, and the benefits of nanosecond accuracy for certain types of events. Finally, a guide to embedded computing solutions is provided to help users to establish smart substations with less effort.



Recovery Time < 20 ms

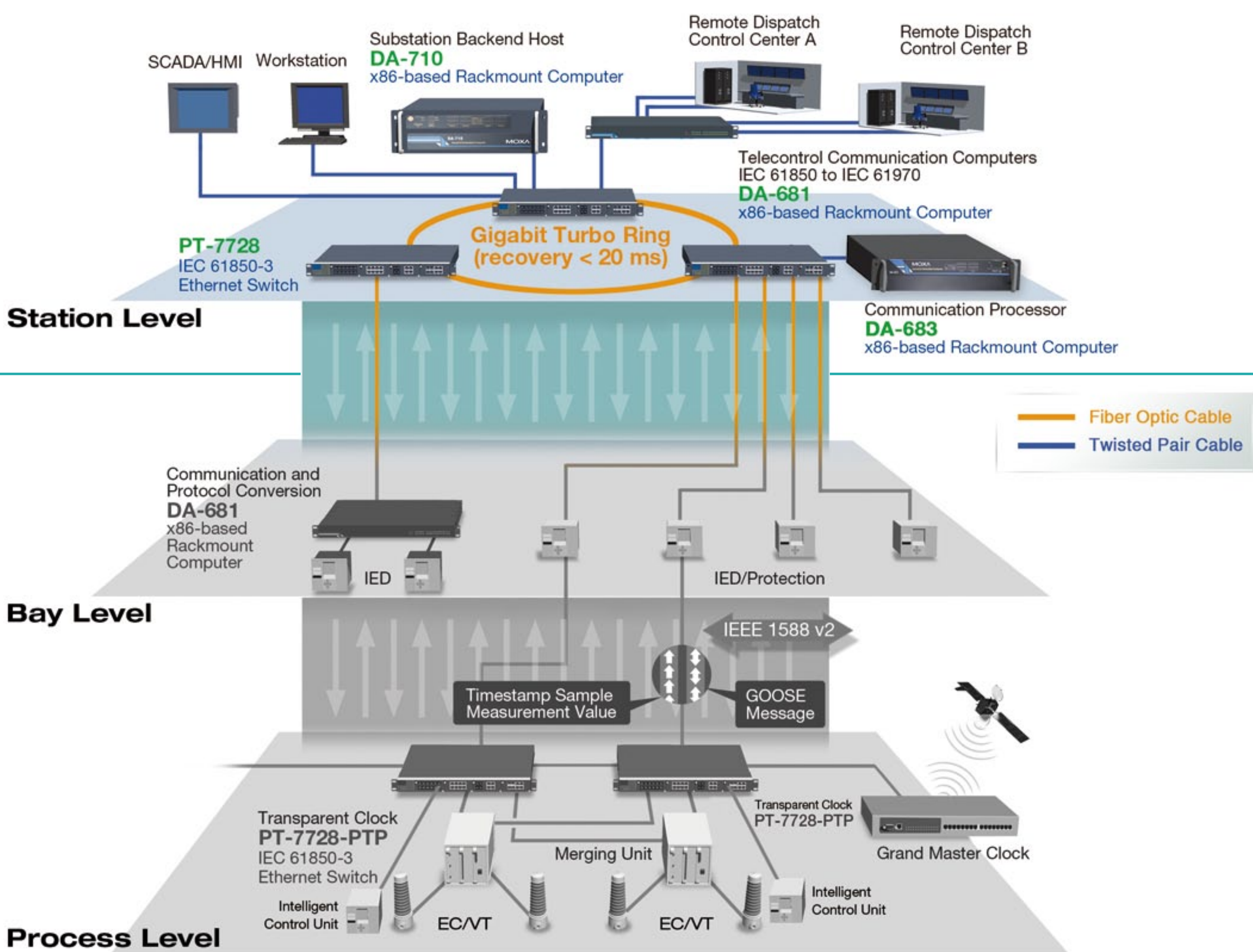
Breakthrough in Network Redundancy

- Turbo Ring and Turbo Chain
- IEC 62439 PRP & HSR Protocol

Turbo Ring and Turbo Chain

IEC 61850 Ethernet-based Substation Automation System

In a substation automation system, system redundancy is a critical issue and is necessary to guarantee continuous operation for different levels, including the station level, bay level and process level.



Turbo Ring

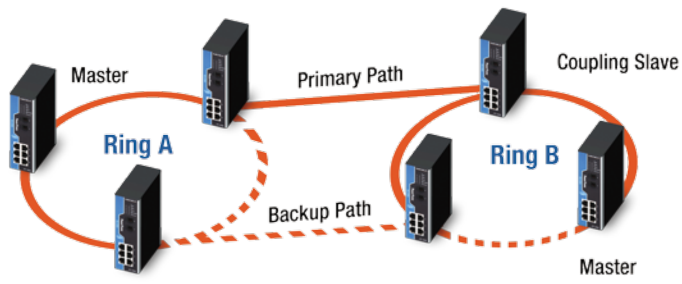
MOXA Turbo Ring is a self-healing technology that enables the fastest fault recovery of less than 20 ms, and allows for larger ring configurations. You can choose from a variety of Turbo Ring topologies to reduce cabling and network planning costs, and to build the highest reliability available into your industrial network applications. Currently, Turbo Ring runs through the standard STP or RSTP redundant protocols.

Multiple Ring Coupling Functions for Flexible Configuration

The ring structure can be implemented with various typologies, optimizing your system communication for considerations of cost, field site and purpose.

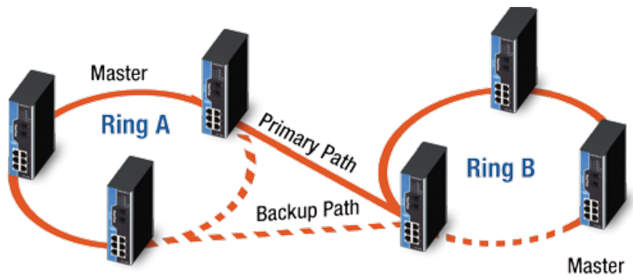
Ring Coupling

For some systems, it may not be convenient to connect all devices in the system to create one big redundant ring, since some devices could be located at a remote site. Turbo Ring's "Ring Coupling" function helps you separate those distributed devices into different smaller redundant rings, without any control line, but in such a way that the smaller rings will still be able to communicate with each other.



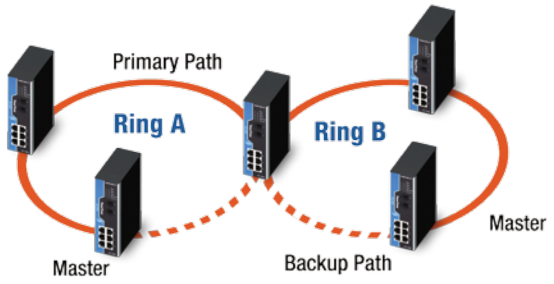
Dual-Homing

You can configure the network for Dual-Homing, which involves coupling two separate rings with a single PT switch connecting to two independent connection points. The back-up path will be activated if the operating connection (or main path) fails.



Dual-Ring

The Dual-Ring function can also add reliability by using a single PT switch to connect two separate rings for applications that present cabling difficulties.

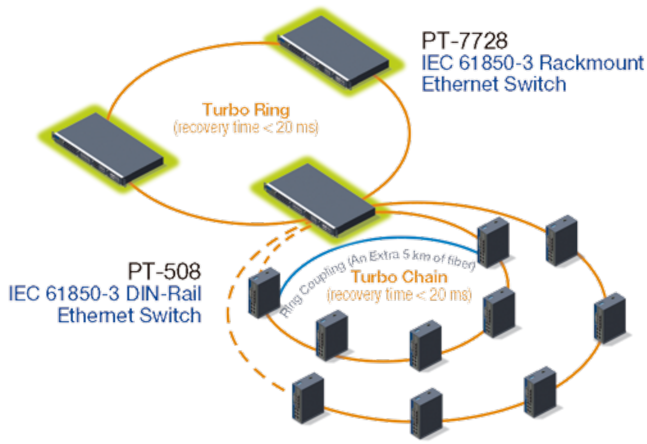


Turbo Chain

Moxa Turbo Chain outperforms traditional ring topologies by providing the best flexibility, unrestricted expansion, and cost-effective configurations when connecting separate redundant rings. With Turbo Chain, you can create any complex redundant network that corresponds to your needs, while still ensuring the greatest reliability and availability for your industrial Ethernet network applications.

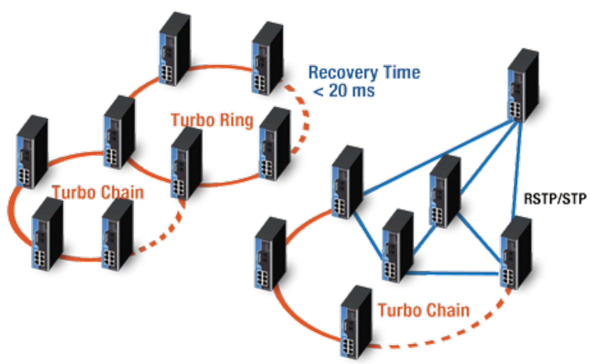
Flexible and Expandable Redundancy

With Moxa's Turbo Chain, network engineers have the flexibility to construct any type of redundant topology with minimum effort and maximum ease by simply linking Turbo Chain to the Ethernet Network. Turbo Chain allows for unrestricted network expansion. Network engineers no longer need to go through the hassles of reconfiguring the existing network. They can simply use Turbo Chain to scale up the redundant networks.



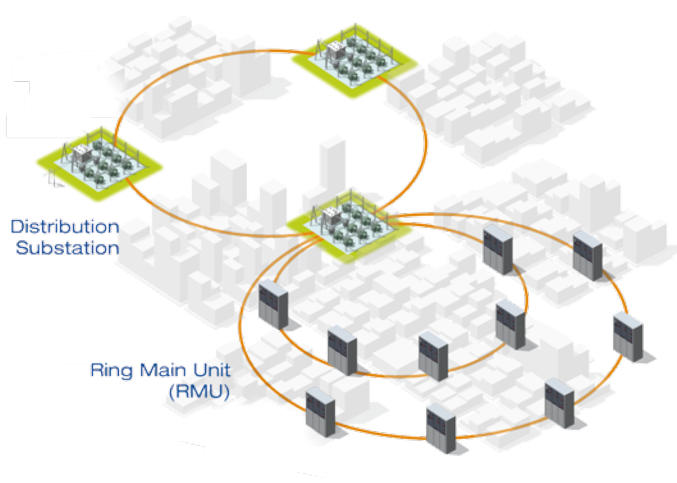
Recovery Mechanism

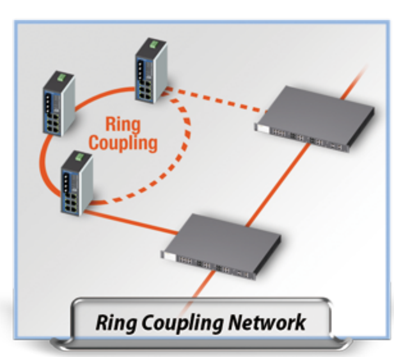
Turbo Chain is able to withstand network-segment failures; if a link in a network fails, Turbo Chain will instantaneously activate the blocked path to continue forwarding the data with a recovery time of less than 20 milliseconds! In addition, Turbo Chain can be used with other redundant protocols, such as RSTP, STP, and Moxa's Turbo Ring.



Cost-efficient Deployment

Moxa’s breakthrough Turbo Chain redundancy technology dramatically simplifies the creation of multiple redundant connections over a widely dispersed power distribution network. With Turbo Chain, PT Ethernet switches can be daisy-chained together from one Ring Main Unit (RMU) to another, with each “chain” connected to the distribution substations.





Simple 3-step Configuration

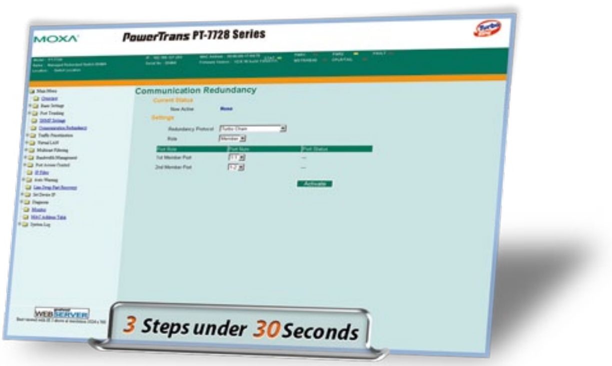
Moxa introduces a quick and simple 3-step configuration to simplify Turbo Chain setup; setup requires less than one minute—literally! Step one: log in to Web UI; step two: select redundancy protocol; step three: define the switch's role. That's it!

1. Log in to web UI

2. Select redundancy protocol

3. Define switch's role

To enable Turbo Chain, users simply select the Turbo Chain redundant mode with the browser-based configuration tool, and then define the switch's role (e.g., head switch, tail switch, or member switch) as well as the port status.



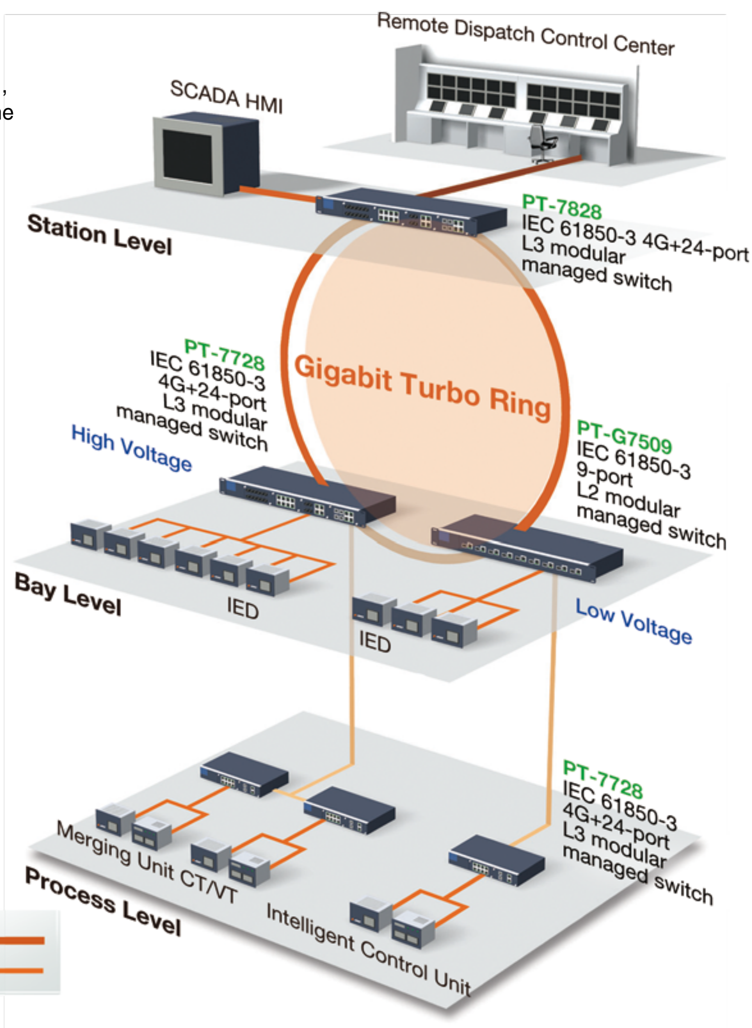
Communication Networks for Substation

To enable Turbo Chain, users simply select the Turbo Chain redundant mode with the browser-based configuration tool, and then define the switch's role (e.g., head switch, tail switch, or member switch) as well as the port status.

- IEC 61850-3 or IEEE 1613 compliance
- IEC 61850-3 or IEEE 1613 compliance
- Redundant Ethernet infrastructure
- Fiber cabling for long haul transmission & EMI/ RFI immunity
- Layer 3 routing capability

Moxa offers Ethernet switches that can fully perform Turbo Ring redundancy with the following features:

- IEC 61850-3 Ethernet switch
- Turbo Ring media redundancy
- Redundant power input
- -40 - 85°C operating
- Up to 28 fiber ports
- L3 IP routing protocol support



Gigabit Fiber Optic Cable
Fiber Optic Cable

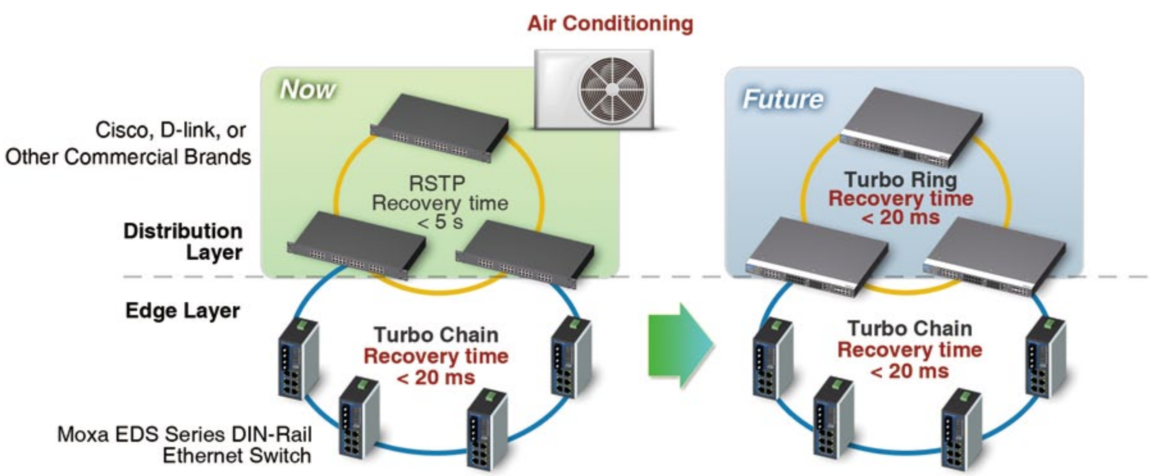
Expand Industrial Ethernet to Distribution Layer

Currently, in the application using RSTP protocol, the recovery time is usually under 5 seconds; however, the Turbo Ring can reduce the recovery time to 20 ms. The combination of Turbo Ring and Turbo Chain can bring the following benefits:

1. Complete network solutions from Moxa
2. Save time for system integration and maintenance cost
3. Reduce recovery time under 20 ms for higher system reliability

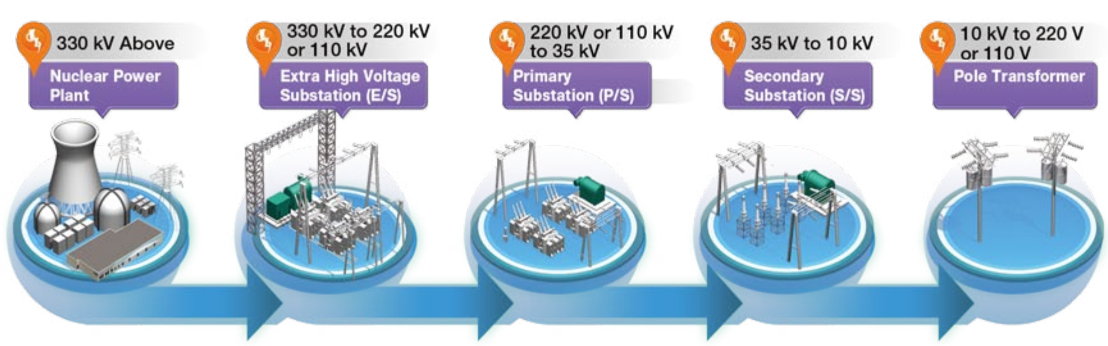
Benefit

1. *Converged network solutions from Moxa*
2. *Save integration and maintenance costs*
3. *Entire network recovery time < 20ms*



The Issue with Traditional Power Distribution

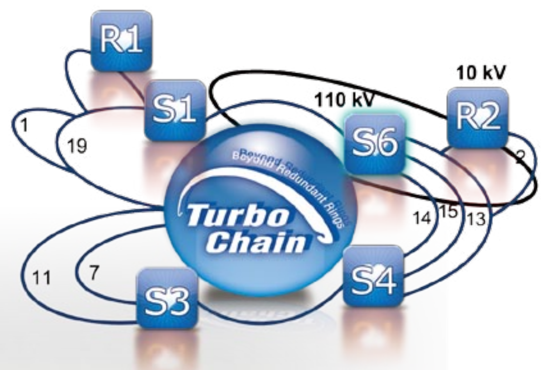
Lack of information at the base station (<33 kV sub-station) on the load and health status of the transformer (11 kV/415 V) is one primary cause of inefficient power distribution.



Therefore, the object of a smart power distribution system is to improve the reliability, efficiency and safety of power delivery and monitor power load and health status.

Typical Power Distribution Topology

A typical power distribution topology consists of three parts: main substation, sub-substation, and ring main unit—all can be connected with Moxa's Turbo Chain technology.



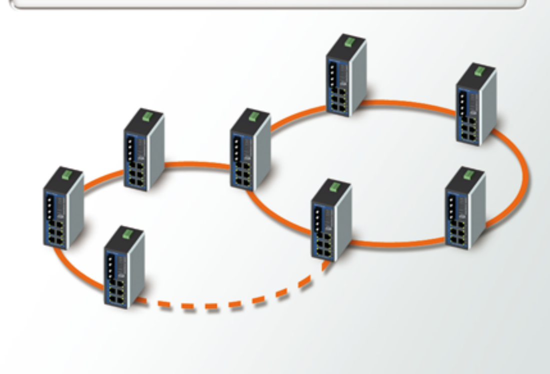
Power Distribution Features

- From control single device to control Ring Main Units (RMU)
- Distributed topology with large number of communication nodes
- Tough environmental conditions
- Communication infrastructure follows original power line
- Future expansion possibilities

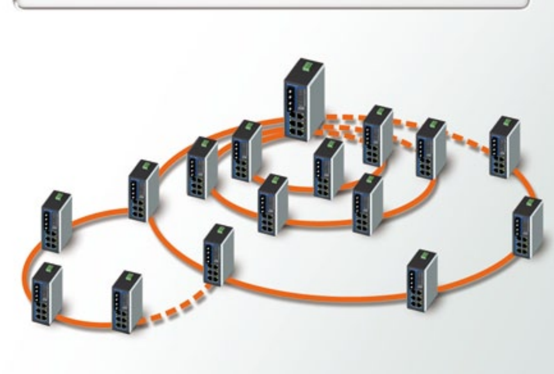
Turbo Chain Topology for Smart Power Distribution

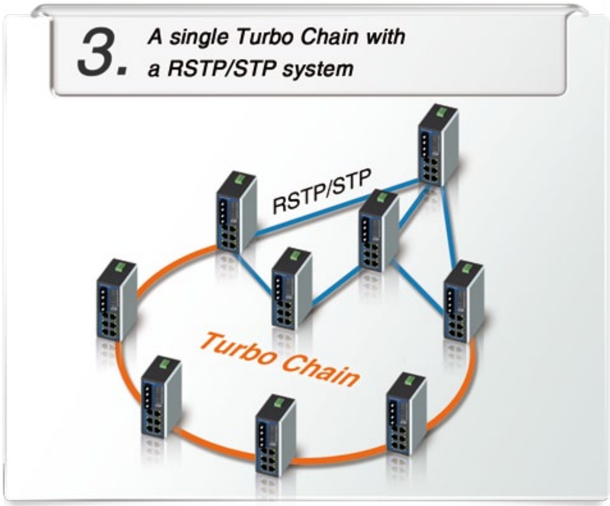
In smart power distribution systems, Turbo Chain can be used in various typologies:

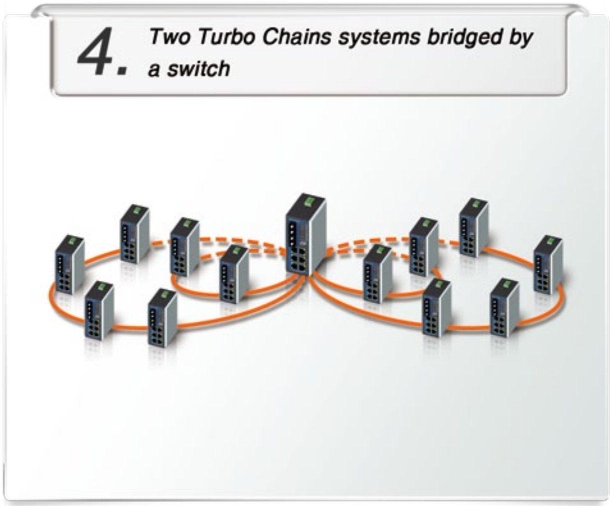
1. A single Turbo Ring system with a single Turbo Chain structure



2. Multiple Turbo Chain systems with a single Turbo Chain connection







Benefits for Turbo Chain

- Fast recovery (<20 ms)
- Saves installation cost and time
- Easy extension (can link to STP, RSTP, Turbo Ring, and Turbo Chain)

IEC 62439 PRP & HSR Protocol

Introduction to Redundant Protocols under IEC 62439 Standards

A substation automation system requires a highly redundant solution that guarantees the continuous operation. Therefore, a network communication redundancy protocol has become an essential and necessary part within a substation automation system. Under the IEC 62439 standards, several redundancy protocols have been defined:

- **PRP:** Parallel Redundancy Protocol
- **HSR:** High Available Seamless Automation Ring
- **MRP:** Media Redundancy Protocol based on a Ring Topology
- **CRP:** Cross-network Redundancy Protocol
- **BRP:** Beacon Redundancy Protocol

These protocols all aim to deliver a redundancy platform that ensures reliable communication within the substation automation systems. They all will be supported by IEC 61850 Edition II. In addition, IEC 61850 Ed. II requires zero recovery time (bumpless) for the network redundancy system of the HSR protocol. IEC 62439 Edition I was finalized in February 2010, and IEC 62439 Edition II is scheduled for publication at the end of 2011.

IEEE PSRC H7

Communicating Patrners	Service	Application Recovery Delay	Recovery Delay of Communication
SCADA to IED, client-servert	IEC-61850-8-1	800 ms	400 ms
IED to IED interlocking	IEC-61850-8-1	12 ms (with Tmin set to 4 ms)	4 ms
IED to IED, reverse blocking	IEC-61850-8-1	12 ms (with Tmin set to 4 ms)	4 ms
Protection trip excluding Bus Bar Protection	IEC-61850-8-1	8 ms	4 ms
Bus Bar protection	IEC-61850-8-1	< 1 ms	bumpless
Sampled values	IEC-61850-9-2	Less than two consecutive samples	bumpless

HSR & PRP of IEC 62439 fulfills it

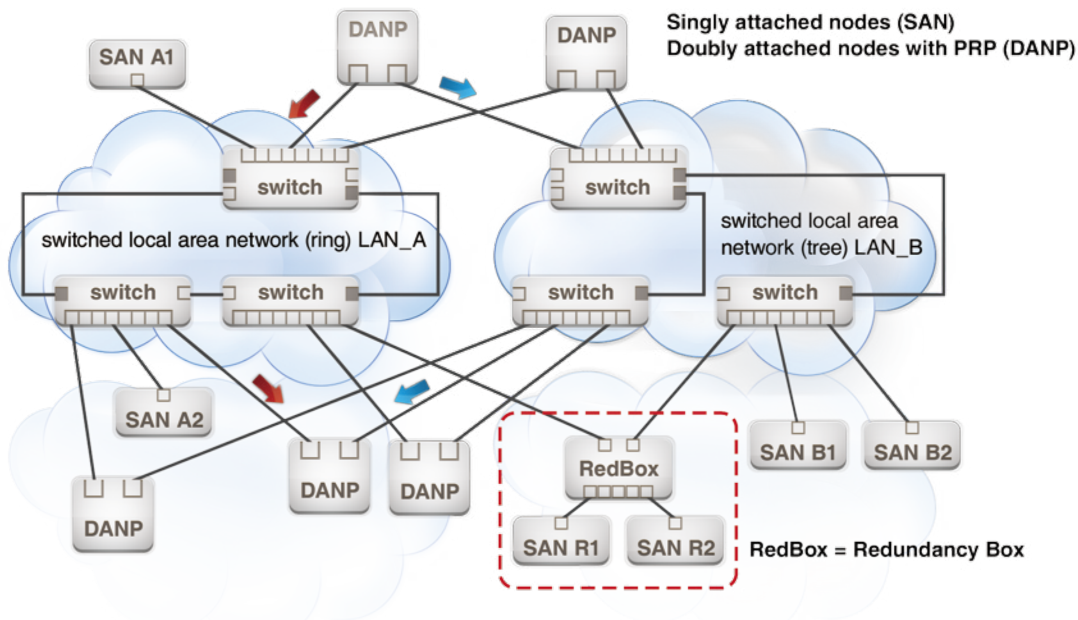
HSR:
Redundancy with no recovery time. Required in IEC 61850 ED.II

PRP: Parallel Redundancy Protocol

***Features*:**

- Defined in IEC 62439-3 Clause 4 (IEC WG15)
- "Redundancy in the devices", using devices with two network interfaces attached to redundant networks (doubly attached devices)
- Can be used with Ethernet and topology
- Achieves zero recovery time
- Tolerates any single network component failure
- Does not reply on higher layer protocols, within Layer 2 protocol
- Allows nodes not equipped for redundancy to operate
- Supports time synchronization

PRP Redundancy Network Architecture

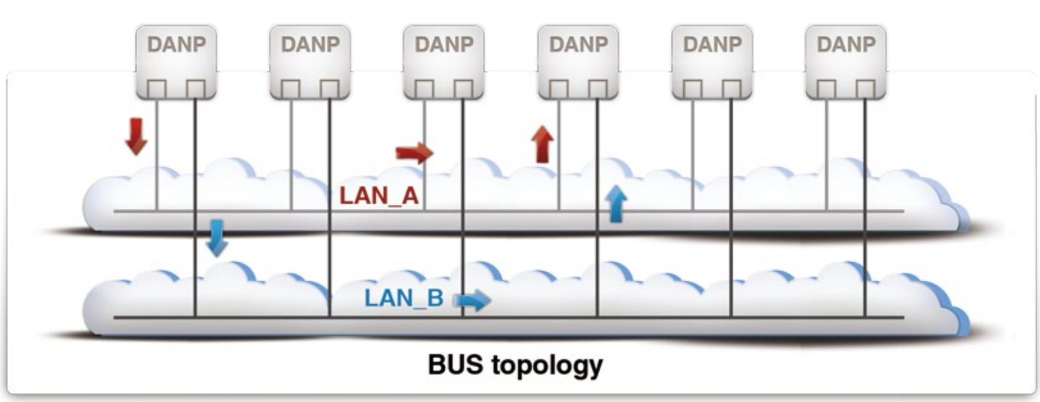


In this architecture, both SAN and DANP can be regarded as the end devices, such as relays, switch gears, and IEDs, in the power substation system. They can both appear in the same system. For the DANP, two identical packets will be sent immediately to both LAN A and LAN B packets will then be sent to the remote DANP. When both LAN A and LAN B work, the DANP will receive two same packets from two LANs. However, this DANP will automatically decide to drop one of the packets and save the other packet. When one LAN fails, the DANP will still receive the packet from the other LAN that still works well.

However, for SANs that do not come with PRP protocol, a RedBox will be an optimal solution to construct a zero time recovery system. This RedBox will connect to both LAN A and LAN B and can perform the PRP protocol to which the SANs can connect to guarantee a continuous operation even when one LAN fails.

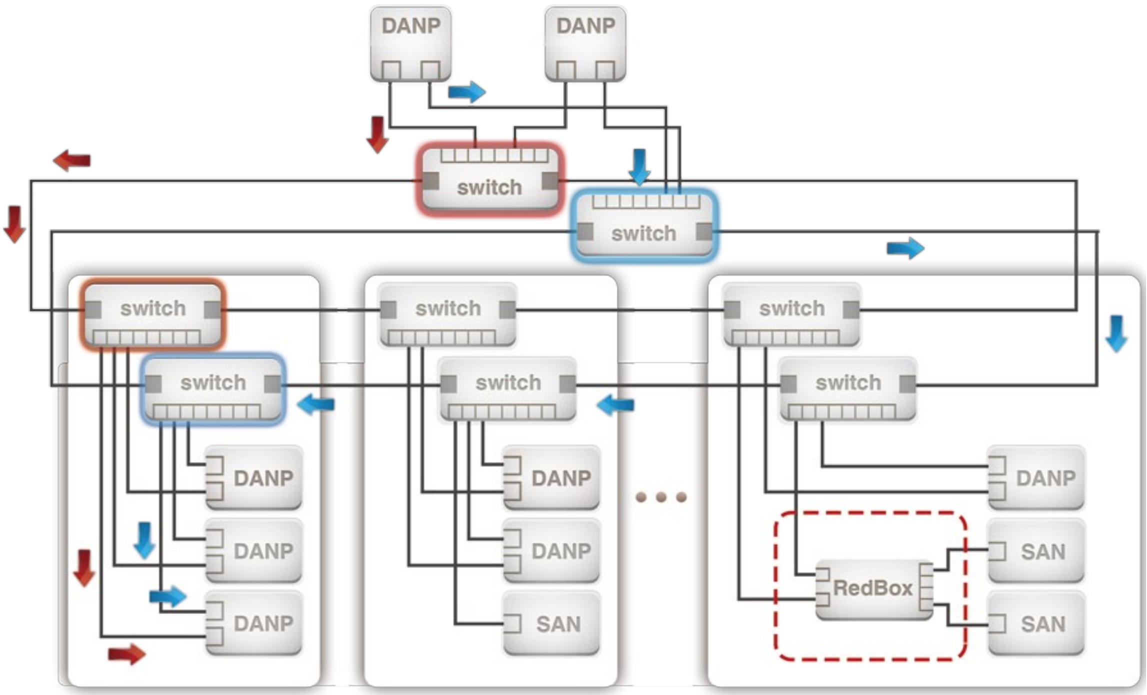
PRP Two LANs Architecture

Within the 2-LAN architectures, each DANP will connect to both LAN A and LAN B. This can guarantee a continuous operation when either LAN has been disconnected.



HSR: High-availability Seamless Redundancy

Within a ring architecture, two DANPs will connect two switches to enable zero recovery time. However, for one or several SANs, a RedBox can be implemented to help construct an immediate recovery system for continuous operation.



Substation Network Ring

- Defined in IEC 62439-3
- Suits any industrial Ethernet network in IEC 61784-2
- Seamless switchover (zero switchover time)
- Standard switches and protocols can be used unmodified (ARP, DHCP, TCP/IP, etc.)
- Ensures fail-independence of the redundant networks
- Reduces risk of implementing new control & protection technologies
- Reduces cost by converging critical and non-critical networks into a single network

HSR Redundancy Network Architecture (Link Steady)

- Requires complete doubling of the network
- Requests that singly attached nodes that need to communicate with each other are connected all to the same LAN
- Takes four bytes in a frame

HSR: High-availability Seamless Redundancy

Features:

- **A more cost-effective redundancy solution**
- **Ensures packet delivery on single point of failure in network and zero recovery time**
- **Fits a variety of topologies, basically rings and dual rings**
- **Meets reliable and real-time requirements of the most demanding applications such as substation automation and motion control**
- **Does not require switches**

HSR (High-availability Seamless Redundancy) is a redundancy protocol for substation automation in the IEC 61850 standard.

HSR provides zero recovery time when any component fails, and thus is more suitable than the RSTP (Rapid Spanning Tree Protocol) for electrical substation automation and other applications that demand high availability and short reaction time.

HSR is application protocol-independent, and can be used by most Industrial Ethernet of the IEC 61784 suite. The HSR topology is not limited to a single ring. In fact, users can build a system of rings with many structures.

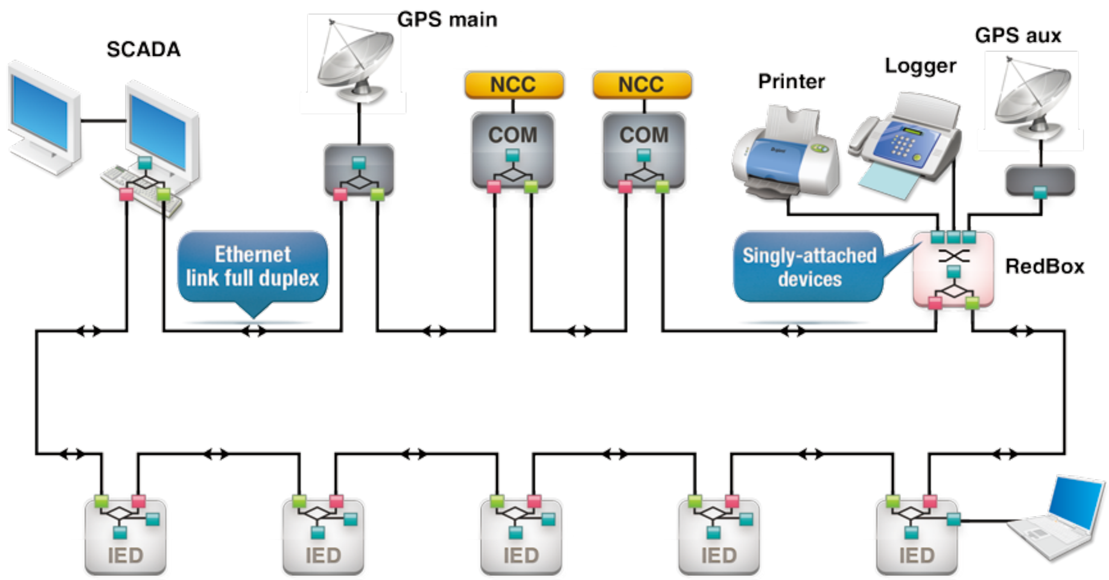
HSR is widely used in a ring topology; however, it is possible to create redundant connections to other networks in mesh topology.

The nodes (devices) in an HSR network are attached by two Ethernet ports. A source node sends the same frame to both ports. A destination receives two identical frames in the fault-free state within a certain time skew, then sends the first frame to the applications while discarding the second frame if it comes. A sequence number is used to recognize such duplicates.

In contrast to PRP (IEC 62439-3-Clause 4) which uses the same operating principle, HSR nodes can be arranged into a ring, allowing it to operate without dedicated switches, since every node is able to forward frames from port to port.

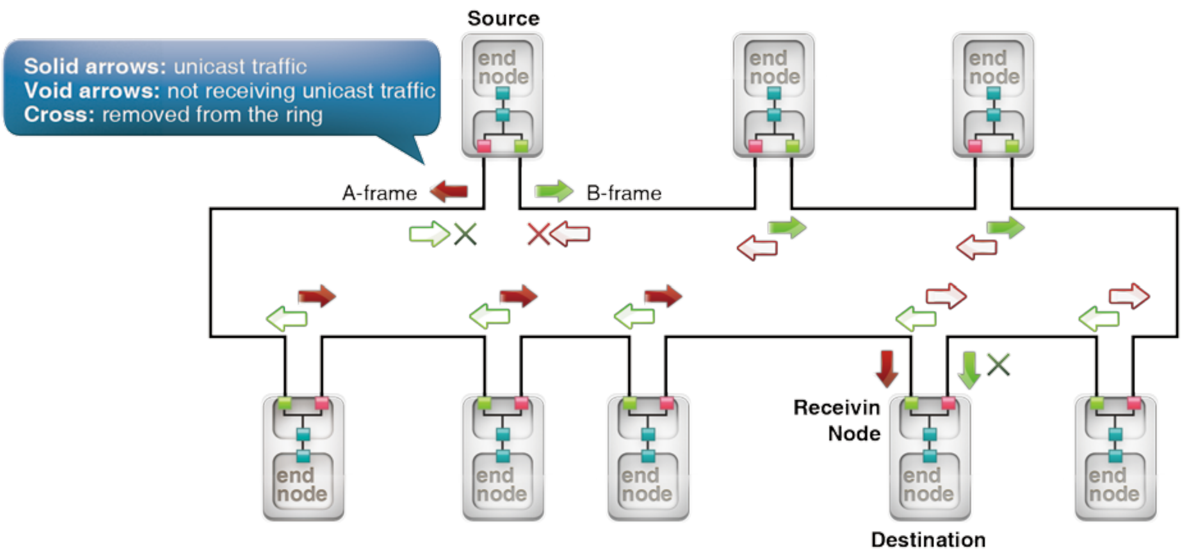
The HSR protocol has been defined by the IEC 65C WG 15 (highly available automation networks), and appeared in the IEC 62439-3 standards. It is still being defined in the IEC 61850 Edition II, by the IEC TC57 WG10.

Substation Network Ring



- Cost-effective: All nodes are “switching nodes”; there are no dedicated switches in the ring
- Non-ring nodes are attached through a “RedBox”

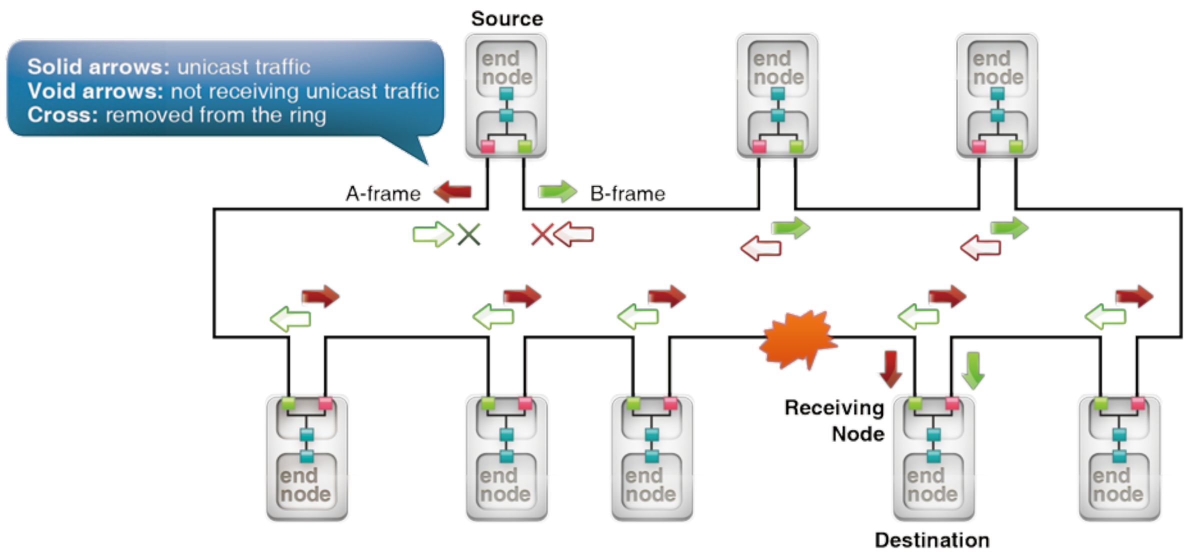
HSR Redundancy Network Architecture (Link Steady)



- Duplicate frames sent in different directions
- Frames are moved through the HSR network

HSR Redundancy Network Architecture (Link Failure)

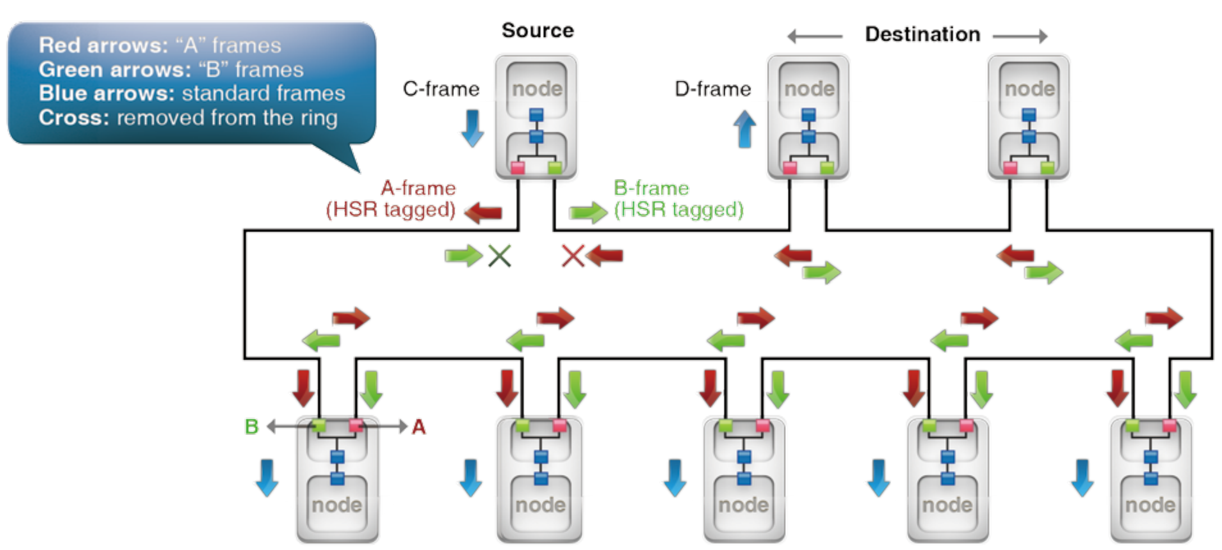
When one connection fails, one frame will not be successfully sent to the end devices. However, the other frame is still working reliably and can be sent to the end devices. This ensures that no data loss and no network delay will occur even when one connection fails.



- In link failure, the frame still makes it through to the receiving node from the opposite direction
- No data loss and no delay for network failure

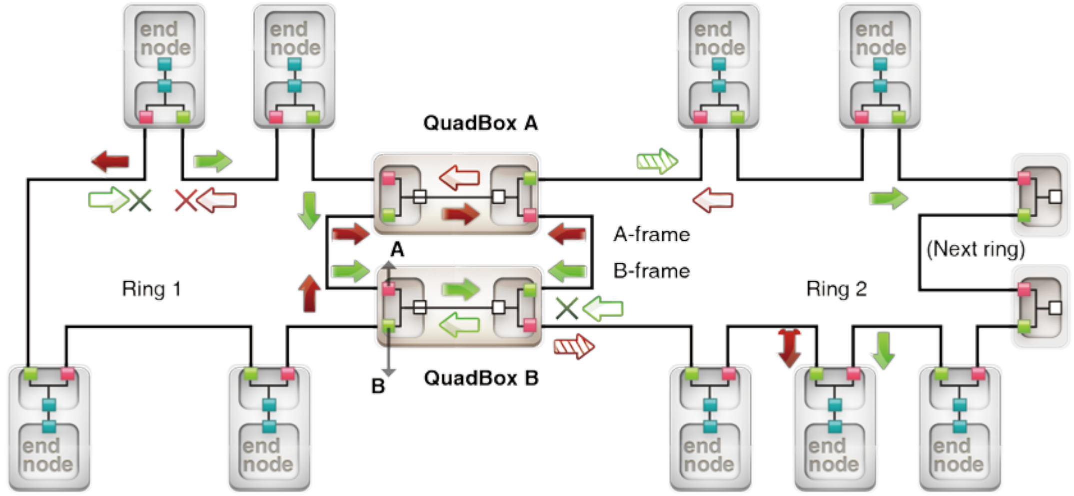
HSR with Multicast Frames

In the multicast structure, nodes (devices) are arranged as a ring; each node has two identical interfaces, port A and port B. For example, when C frame has been sent, it will be duplicated as A frame and B frame, both identical and HSR tagged. These frames will be transmitted with different directions to the destination nodes. However, one of the frames will be deleted once the end node received the frame. Even when there is a disconnection and one frame fails to transmit, the other frame still works, fulfilling the zero recovery and immediate redundant requirement.



Coupling Two HSR Rings with a QuadBox

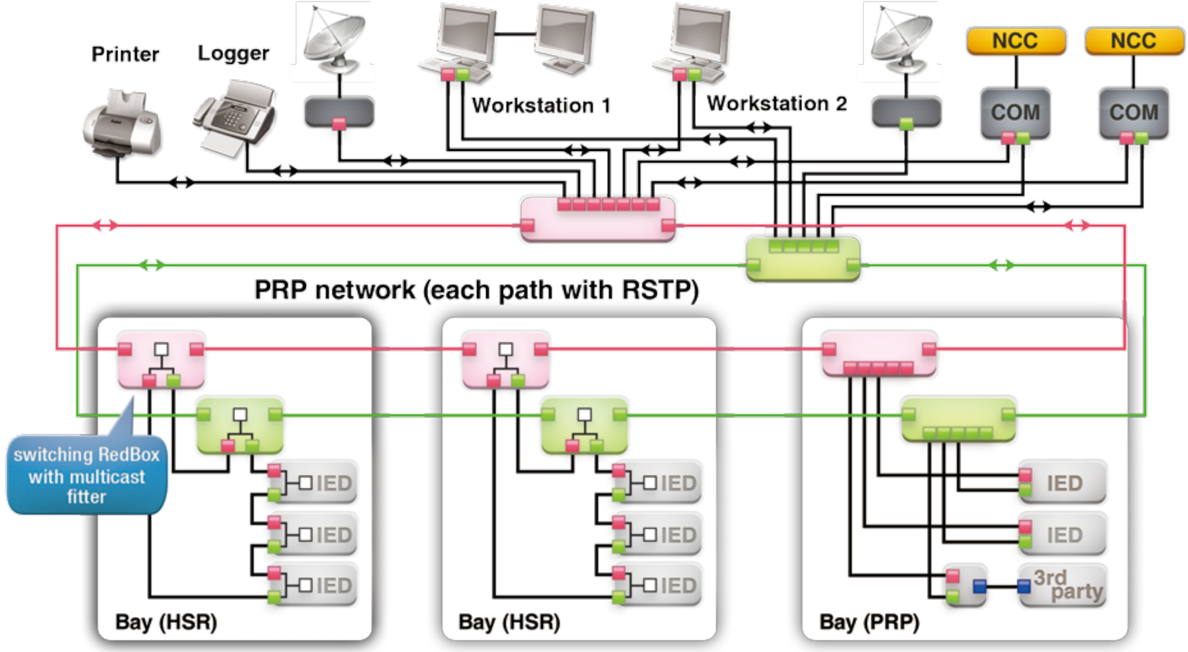
HSR protocol can also be implemented within two rings along with the QuadBox solution. In this structure, two rings will be connected with two QuadBox units. One frame will still be copied as A frame and B frame and transmitted to two different directions through QuadBox A and QuadBox B. One of the frames will be dropped if both frames have been successfully sent to the destination nodes. Even when any single point fails, communication can still operate reliably through the redundant frame and QuadBox. This solution guarantees that the two rings can keep connecting in case of any device or communication failure, and data loss can be completely avoided.



Two QuadBoxes are needed to avoid a single point of failure

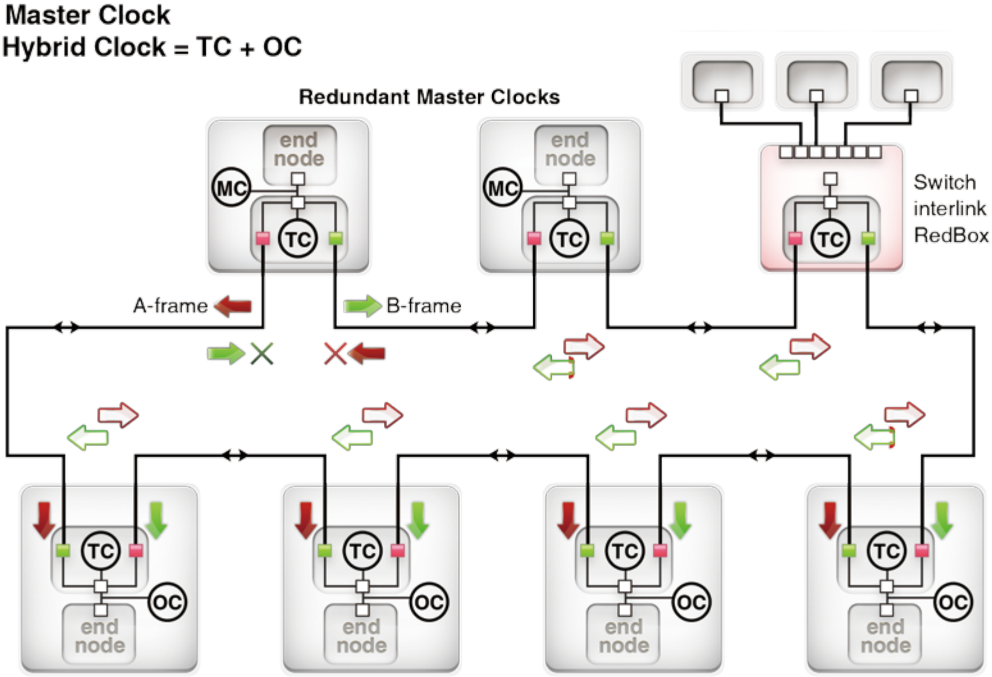
Example of PRP/HSR Network Hierarchy

Both PRP and HSR protocols can be simultaneously implemented in the same network. They can also be connected with two rings, and work with HSR or PRP protocol separately.



IEEE 1588 Clock in HSR Network

MC Master Clock
HC Hybrid Clock = TC + OC



- TC operates in both directions
- OC takes the time from the SYNC messages, from whichever direction

HSR Advantages

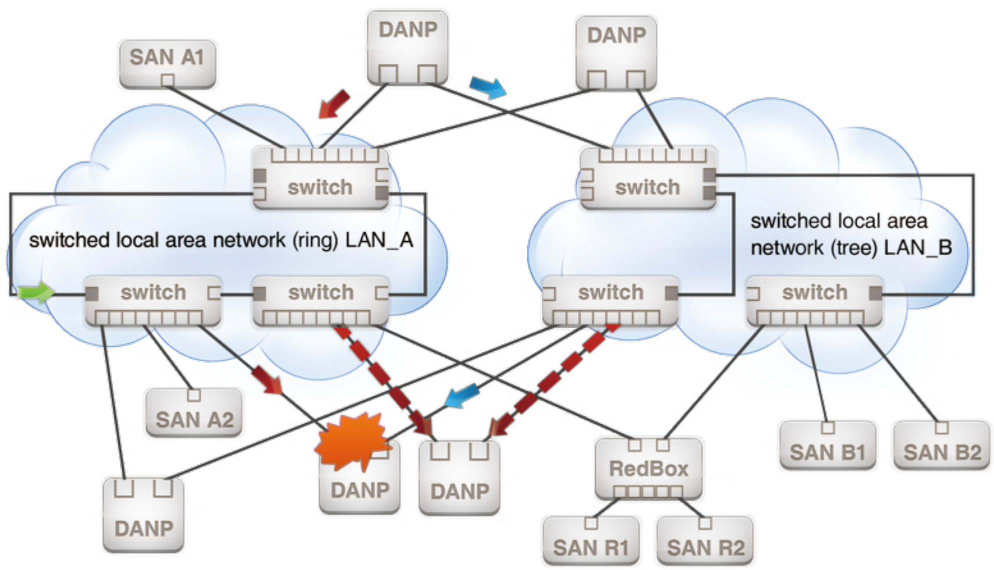
- Seamless failover in case of failure of a node or reinsertion of a repaired node
- Reduction of number of devices – elimination of switches
- International standard (IEC 62439-3 Clause 5)
- Guaranteed behavior under failure conditions
- Deployable for any industrial Ethernet
- Reduced cost by converging critical and non-critical networks
- Specified as the redundancy solution in IEC 61850 Ed. 2

HSR Disadvantages

- Reduces slightly the available network bandwidth for multicast messages
  (All traffic must go through each device)
- Requires a hardware implementation (ASIC or FPGA) to meet the real-time constraints
- Non-HSR devices can only be inserted over a “RedBox or a “Quadbox”

China Power Substations Using HSR and PRP

In the China market, PRP systems will be preferred, as ring topologies are not usually used in the process level. The PRP protocol is recommended by official requirements: If two paths fail simultaneously, only one power device is influenced and other communication remains live.



Moxa's Solution in HSR RedBox (Preliminary)

Features:

- Compliance with IEC 61850 IEC 62439 HSR
- 3 FE ports Interface
- Handle 256 connections
- Supports QuadBox (optional)
- Dual power input
- Supports IEEE 1588 v2 time synchronization

Moxa's Solution in PRP Embedded (Preliminary)

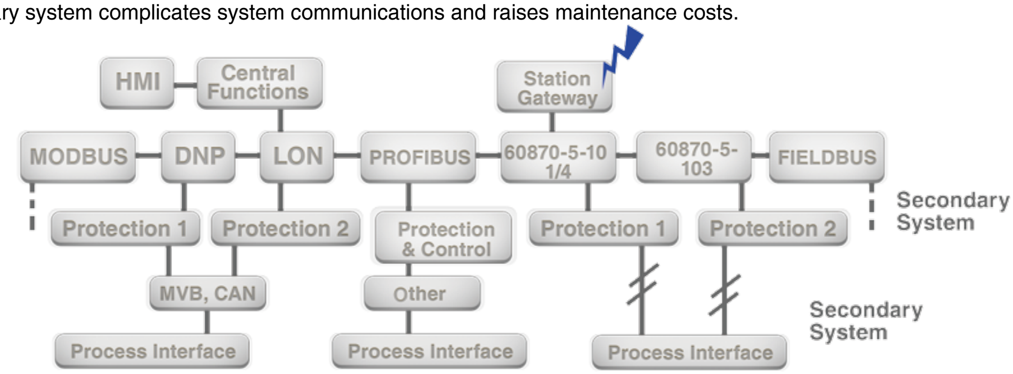
Features:

- Compliance with IEC 61850 IEC 62439 PRP
- 3 FE ports Interface
- Handle 256 connections
- Dual power input
- Supports IEEE 1588 v2 time synchronization

Breakthrough in Secondary System Networking

Traditional Substation Structure

A traditional substation system structure employs a two-tier architecture that runs a variety of different complicated protocols. The primary system consists of many devices that directly connect to power equipment. The secondary system consists of protection devices and control devices. However, the secondary system usually runs different protocols from the primary system, such as Modbus, DNP, LON, 68070-5/-101/4, 60870-5/103 and Profibus. The complexity and protocol proliferation of the primary and secondary system complicates system communications and raises maintenance costs.

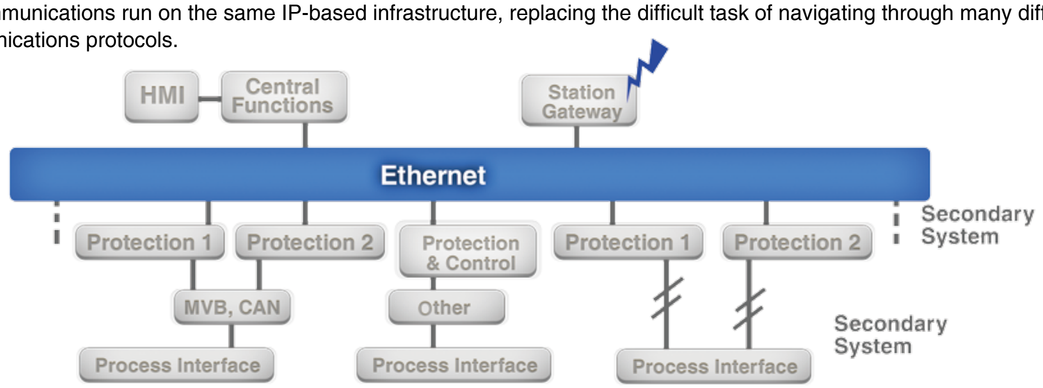


Substation Secondary Systems

Substation secondary systems employ many devices that are designed to perform certain specific tasks, such as control, protection, measuring, metering, recording, and communication. The secondary system connects to many devices in the first system, including IEDs, RTUs, and power meters.

Networking the Secondary System

The future of the substation secondary system is Ethernet networking. Upgrading the secondary system to use Ethernet to communicate with the control system simplifies the gap between the secondary system and the back-end center; now all the communications run on the same IP-based infrastructure, replacing the difficult task of navigating through many different communications protocols.



Objectives of Secondary System Networks

The secondary system network strives to achieve the following goals:

- Maximize reliability and availability of each component
- Reduce system communication downtime
- Expand ROI; deliver the quickest possible return on investment costs with maximized profit
- Minimize maintenance costs during the entire life cycle
- Meet environmental requirements

Solutions for Secondary System Networking

A secondary system network solution should achieve the following requirements:

- Self-healing redundant ring to minimize system recovery time
- Dual LAN redundancy for continuous system operation
- Alternative communication route for system stability and reliability
- All-in-one-box hybrid communication for serial and Ethernet devices that construct a complete substation automation system

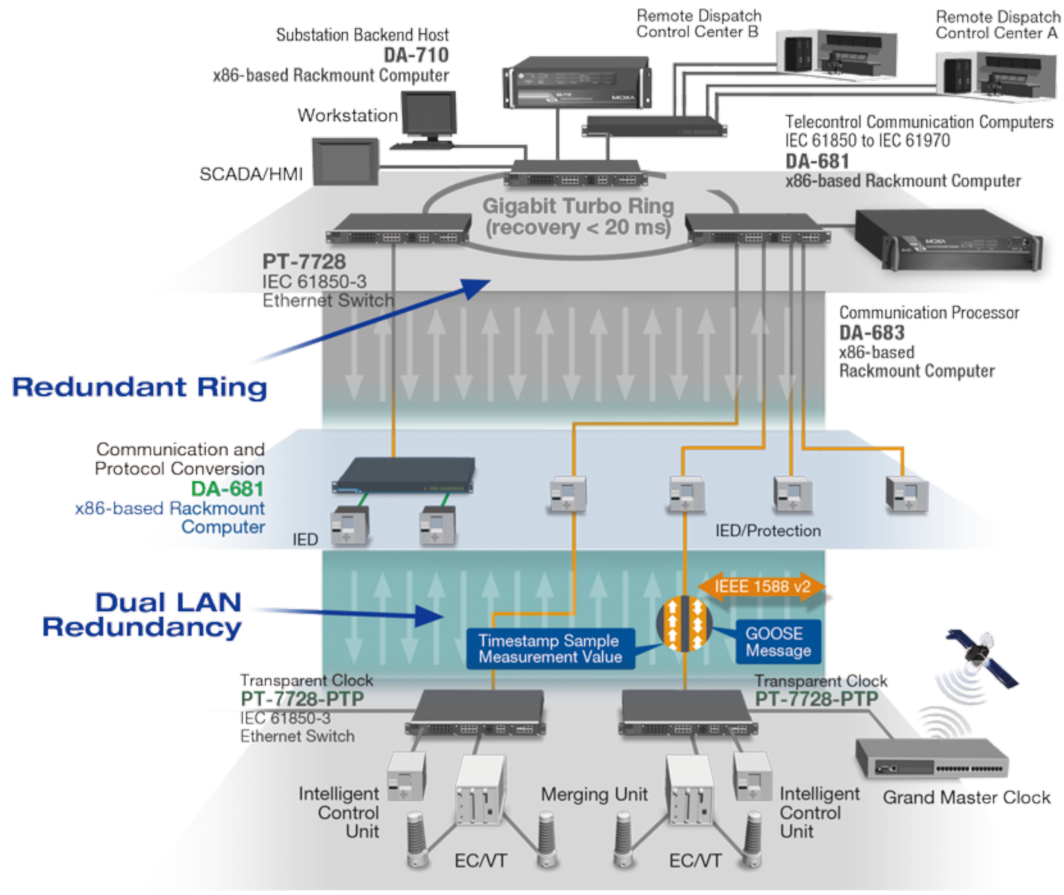
In order to meet the requirements of secondary system networking, the network will need to deploy many devices:

- **Ethernet Switches:** Serve as the core units for data communication, based on the Ethernet standard
- **Industrial PCs:** Serve as the core units that perform many tasks, such as data acquisition, data computing, event analysis,and protocol conversion
- **Serial Device Servers:** Serve as the main units to connect to devices in the primary system for protocol conversion

Networking Serial-based Secondary Equipment

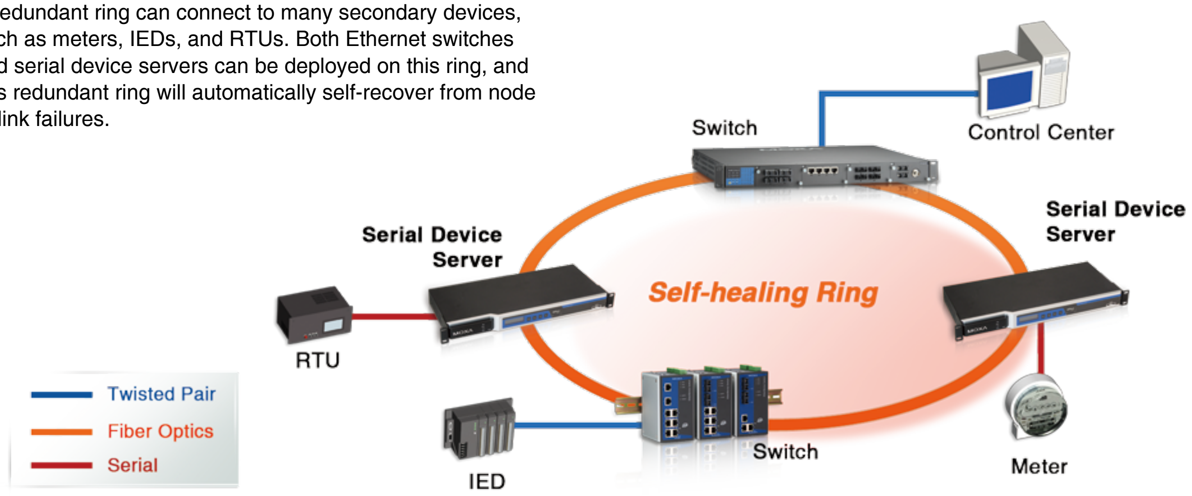
Networking Ethernet-ready IEDs

Substation systems using Ethernet-based devices need a technology that enables network recovery from node or link failures. A redundant ring structure can be easily constructed within the station level, and a dual LAN redundancy mechanism can be deployed as well. Both solutions deliver reliable and continuous system operations.



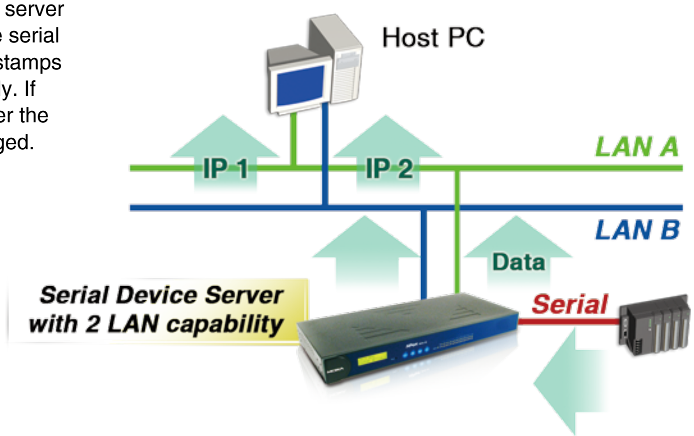
Networking Serial-based Secondary Equipment — Redundant Ring

A redundant ring can connect to many secondary devices, such as meters, IEDs, and RTUs. Both Ethernet switches and serial device servers can be deployed on this ring, and this redundant ring will automatically self-recover from node or link failures.



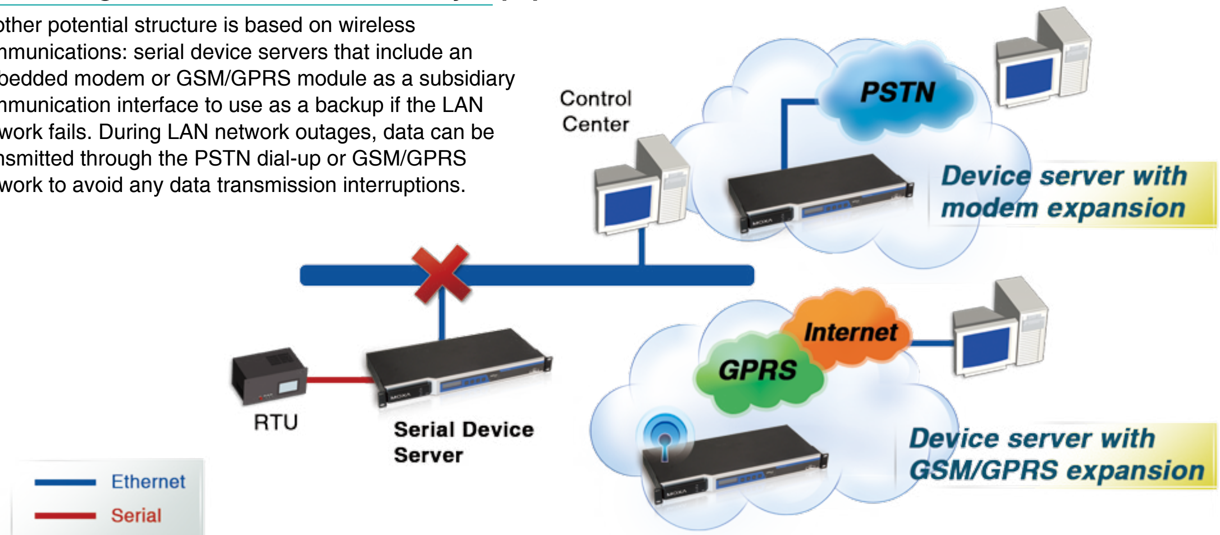
Networking Serial-based Secondary Equipment — Dual LAN Redundancy

Dual LAN redundancy is an alternative approach for substation systems using serial-based devices. In a dual LAN network, both the host PC and the serial device server have two LAN ports with separate IP addresses. The serial device server will duplicate the serial data with time stamps and transmit data through 2 LAN ports simultaneously. If one LAN fails, the other link will immediately take over the communications so that no data will be lost or damaged.



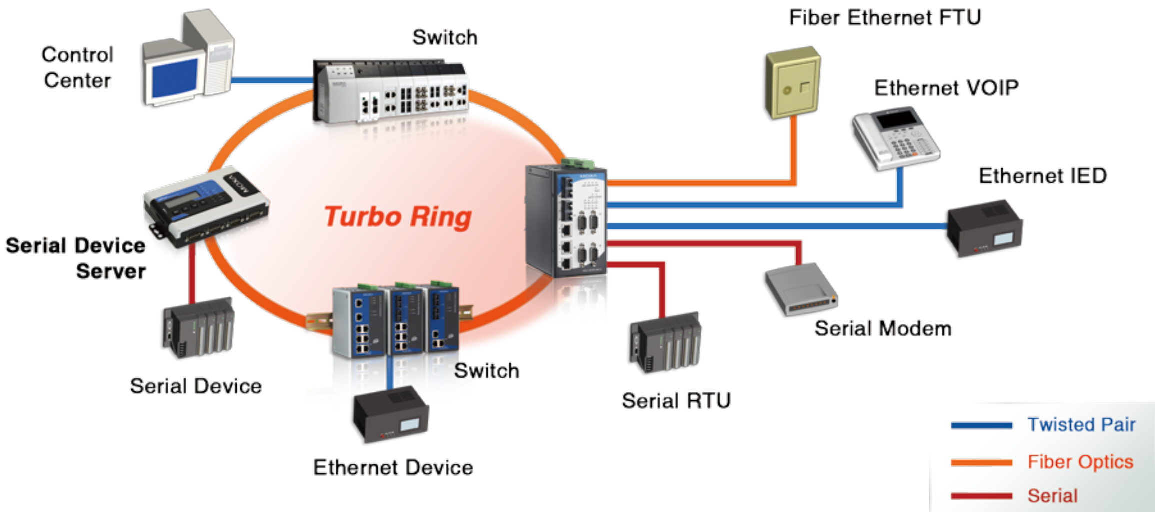
Networking for Serial-based Secondary Equipment — Alternative Route

Another potential structure is based on wireless communications: serial device servers that include an embedded modem or GSM/GPRS module as a subsidiary communication interface to use as a backup if the LAN network fails. During LAN network outages, data can be transmitted through the PSTN dial-up or GSM/GPRS network to avoid any data transmission interruptions.



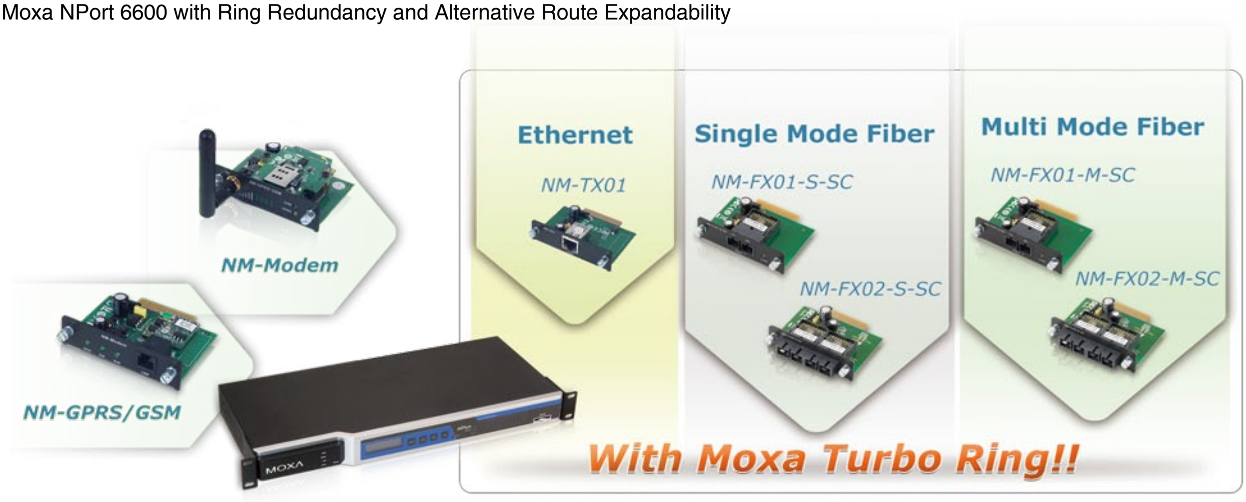
All-in-one-box Hybrid Communication for Serial and Ethernet Device

Hybrid communications devices combine the functionality of switch and device server units and connect to both IP-based and serial-based devices. This flexibility creates a cost-effective solution that simplifies system construction and reduces time-to-market.



Product Highlights

Moxa NPort 6600 with Ring Redundancy and Alternative Route Expandability



Moxa CN2600 with Dual LAN Redundancy

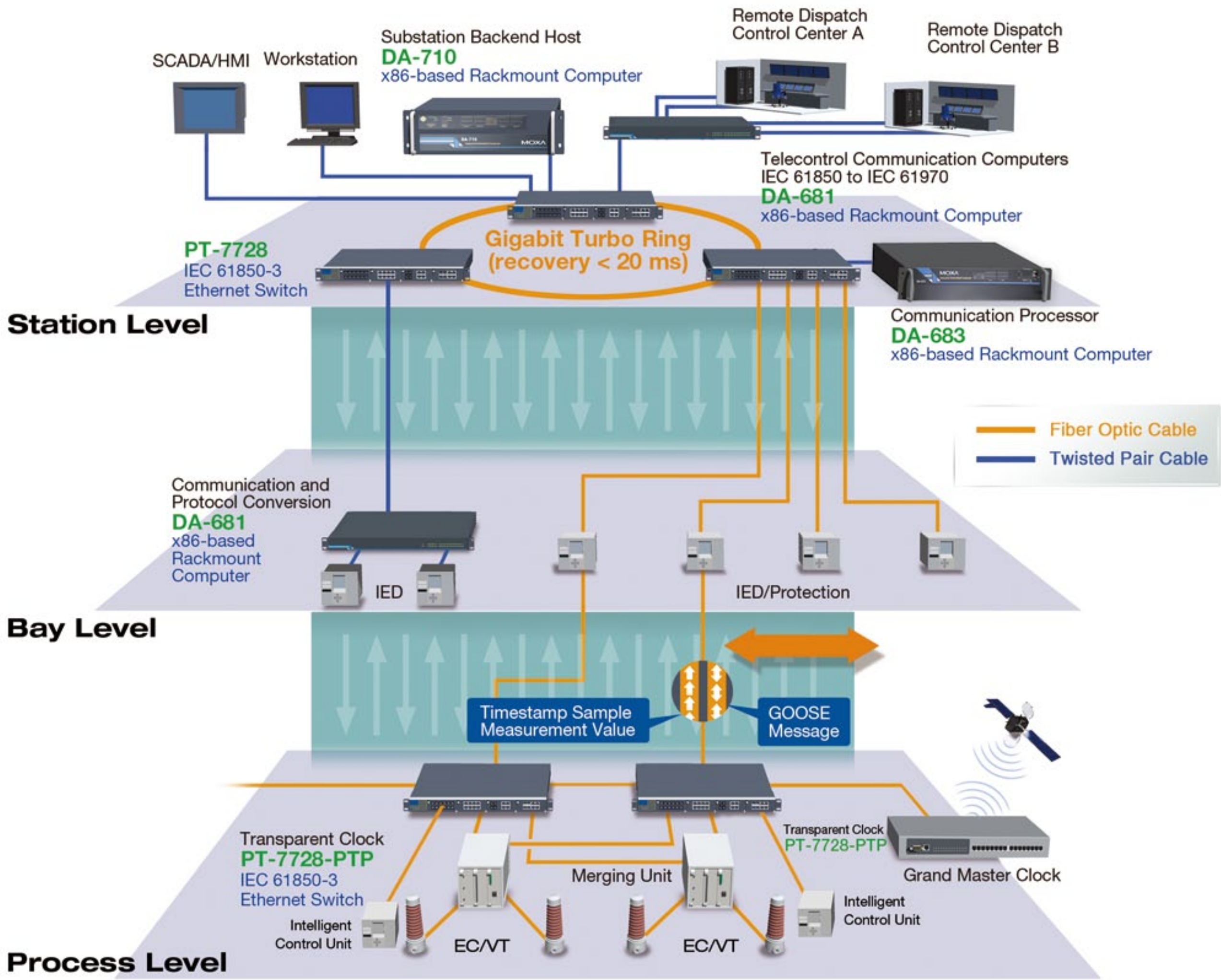
- Dual LAN Redundancy
  - Dual LAN with two IP addresses and two MAC addresses
  - Patented "Redundant COM" for effortless dual active network connections
  - Patented "DRDAS" for dual host backup
- Dual AC Power input for power redundancy
- Secure Management—HTTPS, SSH
- 128K off-line port buffering for each port
- 128K serial data log for each port

NPort S8458 Combo Switch Device Server

- Compact all-in-one-box hybrid networking solution
- 4 fiber Ethernet ports
- 4 copper Ethernet ports
- 4 3-in-1 serial ports
- Moxa Turbo Ring and Turbo Chain redundancy
- Rugged hardware design
  - Serial/Ethernet/Power line surge protection
  - Level 4 ESD protection
- Complete device server and industrial switch software function

Breakthroughs in Embedded Computing

As illustrated in the following figure, an IEC 61850/IEEE1588 based substation is composed of a networking/computing infrastructure in three layers.



Station Level: the main tasks are system control, disturbance data analysis, event logging, system diagnostics, and alarms.

Bay Level: the main tasks are system control, line/transformer protection, bus-bar protection, breaker failure protection, measurement and metering, event/fault recording, and alarms.

Process Level: the main task is communication between protection units, and communication from control IEDs transmitting sampled values and binary status signals to the process.

Technology Breakthroughs in Substation Automation

In an automated substation, some technology barriers including EMI and EMS effects, precise time synchronization, and real-time monitoring need to be addressed. Focusing on these needs, Moxa engineers have has made some breakthroughs in supporting substation automation. These breakthroughs include getting industrial certification for EMC level 4 and IEC 61850-3 standards, developing an IEEE 1588 slave clock for precise time synchronization, and providing an application programming interface (API) for monitoring and managing substation computers.

EMC Level 4 Certified

Electromagnetic interference is a constant challenge for engineers who design and develop embedded systems. Moxa's embedded computers use industrial-grade components that meet all international EMI standards and directives in order to reduce radiation effects and provide a reliable embedded platform for any industrial application.

Within a substation automation system, the EMI (Electromagnetic Interference) and EMS (Electromagnetic Susceptibility) standards have been the key benchmarks that differentiate products into different classes.

EMI (Electromagnetic Interference) refers to disturbances created by the product itself. Electromagnetic disturbances, which affect an electrical circuit due to either electromagnetic induction or electromagnetic radiation emitted from the product, can be classified to the following levels:

***Class A**: for industrial purposes*

***Class B**: for commercial purposes*

EMS refers to disturbances created by external sources. The tolerance of circuits and components to all "External Sources" of interfering electromagnetic energy can be classified into the five levels listed in the table.

IEC 61000 & China National Standard GB/T17626-1999 5 Levels	
Level 1	Protected environment
Level 2	Protected environment
Level 3	Typical industrial environment
Level 4	Harsh industrial environment
Level 5	Special environment that needs to be analyzed

EMC Level 4 Certification

The electric cables and devices in a substation are major sources of EMI. Switches, relays, and sensors can all easily create interference when operating in a substation. Usually, computers that operate in commercial applications only need IEC 61000 EMC Level 2 protection. However, computers deployed in a substation automation system need to meet a higher standard, Level 4, to possess sufficient protection. The Level 4 standard guarantees that the computers are able to endure the interference produced in a substation and work reliably in this harsh environment. Moxa's DA Series computers have been EMC Level 4-certified, and can offer reliable and stable operations in a substation automation system.

EMS Level 4 Certification

EMS standards have been classified into five levels, with specific different requirements for different applications. General-purpose computers used in typical conditions only need to meet the Level 2 standard, but computers used in substations must meet the higher Level 4 standard for reliable operation. Moxa's DA-683 computers have passed EMS Level 4 certification, and can withstand many types of interference, such as electrostatic discharge, power surge, and radio interference. This ensures system stability in harsh substation environments.

IEC 61000-4			General EPC		Moxa DA-683	
Test Items		Level 1	Level 2	Level 3	Level 4	Level 5
IEC 61000-4-2	Electrostatic discharge	2 kV 2 kV	4 kV 4 kV	6 kV 8 kV	8 kV 15 kV	
IEC 61000-4-3	Radiated, radio-frequency, electromagnetic field immunity	1 Vm	3 Vm	10 Vm	*	
IEC 61000-4-4	Electrical Fast Transient/burst immunity	0.5 kV (5 kHz) 0.25 kV (5 kHz)	1 kV (5 kHz) 0.5 kV (5 kHz)	2 kV (5 kHz) 1 kV (5 kHz)	4 kV (2.5 kHz) 2 kV (5 kHz)	
IEC 61000-4-5	Surge immunity	0.5 kV	0.5 kV 1 kV	1 kV 2 kV	2 kV 4 kV	*
IEC 61000-4-6	Conducted disturbances, induced by radio-frequency fields	1 V	3 V	10 V	10 V	
IEC 61000-4-8	Power frequency magnetic field immunity	1 A/m	3 A/m	10 A/m	30 A/m	
IEC 61000-4-11	Voltage dips, short interruptions and voltage variations				100 A/m	
IEC 61000-4-9	Pulse magnetic field immunity			100 A/m	300 A/m	1000 A/m
IEC 61000-4-10	Damped oscillatory magnetic field			10 A/m	30 A/m	100 A/m

IEC 61850-3 Certified

The IEC 61850-3 standard establishes a common, interoperable specification for devices in a power system, so that operators can combine devices from many different manufacturers and still share data, services, and functions. The IEC 61850 standard covers a wide variety of power sectors, such as relay-to-relay communication, substation configuration language, system configuration, and definitions for protection and control functions. With this one standard, true interoperability among devices can be achieved.

The IEC 61850-3 standard specifies general requirements for the hardware design of IEC 61850 devices used in substations. IEC 61850-3 devices must meet the following requirements:

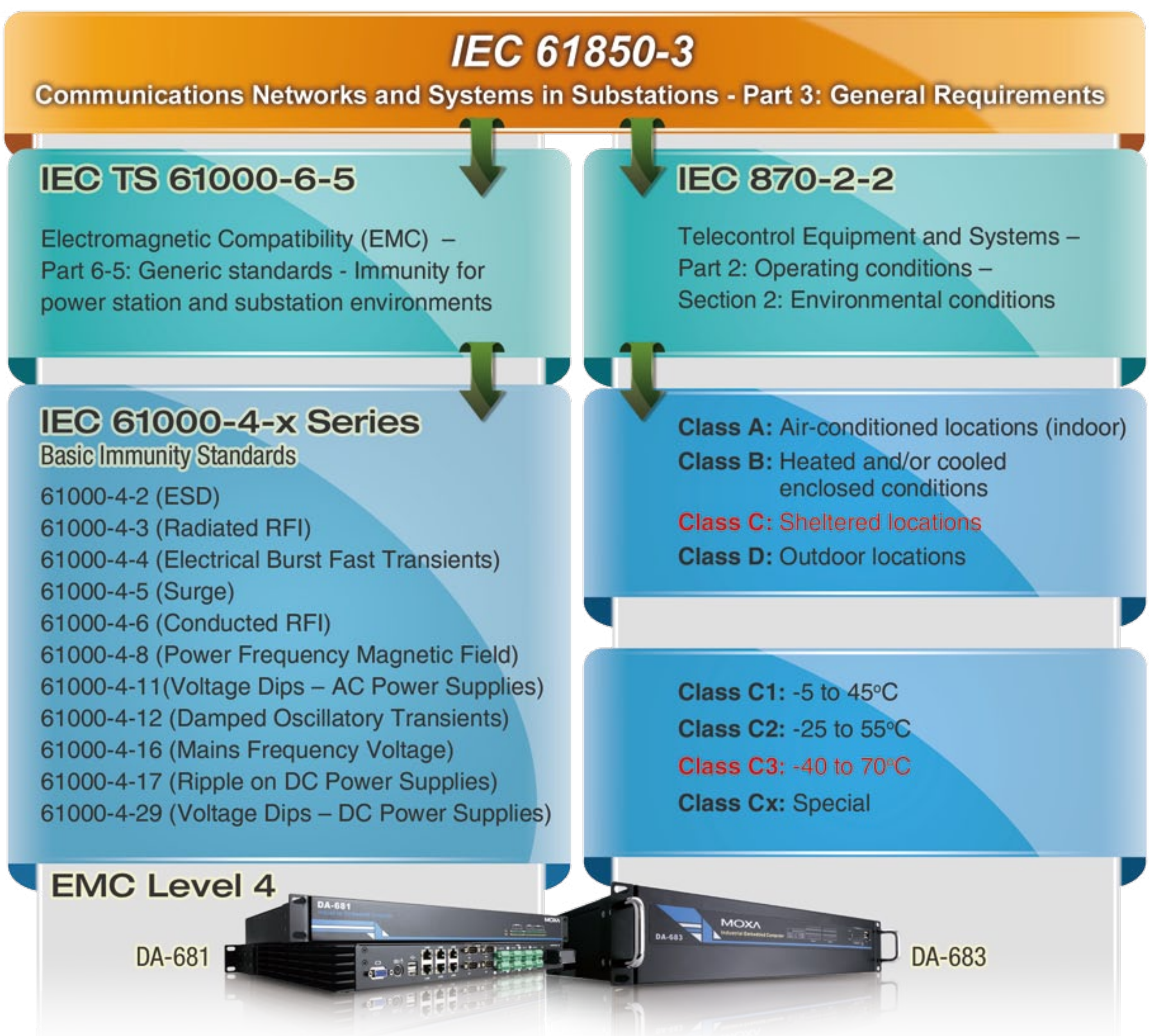
Strong EMC design to protect against EMI: As mentioned in the previous section in this chapter, EMC (electromagnetic compatibility) is important since unprotected devices are easily damaged or destroyed when exposed to high levels of EMI (electromagnetic interference). Providing the necessary protection presents hardware engineers with a serious challenge, since it often requires using expensive components designed to handle electromagnetic interference. In addition to choosing the right components, engineers must also spend a good deal of time testing their design.

-40 to 75°C operating temperature range: The wide temperature requirement is important since substation environments can experience temperatures as high as 75°C and as low as -40°C. The wide temperature requirement can be satisfied with an efficient heat dissipation design for extremely hot surroundings, and an intelligent self-warming system that kicks in when the temperature drops to extremely cold temperatures.

Anti-vibration and anti-shock: IEC 61850 devices must meet a 50 G anti-shock and 5 to 500 MHz anti-vibration requirement to ensure continued operation in the event of a fall from the rack in the device cabinet. The key to satisfying this requirement is to use protective components that serve as a cushion to protect the device when it falls.

IEC 61850-3 standards

IEC 61850-3 includes multiple standards that can be divided into two parts: IEC TS 61000-6-5 and IEC 870-2-2.

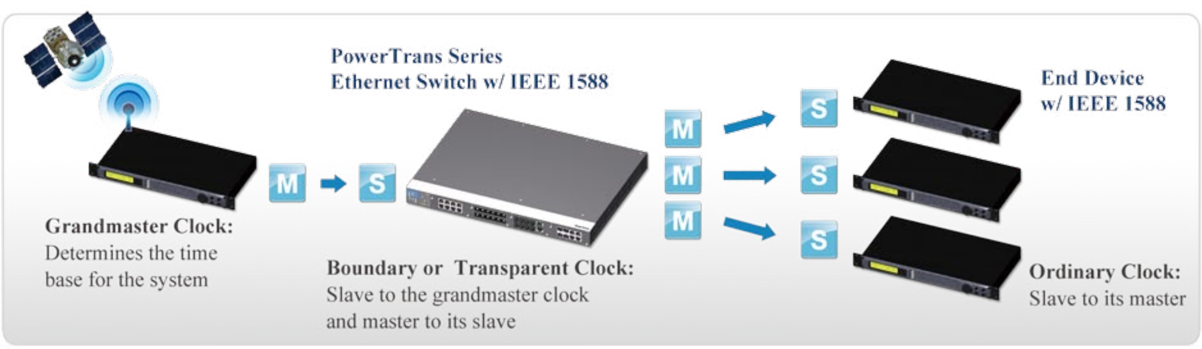


Moxa's DA-681 and DA-683 computers have passed the IEC 61850-3 requirements, and can deliver reliable and stable operations in a substation automation system.

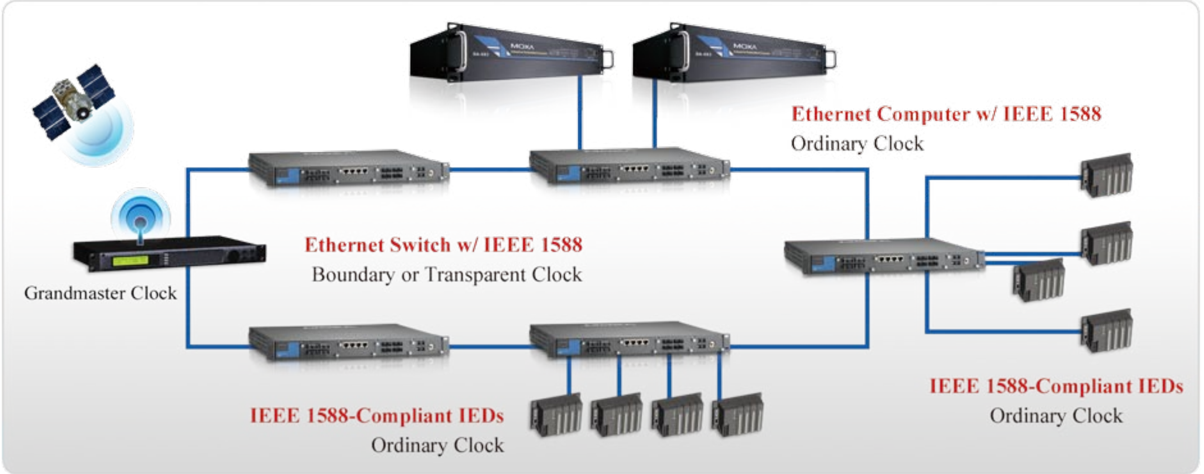
Under the IEC TS 61000-6-5 standards, both computers exceed EMC Level 4. Under the IEC 870-2-2 standards, both computers are certified to meet the requirements of Class C3 environmental conditions (operating temperature from -40 to 70°C), and Class Cm for severe conditions with strong vibration and shock.

IEEE 1588v2 Technology

Currently, several methods, NTP and SNTP, have been utilized for precise time synchronization for network devices. However, these methods aren't suited for substation operations. Fortunately, IEEE 1588v2 Precision Time Protocol (PTP) is designed specifically for industrial networked measurement and control systems. In a IEEE 1588v2-based network, the grandmaster clock determines the reference time for the entire substation automation system. The Ethernet switch acts as the boundary or transparent clock, and additional devices (such as merging units, IEDs, and protection devices) are designated as ordinary clocks. All of these devices are organized into a master-slave synchronization hierarchy with the grandmaster clock at the top. As illustrated in the figure below, by exchanging PTP packets between master and slave devices, and automatically adjusting the ordinary clocks, the entire network effectively achieves time synchronization. The grandmaster clock only needs a connection to GPS timekeeping so that the data can be accurately distributed to the devices in the network.



An Ethernet switch that supports IEEE 1588v2 can guarantee time-stamping accuracy to within 1 μs, and be configured for master, boundary, or transparent clock functionality. To achieve true precise time, the rest of the network needs to support IEEE 1588v2 as well. In an industrial computing network, IEEE 1588v2-compliant computers fill the role of the ordinary clock that receives synchronized time data from the Ethernet switch.



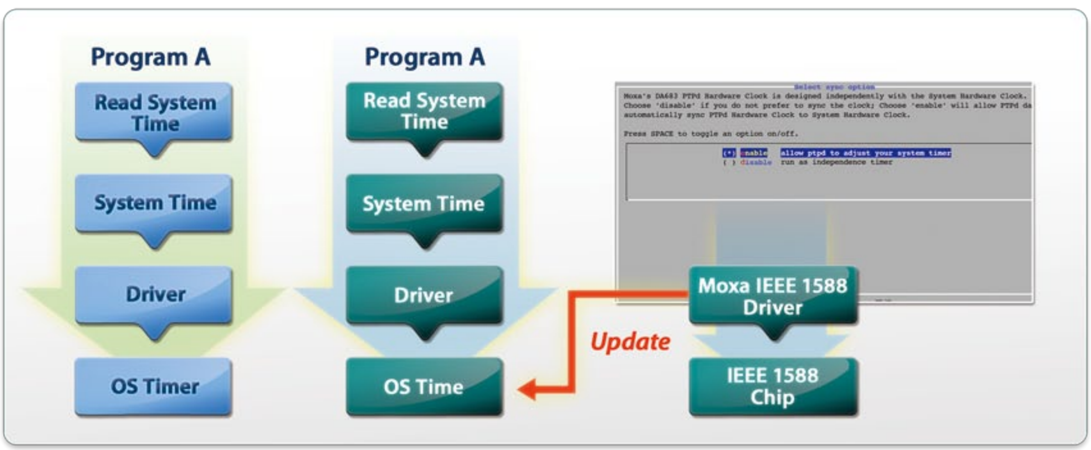
When the entire network supports IEEE 1588v2, the system can coordinate operations down to the nanosecond level and still keep perfectly in sync. This level of coordination is especially valuable in power substation systems, which is why IEEE 1588v2 is part of the IEC 61850-2 standard specifying communications requirements for power automation networks. The IEC incorporates IEEE 1588v2 into the standard because more precise time synchronization allows electrical substations and power automation networks to achieve the following benefits:

- **Blackout prevention** through early detection of grid problems, early location of disturbances, and real-time power islands
- **Accurate fault recording and event loggers** that enable precise event analysis down to the nanosecond level
- **More efficient use of assets** through congestion relief and equipment condition monitoring
- **Demand response through** time-of-use billing, virtual power generators, and outage management

IEEE 1588v2's cost-effective nanosecond-level accuracy gives substation and other power utility networks a competitive edge just as formidable as the edge gained by Britain's navy when they adopted chronometers. As part of a "Smart Grid," highly synchronized substations are more efficient, more economical, more sustainable, and more responsive. These advantages allow electricity providers to increase the profitability of their operations and reduce their impact on the environment.

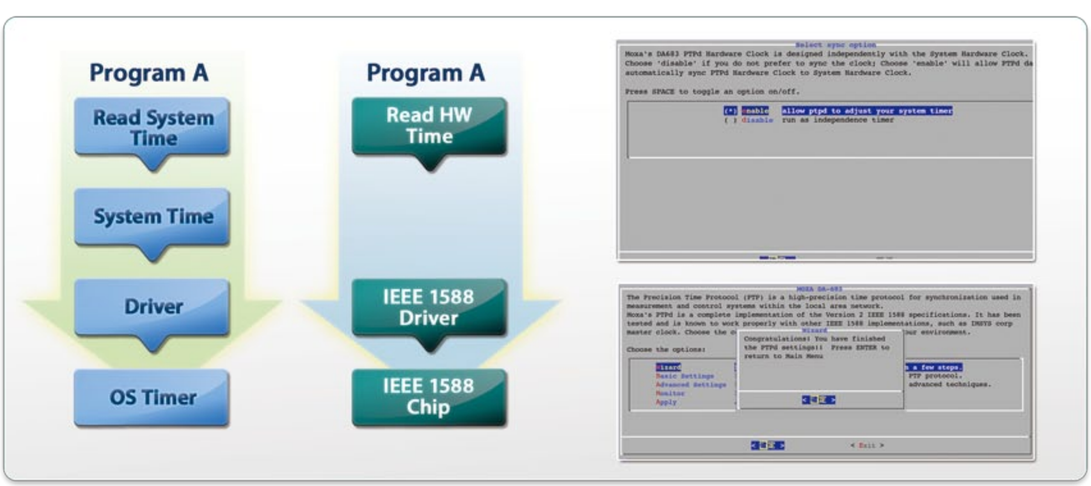
IEEE 1588 Slave Clock

Moxa's DA-683 computers make it easy to add IEEE 1588 v2 time synchronization.



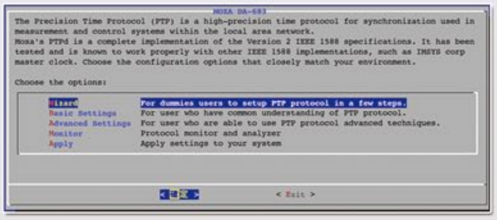
Once Moxa's IEEE 1588 v2 driver is activated, it can automatically update the OS time and the chipset of the computer.

This solution enables users to read time from IEEE 1588 v2 hardware. Moxa also offers an easy-to-use configuration interface for setting up IEEE 1588 v2 time synchronization in just a few steps.

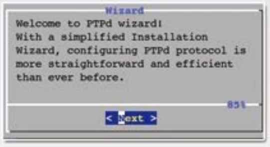


Moxa offers an easy-to-use interface to configure necessary settings. For example, time synchronization can be configured in just a few steps.

1. On the main menu, Select <**Wizard**> (by pressing the Enter key) and then select <**OK**> to continue.



2. On the "Wizard" panel, Select <**Next**>.



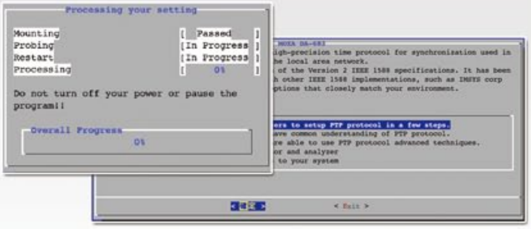
3. The "Select Interface" panel comes up. Use up/down arrow keys to move the cursor to the LAN port to which you will deploy the IEEE 1588 protocol. Press the space key to confirm your selection. Then, click <**Next**> to continue, or use right arrow to click <**Cancel**> to quit the process.

4. Use up/down arrow keys to move the cursor to the mode for the PTP protocol. Then, select <**Next**> to continue.

5. Use up/down arrow keys to move the cursor to either LNB mode or HAC mode. LNB mode drives the system to reduce access frequency to the time stored in the IEEE 1588 chip, which frees the CPU power of the system to handle other tasks more efficiently. HAC mode drives the system to consume more CPU power, which will reduce clock accuracy. When the selection is done, select <**Finish**>.

6. Select <**OK**> to complete the wizard.

7. Go back to the main menu and click <**Apply**> to activate. It takes about 10 minutes to complete the configuration.



8. On the main menu, click <**Exit**> to exit the configuration.

MDM API Software

Moxa Device Manager (MDM for short) API is a software framework that provides you (system or software developers) with the following benefits.

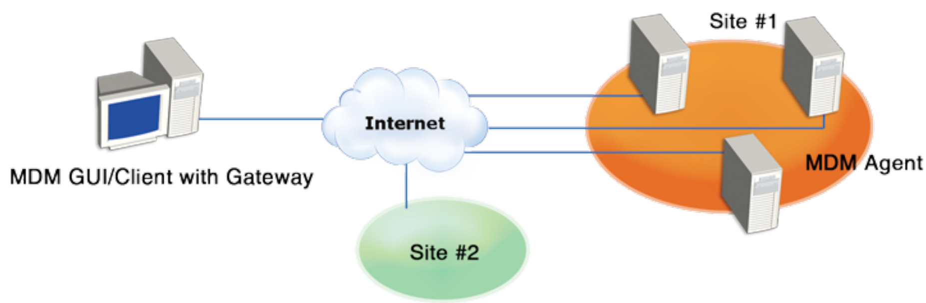
1. You can utilize existing MDM components to monitor remote embedded computers, including the health status, CPU usage, and storage utilization of the computers.

2. You can set up mass deployment such as setting IP addresses (based on a mapping table of MAC and IP), and uploading configuration files to multiple embedded computers. This alleviates the work load and helps prevent manual errors in the configuration process.

3. You can develop and format your own application logic into dynamic link libraries and integrate them into the MDM framework. This integration utilizes the existing client and server architecture of the framework, and accordingly saves time in developing TCP/UDP connection and message protocols.

In short, MDM API allows you to remotely manage embedded computers over the Internet. It is also very flexible for you to expand your application logics. Ultimately, it reduces your development time.

The figure below shows the MDM system architecture. Each Moxa computer is pre-installed with the "MDM Agent" program, which is a daemon program serving requests from remote “MDM Client”. These requests include remote file management, IP address change, remote/automatic execution, etc.



MDM programs are driven by messages over UDP/TCP connections. A message is used when an MDM program needs to communicate with the other MDM program. The following shows the message structure.

2	2	n
Len	Tag	Data

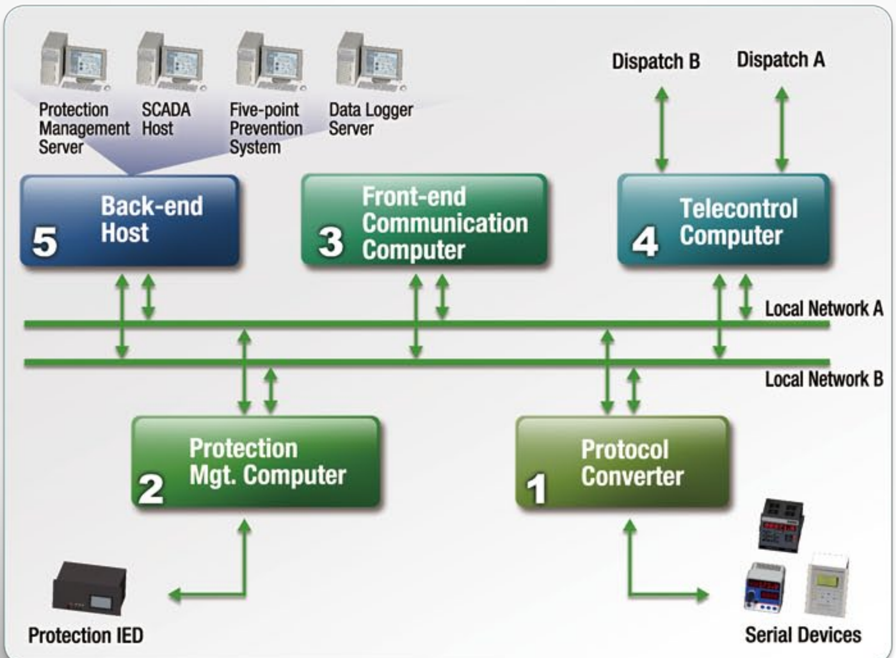
The first field indicates the length of data (i.e., third field). It is followed by an identification of the message. Each field takes two bytes and its value is in Big-Endian format.

Currently, MDM API software resides in the PC which plays the role of the “MDM Client”. Moxa makes all of these API functions comprehensive enough for system developers to use. When a TCP connection is made to the “MDM Agent”, the rest of the tasks simply focus on sending/receiving messages to/from the “MDM Agent”.

Moxa Substation Computing Solutions

Embedded Computers are Available for Each Substation Type

The three types of substation require different types of embedded computers, depending mainly on the voltage level used at the substation and the scale of the operation. Generally speaking, embedded computers can be divided into five types, depending on functions.



Why Moxa?

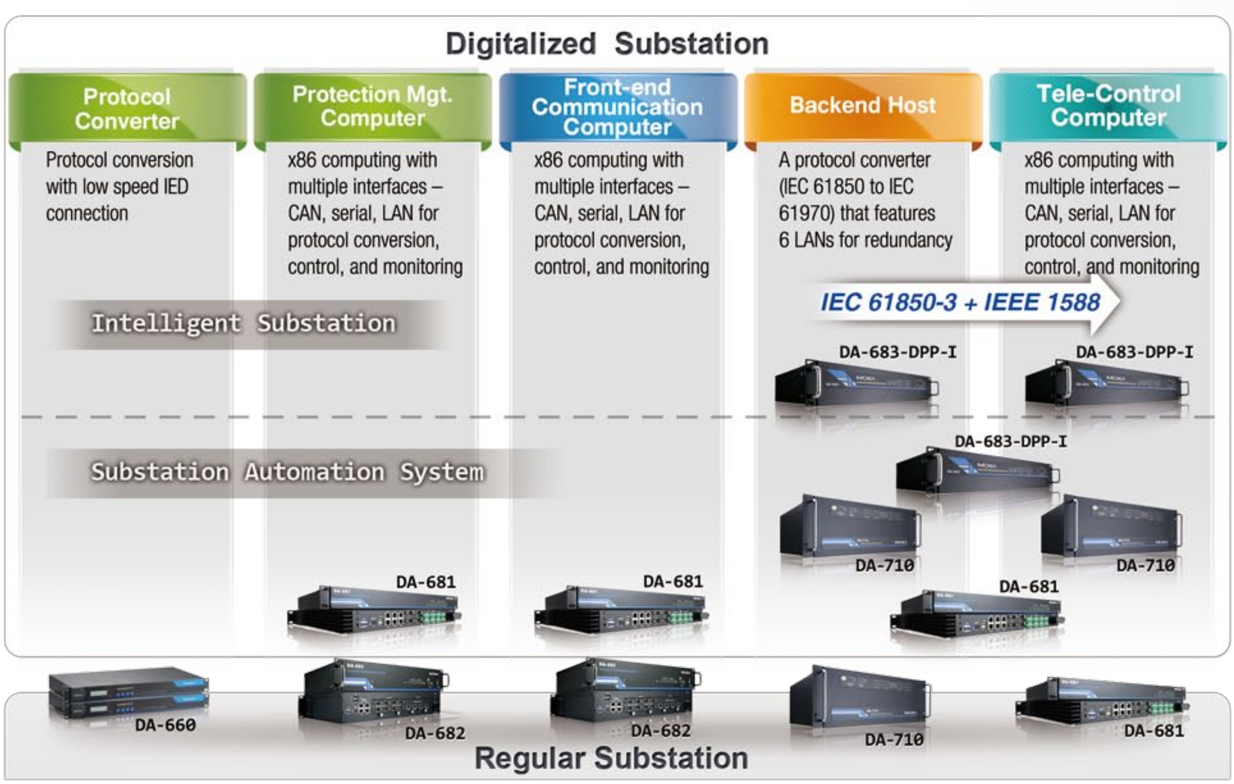
1. Protocol Converter
   - Suitable for basic data processing
   - Connects to multiple serial devices
   - Converts protocols from different sources

2. Protection and Management Computer
   - Converts protocols from different IEDs
   - Management function
   - Monitor function (depending on the application)
   - IEC 61850-3 certified
   - Connects IEDs using different protocols
   - Responds to emergencies in an instant

3. Front-end Communication Computer
   - Collects information from other protocol converter computers for delivery to the control center
   - More powerful processing than normal protocol converters
   - HMI support (depending on the application)

4. Tele-control Communication Computer
   - Supports 4 to 6 LANs
   - High performance processor
   - Fanless design helps ensure system reliability
   - IEC 61850-3 certified

5. Backend Host
   - HMI interface display function
   - Control function
   - SCADA software support
   - Powerful processing capability



Moxa provides a comprehensive computer portfolio, the DA series, for fulfilling different needs in implementing substation automation. These rack-mounted computers feature average to high CPU performance, all without requiring fan-based cooling. Operators can choose from this series and easily construct a computing infrastructure for substation automation.

Versatile Expansion Module Solutions

The DA-682/683/710 computers are modular and have two or four expansion bays to give the user more flexibility and convenience when constructing the substation automation system.

Available modules include an 8-port RS-232/422/482 module, 8-port RS-232/485 module, 4-port 10/100 Mbps LAN module, 8-port 10/100 Mbps switch module, and a universal PCI expansion module. Users can add the specific communication interfaces that they need, reducing system deployment costs and accelerating time to market.

Supported Modules

Module Number		Description
	DA-SP08-DB	8-port RS-232/422/485 DB9 connector
	DA-SP08-I-DB	8-port RS-232/422/485 DB9 connector 2 kV optical isolation
	DA-SP08-I-TB	8-port RS-232/422/485 terminal block 2 kV optical isolation
	DA-SP38-I-TB	8-port RS-422/485 terminal block 2 kV optical isolation
	DA-SW08-RJ	8-port 10/100 Mbps switch module RJ45 connector
	DA-LN04-RJ	4-port 10/100 Mbps LAN module RJ45 connector
	DA-UPCI-DK	1-slot universal PCI expansion adapter
	DA-FX04-MM-ST (coming soon)	4-port (10/100 BaseFX) fiber LAN, multi-mode, ST connector

For example, at a field site which needs more switch ports, the operator can add two DA-SW08-RJ switch modules to provide sixteen RJ45 ports for network communications. Alternatively, DA-SP08-DB serial modules can connect multiple serial devices, and DA-UPCI-DK modules add PCI expansion capability.

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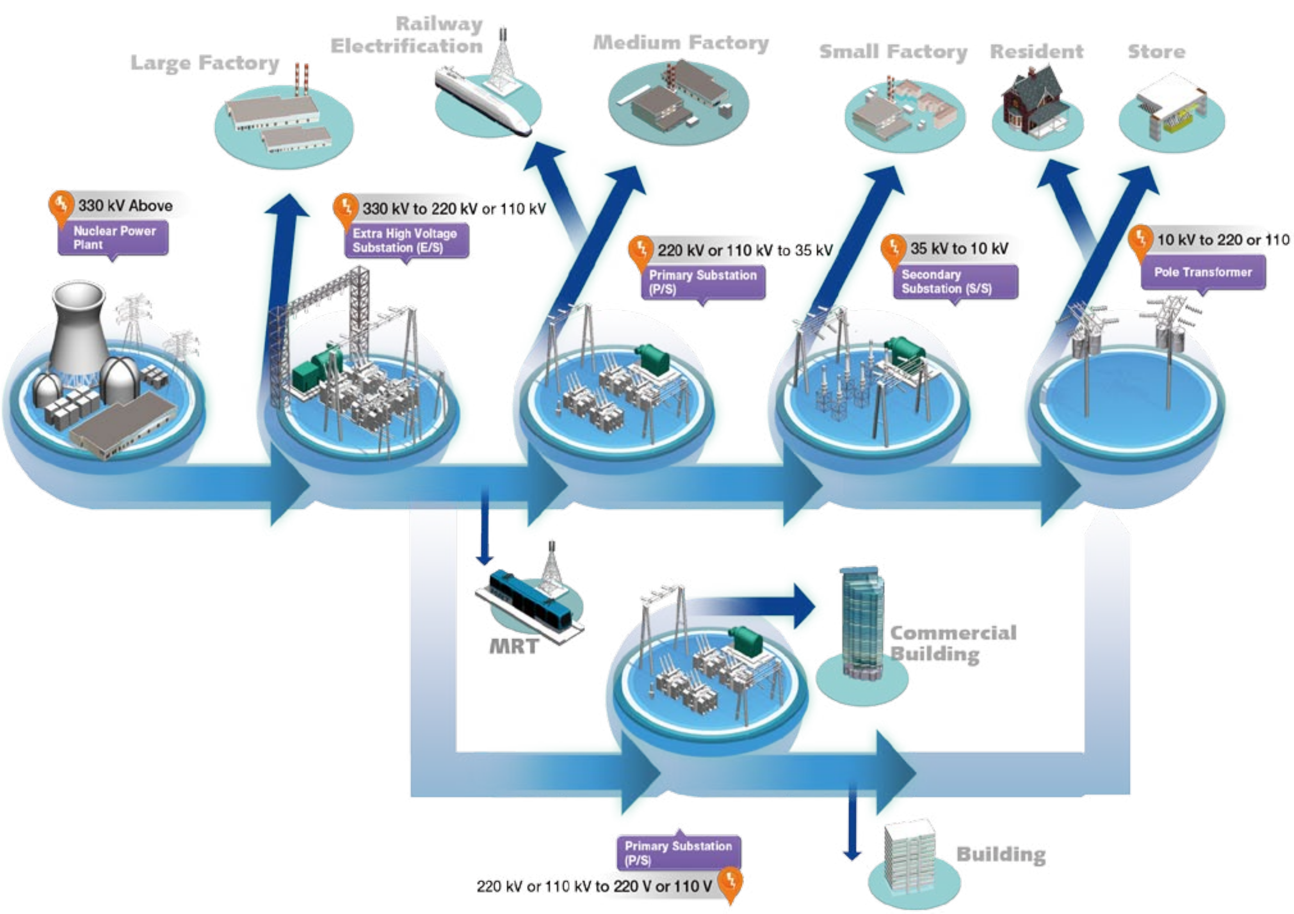
Substation Structure and Case Studies

Power System Flow

The power system flow is usually from the high voltage to the lower ones. It requires various substations to handle the voltage transformation. Meanwhile, these substations can also perform the task for transmitting the power energy to the field sites, such as large factories, commercial buildings, and the railway electricity stations in different voltage levels. In this section, we will address some examples with the applications and see how the substations perform the task of voltage transformations.



Case Study 1

Using IEEE 1588 v2 to Synchronize Sampled Values on the Substation Process Bus

Customer Assessment

Moxa's PowerTrans IEC 61850 industrial Ethernet switches with IEEE 1588v2 deliver both nanosecond-accurate synchronized sample values and zero-packet-loss GOOSE transmissions on the process bus. It enhances utility efficiency and uptime and prevents technological obsolescence by supporting the latest technology.

At a Glance

Region: Suzhou, Jiangsu, China

Substation Voltage: 500 kV

Customer Needs:
The customer sought to add IEEE 1588 v2 technology to the substation in order to have precise synchronized sample measurement values on the process bus. Powerful embedded computers are also required at the back-end host for data analysis and processing.

Key Benefits

- IEEE 1588 v2 delivers precise timing accuracy to improve monitoring and troubleshooting capability.
- IEEE 1588 compatibility eliminates the requirement for dedicated time synch equipment and reduces cost of wiring sensors
- Using the latest IEEE 1588 v2 technology prevents technological obsolescence
- Powerful industrial computers at the control center for data analysis and data processing
- Quick and customizable service tailored to customer demands

System Requirements

- Nanosecond-level time synchronization of SMV streams
- Zero-packet-loss Ethernet switches for mission-critical GOOSE transmissions
- Next generation IEDs/protection relays with support for IEEE 1588 Ordinary Clock functionality
- Powerful processing ability for back-end host
- EMC level 4 standards for harsh environment

Project Introduction

Jiangsu province's rapid economic growth over the past few decades has made it one of the most energy-demanding provinces in China. With a 500 kV grid as its backbone, Jiangsu uses one of the largest electricity grids in China. 220 kV transmission plants cover all the urban and rural areas across the province. Key selection criteria in Jiangsu Provincial Electric Power Co.'s procurement process for electrical networking devices are advanced technology, high reliability, and excellent service.

In the Suzhou 500 kV substation, electronic current/voltage transformers (CT/VTs) and merging units convert analog signals to the IEC 61850-9-2 digital format. To deliver highly accurate synchronization of the sampled measurement values (SMV) on the process bus, Jiangsu devised a novel design based on the IEEE 1588 merging unit synchronization standard. In this project, Moxa provided IEC 61850 compliant Ethernet switches with IEEE 1588 v2 nanosecond-precise time synchronization solutions on the IEC 61850 process bus.

System Description

Highly accurate sampled measurement values (SMVs) are a crucial component of accurate system reliability analysis in the process bus environment. Without a well-synchronized SMV process bus stream, the system will be unable to achieve differential protection, synchrophasor measurements, or digital fault recording.

Moxa's IEC 61850 industrial Ethernet switches are used in this project to form a doubly redundant fiber network backbone with dual-tree topology for extra reliability. The electronic CTs/VTs and Merging Units are installed in pairs. On the process bus, the Moxa Ethernet switches use IEEE 1588 v2 transparent clock functionality for nanosecond-level accuracy synchronization of SMV streams while also eliminating the extra cabling requirements of 1PPS or IRIG-B to propagate highly accurate timing signals. In addition, rugged Moxa Ethernet switches provide zero packet loss for GOOSE transmissions.

DA-710 computers are deployed as control units at the back-end host that help handle complicated computing tasks such as data analysis and device connections. These back-end computers leverage their powerful performance to reduce the workload of front-end tasks. With 4 PCI slots, the DA-710 are very flexible in accommodating future system expansions and reducing the cost of system deployment.

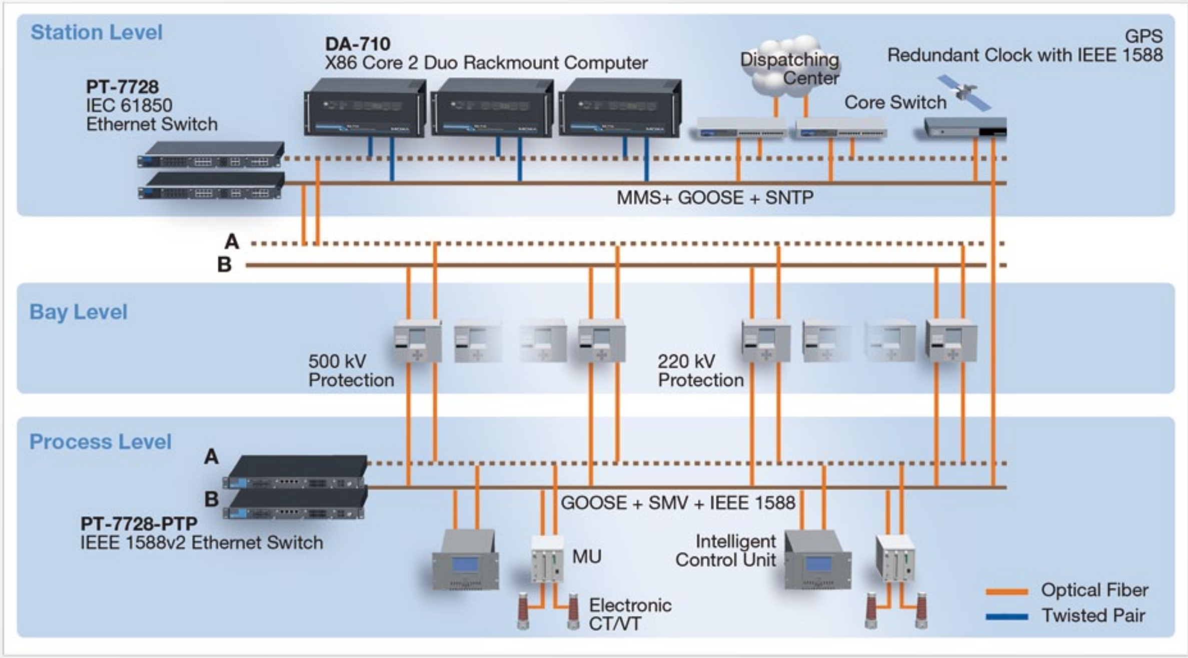
The IEEE 1588 v2 standard will only become more important for electric utilities in the future. By deploying the technology now, Jiangsu puts their network ahead of the curve and prevents costly system obsolescence. In the meantime, the technology pays dividends today by increasing the electric utility's efficiency and uptime through improved monitoring and troubleshooting.

Why Moxa?

Moxa's IEC 61850 compliant Ethernet switches support IEEE 1588 version 2 technology to support highly precise SMV synchronization and transmit mission-critical GOOSE message with zero packet loss. Moxa's embedded computers have a fanless design and support

On the computing side, the DA-710 computers are fanless, powered by a powerful T7500 Core2Duo processor. This gives it enough power to shoulder multiple tasks, including data analysis, data distribution, managing communications among substations. The modular design gives the system excellent flexibility, and can support up to 20 LAN ports for network redundancy.

System Diagram



Products

PT-7728-PTP Series

IEC 61850-3 modular managed Ethernet switches

- Hardware IEEE 1588 PTP for precise time synchronization of networks
- Isolated redundant power inputs with universal 24/48 VDC or 110/220 VDC/VAC power supply range
- Zero package loss under harsh EMI stress (KEMA tested)
- -40 to 85°C operating temperature range (fanless)

DA-710 Series

x86-based industrial computers with expansion modules

- 4 PCI slots for expansion modules
- Fanless design with high performance and low 60W power consumption
- Intel Core 2 Duo T7500 2.2 GHz processor (upgrade version; available by request)
- 1 X 200-pin DDR2 SODIMM socket, up to 2 GB DDR2 533 RAM
- Quad 10/100/1000 Mbps Ethernet for network redundancy
- Dual 100 to 240 VAC/VDC wide range power input provided
- EMC level 4 for anti-electromagnetic interference
- 19-inch rackmount model, 4U high

Case Study 2

Using IEEE 1588 v2 to Realize Nanosecond-precise Time Synchronization

Customer Assessment

Moxa's PowerTrans IEC 61850 industrial Ethernet switches support IEEE 1588v2 and deliver nanosecond-precise synchronized sample values on the process bus. By supporting the latest technology, PowerTrans switches enhanced the efficiency of a major Chinese power utility, and increased uptime while minimizing technological obsolescence.

At a Glance

Region: Xi-Ging, Wuxi, Jiangsu, China

Substation Voltage: 220 kV

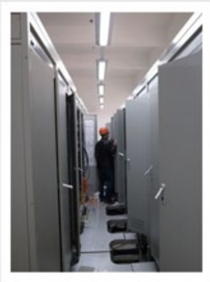
Customer Needs:
Time synchronization distributed over an IEEE 1588-enabled Ethernet network

Key Benefits

- Highly accuracyte sampling values of electric current and voltage improves monitoring and troubleshooting capabilities.
- IEEE 1588 eliminates dedicated time synchs, which reduces the cost of wiring to sensors.
- Using the latest IEEE 1588 v2 technology to future-proof substation networks

System Requirements

- Nanosecond-level time synchronization of SMV streams
- Rugged design of IEC 61850-3 Ethernet switches to withstand the harsh environmental factors founded in substations
- Zero-packet-loss Ethernet switches for mission-critical GOOSE transmissions



Project Introduction

China's new generation of smart substations rely on synchronized GPS-based time stamping, high data sampling rates, and increased accuracy to deliver increased efficiency and reliability. For a 220 kV substation in Xi-Ging, a city in Jiangsu Province, China's state utility provider used IEEE 1588 v2 technology to add nanosecond-precise time synchronization and make their monitoring, control, and protection applications more efficient. Thanks to IEEE 1588 v2 technology China's electricity grid has access to highly accurate sampled measurement values (SMVs) of electric voltage and current, empowering system operators with high-value data that improves their ability to maintain and analyze the process bus environment.Synchronized GPS based data time stamping, high data sampling rates, and increased accuracy are necessary for China's new generation smart substations today. In this project, China's state grid used IEEE 1588 v2 technology in the 220 kV substation of Xi-Ging, Wuxi, Jiangsu, to achieve nanosecond-precise time synchronization for more efficient monitoring, control and protection applications. With IEEE 1588 v2 technology in new smart substations, highly accurate sampled measurement values (SMVs) for voltage and current rates can be realized to enable a more accurate system reliability analysis in the process bus environment.

System Description

Sampled measurement values (SMVs)

In the Xi-Ging 220 kV substation, electronic current/voltage transformers (CT/VTs) and merging units convert analog signals into the IEC 61850-9-2 digital format. To deliver highly accurate synchronization of the sampled measurement values (SMV) on the 110 kV substation process bus, Moxa's PT-7728-PTP IEC 61850 compliant Ethernet switches are installed on the IEC 61850 process bus to form a doubly redundant fiber network backbone with dual-tree topology for extra reliability. The electronic CTs/VTs and Merging Units are installed in pairs.

On the process bus, the Moxa PT-7728-PTP Ethernet switches use IEEE 1588 v2 transparent clock functionality for nanosecond-level accuracy synchronization of SMV streams while also eliminating the extra cabling requirements of 1PPS or IRIG-B to propagate highly accurate timing signals. In addition, rugged Moxa Ethernet switches provide zero packet loss for GOOSE transmissions for high priority information.

Jiangsu province's rapid economic growth over the past few few decades has made it one of the most energy-demanding provinces in China,, and correspondingly it is also the most advanced province in China in terms of Smart Grid development which is therefore made Jiangsu one of the most advanced province for Smart Grid development in China. . By deploying the IEEE 1588 technology now, Jiangsu puts their network ahead of the curve and prevents costly system obsolescence.

Why Moxa?

Only one IEC 61850 compliant Ethernet switch with support for IEEE 1588 v2 technology is needed to synchronize the SMVs and transmit mission-critical GOOSE messages with zero packet loss.

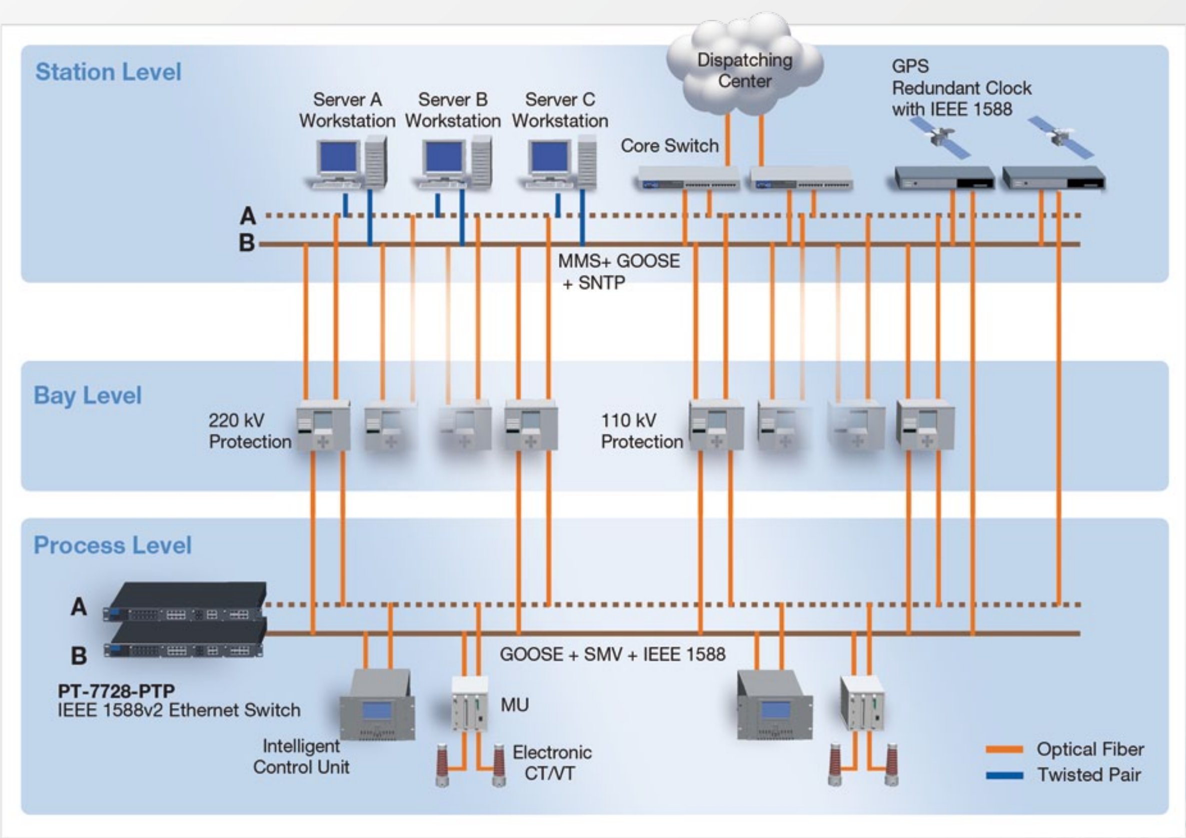
Products

PT-7728-PTP Series

IEC 61850-3 modular managed Ethernet switches

- Hardware IEEE 1588 PTP for precise time synchronization of networks
- Isolated redundant power inputs with universal 24/48 VDC or 110/220 VDC/VAC power supply range
- Zero package loss under harsh EMI stress (KEMA tested)
- -40 to 85°C operating temperature range (fanless)

System Diagram



Case Study 3

Embedded Computers as Front-end Controllers for SCADA in Substation

Customer Assessment

Moxa´s powerful embedded computers excel as front-end controllers for data acquisition, data computing and protocol conversion.

At a Glance

Region: Taiwan

Company: A major power substation solution provider

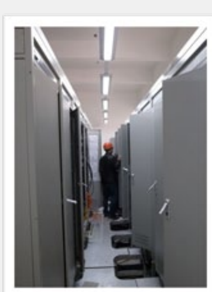
Customer Needs:
The customer needs some computers at the front-end field site for data acquisition and graphics control. These computers must be powerful enough to handle data processing.

System Requirements

- x86-based computers as the front-end controller
- Fanless and robust design
- Reliable and powerful controller for data acquisition, data computing, and graphics control

Key Benefits

- Quick and customizable service tailored to customer demands
- Software consulting support with library and API
- x86-based Core 2 Duo 2.2G computer with powerful performance
- Capable of performing many tasks to reduce front-end workload
- A variety of interfaces for different device connections
- Fanless and robust design



Project Introduction

A company in Taiwan needed powerful front-end controllers to deal with front-end SCADA tasks, such as data computing, data acquisition, and graphics control. These controllers must achieve reliable and stable substation operations in order to reduce the front-end workload. Each substation requires four to five computers to perform these tasks.

System Description

Based on the x86-architecture, the DA-710 computers can perform various industrial tasks such as data acquisition and data computing. Their powerful performance reduces the front-end workload and they can easily manage the front-end substation devices. Moxa's DA-710 computers are particularly well-suited for the distributed architecture of the substation since they can be used with the SCADA system and come with various serial ports, and digital input/output channels. In addition, the four Ethernet ports can be used to establish network redundancy and provide continuous system operation.

Moxa also offers customized service for software development to help the customer achieve their system requirements. Many libraries and APIs are provided for application development, to create a quick, easy, and cost-effective path to system deployment.

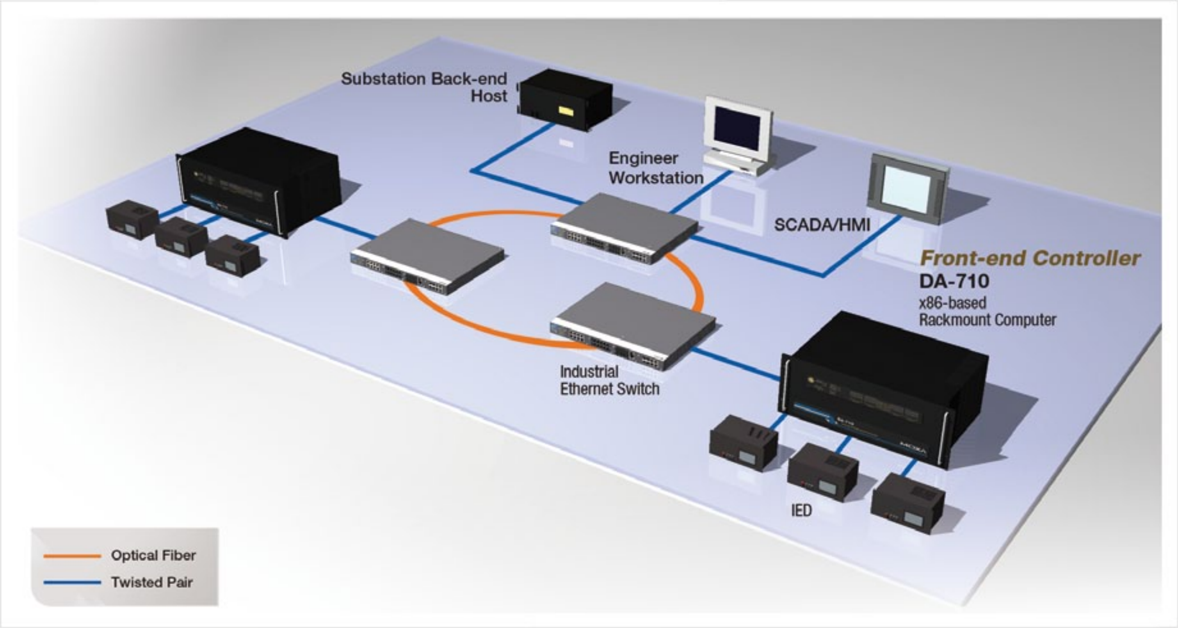
Products

DA-710 Series

x86-based industrial computers with expansion modules

- 4 PCI slots for expansion modules
- Fanless design with high performance and low 60W power consumption
- Intel Core 2 Duo T7500 2.2 GHz processor (upgrade version; available by request)
- 1 x 200-pin DDR2 SODIMM socket, up to 2 GB DDR2 533 RAM
- Quad 10/100/1000 Mbps Ethernet for network redundancy
- Dual 100 to 240 VAC/VDC wide range power input provided
- EMC level 4 for anti-electromagnetic interference
- 19-inch rackmount model, 4U high

System Diagram



Field-site Photos

Case Study 4

Substation Automation for a Steel Factory in China

Customer Assessment

Moxa´s powerful embedded computers excel as front-end controllers for data acquisition, data computing and protocol conversion.

At a Glance

Region: China

Company: 35 kV/10 kV

Customer Needs:
Establish a substation network that needs powerful computers as the front-end controlling units for data acquisition and protocol conversion.

Key Benefits

Powerful and reliable front-end controlling units for a stable platform that can perform data acquisition and protocol conversion.

System Requirements

- Centralized and stable management platform for the distributed system
- Front-end data processing for the field site devices
- Protocol conversion among Modbus, DLT645, and TCP/IP IEC 104
- Redundant network architecture for continuous system operation
- Easy integration with other communication system
- Long MTBF to enhance system reliability
- x86-based computers as the front-end controller
- Fanless and robust design
- Reliable and powerful controller for data acquisition, data computing, and graphics control

Moxa's Advantage

- Moxa's integrated embedded system dramatically improved reliability and development time compared to a self-assembled system.
- CANbus and multiple serial ports offer fast I/O communication and versatile configuration
- Prompt and customized service tailored to customer needs
- Flexible systems provide multi-level open data interfaces and stability for easy integration with third-party devices

Project Introduction

One of the largest steel factories in China needed proper communication control units for data processing and protocol conversion with the devices at remote field sites. These computers would replace the IPCs and can easily create a distributed system at the front-end site with a centralized management platform at the back-end control center.

This stainless steel factory has deployed a power substation system that contains several subsystems. Each subsystem uses smart meters, and needs to optimize resources, centralize management, and enhance efficiency. In addition, all distributed smart meters at the field site need to be centrally monitored and managed by a system called the "CCMS3000 central management system", located at the control center. Each 35 kV/10 kV substation communicates with the back-end server via intranet, and manages the centralized management and monitoring of the 35 kV/10 kV. The entire system aims to optimize the power network management and maintenance cost, enhance power distribution quality and management, and deliver real-time discovery, analysis, recording, and handling of problems.

The CCMS300 central management system is expected to bring reliability to real-time monitoring of the operation status of all devices at the substations. It needs to perform several tasks, such as analyzing historical workload, power consumption, and system balance, as well as enhance system or device operation efficiency.

System Description

This substation system includes the following subsystems.

Factory 1

Main Station: A communication cabinet includes a telecommunication control unit (DA-662), a switch, 2 optical transceivers, and communication units.

Station C: A communication cabinet includes a serial device server (NPort 5430), an optical transceiver, and communication units.

Station D: A communication cabinet includes a serial device server (NPort 5430), an optical transceiver, and communication units.

The telecommunication control unit (DA-662) is responsible for collecting and controlling all data from stations A, B, C, D, E, and the water station from Factory 1.

Factory 2

Main Station: A communication cabinet includes a telecommunication control unit (DA-662), and various communication units. This DA-662 is responsible for collecting and controlling all data from stations G, K, and the water station from Factory 1.

Hot-rolled Factory

Main Station**:** A communication cabinet includes a telecommunication control unit (DA-662), a switch, an optical transceiver, and communication units.

Substation**:** A communication cabinet includes a serial device server (NPort 5430), an optical transceiver, and communication units.

The DA-662 is responsible for collecting and controlling all data from the hot-rolled factory and the hot-rolled water station.

Cold-rolled Factory

Main Station**:** A communication cabinet includes a telecommunication control unit (DA-662), a switch, an optical transceiver, and communication units.

Substation**:** A communication cabinet includes a serial device server (NPort 5430), an optical transceiver, and communication units.

The DA-662 is responsible for collecting and controlling all data from the cold-rolled factory and the cold-rolled water station.

The communication between the DA-662 and the back-end server is based on the TCP/IP IEC 106 protocol. water station.

Products

DA-662-16-LX

RISC-based 19-inch Rack-mounted Data Acquisition Embedded Computer

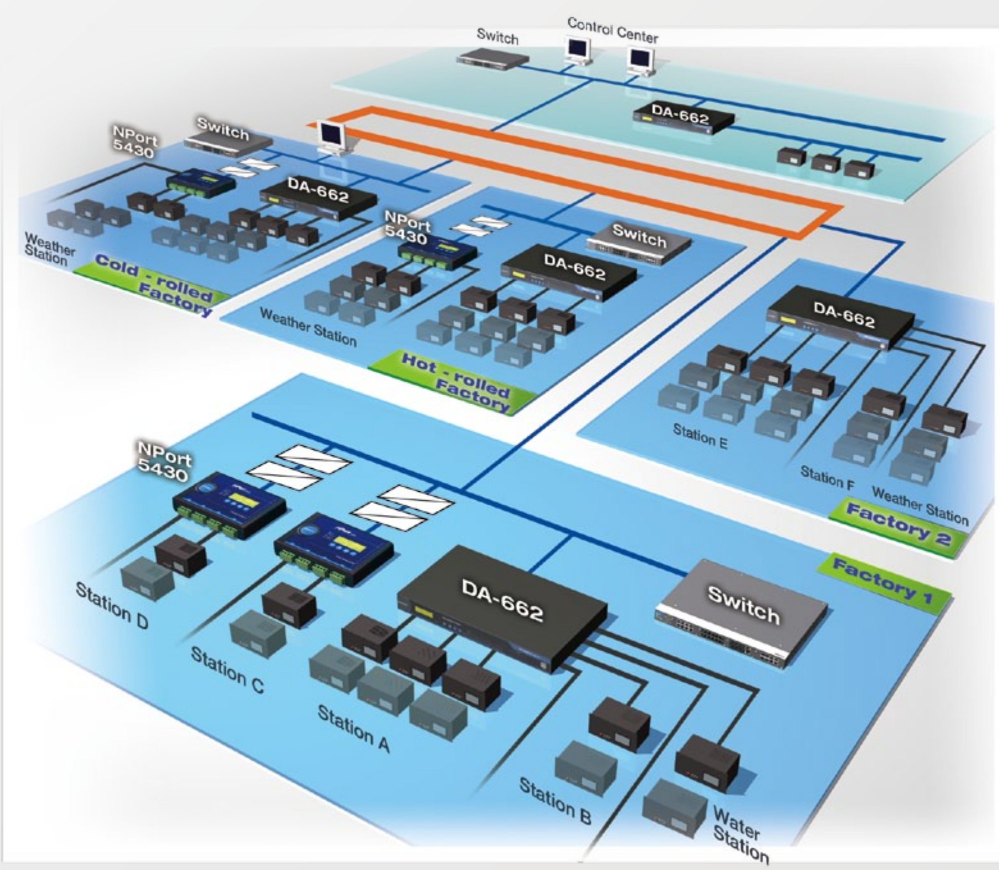
- Intel XScale IXP-425 533 MHz processor
- 128 MB RAM on-board, 32 MB flash disk
- 2 KV optical protection for serial ports

NPort 5430

4-port RS-422/485 serial device servers

- Easy IP address configuration with LCD panel
- 10/100 Mbps auto-sensing Ethernet

System Diagram



Case Study 5

Out-of-the-box Embedded Computing Solutions Simplify Power Distribution Systems

Customer Assessment

Moxa´s product is a powerful embedded computing platform that excels as front-end controllers used in data acquisition, data computing and protocol conversion.

At a Glance

Region: China

Company: A major power substation solution provider

Customer Needs:

The customer's previous power distribution system was composed of a volatile and costly hodgepodge of customer-assembled components and devices. They needed a stable and reliable system with a variety of communication interfaces to act as a gateway to run different protocols.

System Requirements

- A gateway capable of handling multiple devices running different protocols
- Quick system response
- An integrated system with a variety of communication interfaces, including CANbus, DI/DO, serial ports, and Ethernet LAN ports

Moxa's Advantage

- Moxa's integrated embedded system dramatically improved reliability and development time compared to a self-assembled system.
- CANbus and multiple serial ports offer fast I/O communication and versatile configuration
- Prompt and customized service tailored to customer needs
- Flexible systems provide multi-level open data interfaces and stability for easy integration with third-party devices

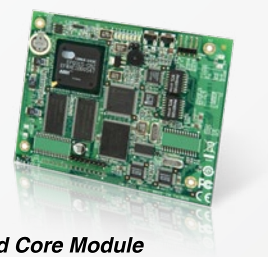
Project Introduction

System stability and reliability are must-haves in power grid applications. Moxa products helped a customer whose previous power distribution system was composed of a volatile and costly hodgepodge of customer-assembled components and devices.

System Description

Moxa's EM-2260 embedded computer module is a convenient and compact solution that improved system stability and helped our customer reduce development time and costs. The EM-2260's multi-level open data interfaces allow easy integration with third-party devices, and it acts not only as a front-end data computer but also as a protocol gateway for protocol conversion, simplifying development.

Products

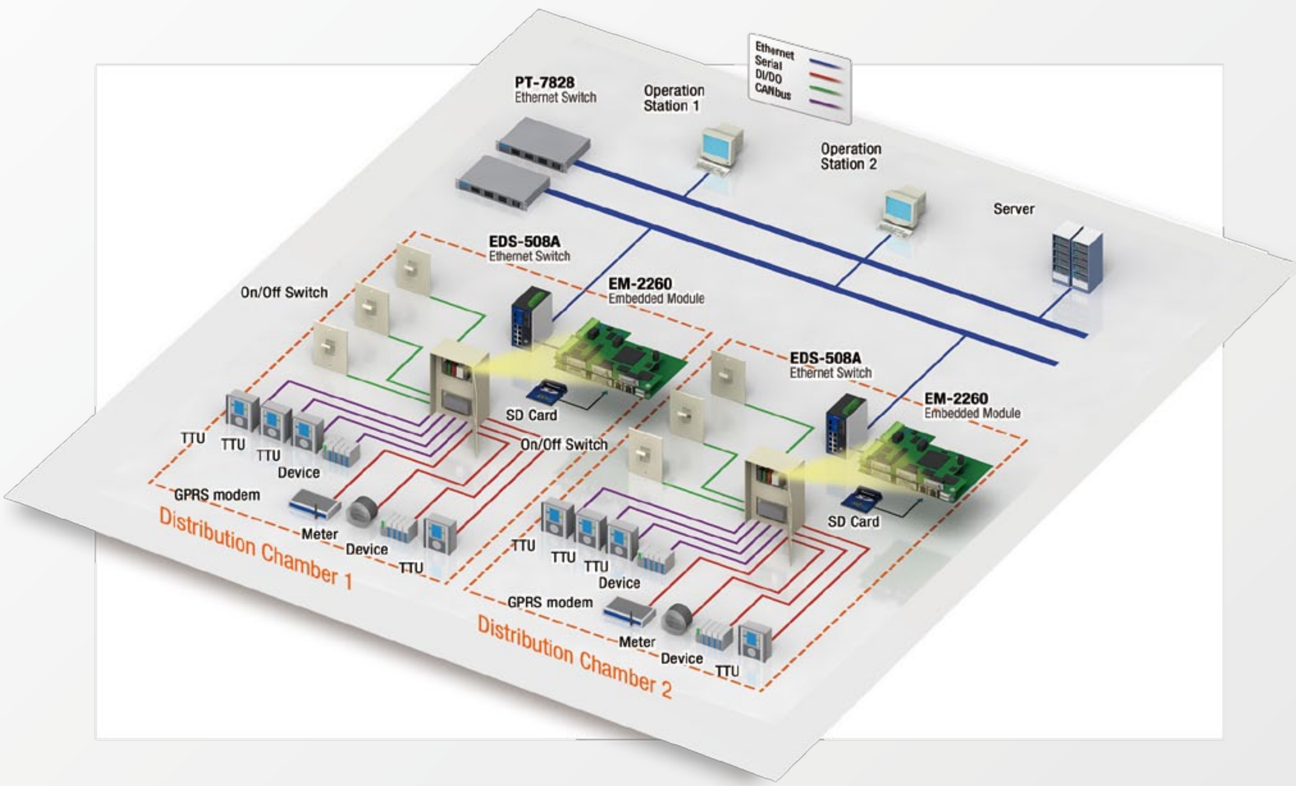


EM-2260

RISC-based Embedded Core Module

- Cirrus Logic EP9315 ARM9 CPU, 200 MHz
- 128 MB RAM on-board, 32 MB flash disk
- Graphical interface for external VGA output connection
- 2 KV optically isolated RS-232/422/485 serial ports
- Dual 10/100 Mbps Ethernet for network redundancy
- 8 DI and 8 DO channels
- Supports CompactFlash and USB 2.0 hosts
- Full-function development kit for quick evaluation and application development
- Ready-to-run WinCE 6.0 or Linux platform

System Diagram

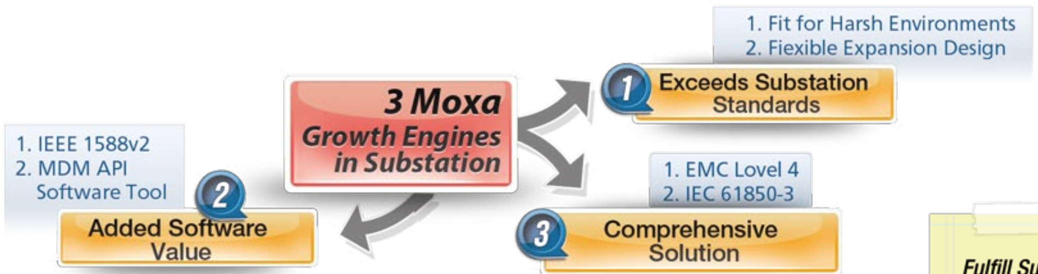


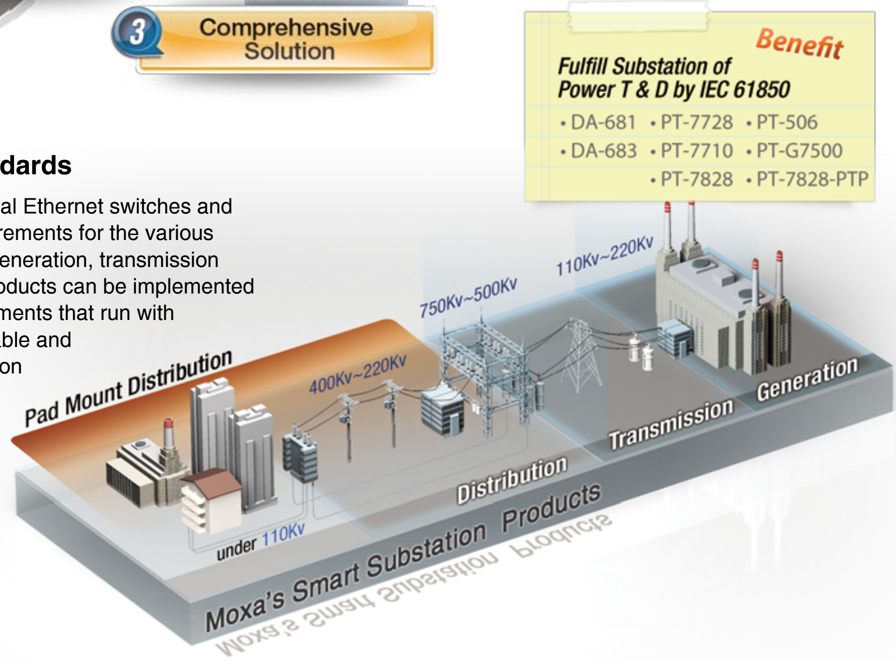
The Way Forword

3 Growth Engines in Substation Segment

- Exceeds Substation Standards
- Value-Added Software and Service
- Comprehensive Solution

3 Growth Engines in Substation Segment



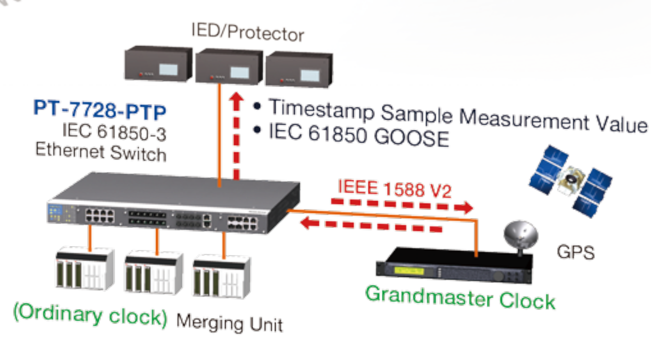


1 Exceeds Substation Standards

Moxa offers IEC 61850-certified industrial Ethernet switches and industrial computers that fulfill the requirements for the various substation automation segments from generation, transmission and distribution. All PT Series switch products can be implemented in the transmission and distribution segments that run with the IEC 61850 protocol, ensuring a reliable and stable operation for substation automation systems. Meanwhile, both DA-681 and DA-683 computers are IEC 68150-3 certified and EMC Level 4 approved for reliable and stable operations in IEC 61850 standards-compliant substation applications.

2 Value-Added Software and Service

IEEE 1588 v2 is a precision time synchronization technology that enables synchronization accuracy to the nanosecond level. For reliable and precise time synchronization over the substation Ethernet network, the Moxa PT-7728-PTP makes the Process Bus more cost-effective, efficient and easier to deploy. Also, DA-683 computers are IEEE 1588 v2 compliant and support precision time protocol and clock synchronization to provide highly precise time accuracy that event loggers in power substation systems require.



Moxa's innovative IEEE 1588v2 technology delivers time synchronization that's precise to the nanosecond level. This is especially useful in substation systems, which need consistent time stamps on their event logs for later analysis.

As an additional value, the MDM API makes it easy for users to develop related application programs and integrate them on existing systems with minimal workload and maintenance costs. Moxa also offers MDM (Moxa Device Manager) software so users can easily control and manage the remote computers, essentially reducing the cost for system establishment and maintenance effort.

Moreover, HSR and PRP technologies are extremely reliable network redundancy technologies that meet the stringent "zero-recovery-time" requirements of substation automation systems. These redundancy technologies guarantee that the system will continue to operate reliably even when one device fails. Moxa's Red Box for HSR and embedded board for PRP both deliver reliable redundant communications for substation automation systems. When combined with Moxa's Turbo Ring and Turbo Chain technologies, these products can be easily implemented and deliver the most cost-effective zero-recovery-time solution.

Moxa's HSR Redbox Solution (Preliminary)

- IEC 61850 and IEC 62439 PRP compliance
- 3 FE ports interface
- Handle 256 connections
- Dual power input
- Supports IEEE 1588 v2 Time Sync

Moxa's PRP Embedded Solution (Preliminary)

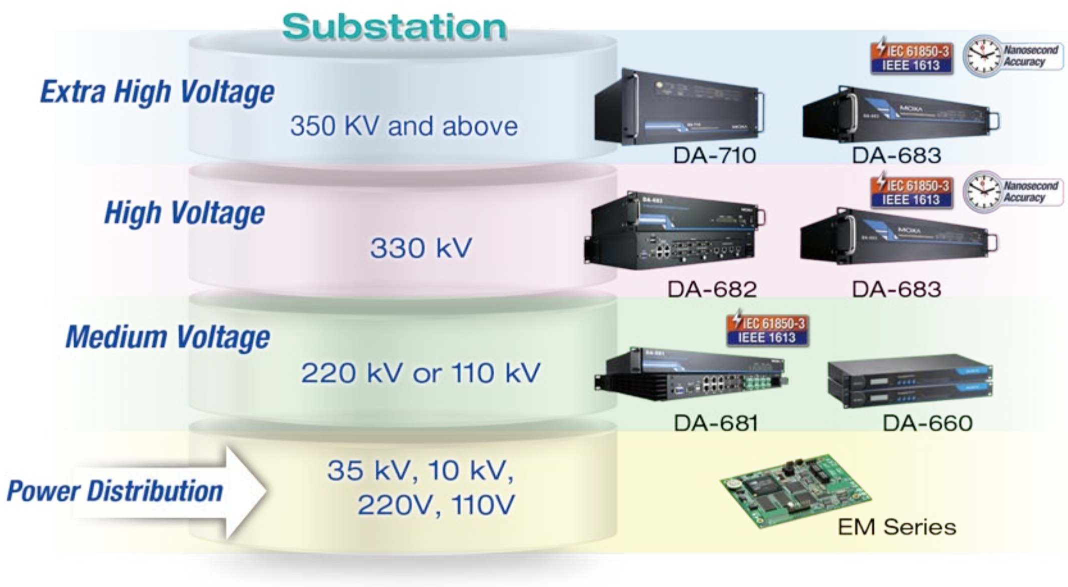
- IEC 61850 and IEC 62439 PRP compliance
- 3 FE ports interface
- Handle 256 connections
- Dual power input
- Supports IEEE 1588 v2 Time Sync

Moxa also offers great flexibility for customization service, fulfilling customers' great demands in various industrial scenarios and applications. This is a particularly big advantage for achieving faster time-to-market. With more than 20 years of R&D experience, Moxa's professional technical support and customer-first culture has made us a world leader in the industrial networking and communication industry. We apply this expertise towards delivering a wide variety of off-the-shelf solutions to meet the requirements of customers' specific industrial applications.

3 Comprehensive Solution

Moxa has the industrial Ethernet networking and computing products to meet the specific requirements of each segment in a substation system. Whether your application is extra-high voltage, high voltage, or medium voltage, Moxa's portfolio includes a computer that will deliver stable and reliable operations. Moxa's products also meet the different requirements at each substation level—both front-end data acquisition and back-end data analysis are easily processed and managed. With various different models for substation system applications, Moxa's substation portfolio includes a flexible selection of both RISC-based and x86-based systems with a variety of different interfaces, and industrial Ethernet switches for reliable industrial network communications. A wide selection of expansion modules is also available so you can easily customize and expand your computers to create the most cost-effective solution.

	Port Interface			Features						
Model	Total No. of Ports	Gigabit Ethernet	Fast Ethernet	Layer 3 Switching	Turbo Ring / RSTP	IGMP Snooping	IEEE 802.1X / HTTPS/SSH	Multi-port Mirroring	IEEE 1588 v2	Temp. Range
 PT-7828	28	4	24	✓	✓	✓	✓	✓	–	
 PT-7728	28	4	24	–	✓	✓	✓	✓	–	
 PT-G7509	9	9	9 (combo)	–	✓	✓	✓	✓	–	-40 to +85°C
 PT-7710	10	2	8	–	✓	✓	✓	✓	–	
 PT-7728-PTP	28	4	24	–	✓	✓	✓	✓	✓	
 PT-508	8	–	8	–	✓	✓	✓	✓	–	



x86-based Rackmount Computers

Model Name	Serial Ports	LAN Ports	Storage			DI/DO	OS		PCI Slot	Power		IEC 61850-3 Certified
		10/100 Mbps	SATA	CF	USB	30 VDC	XPE	Linux		Single	Dual	
DA-681	**RS-232 (4) (Isolated)** **RS-485 (8) (Isolated)**	6	✓	✓	2	-	✓	✓	-	✓	✓	✓
DA-682	**-**	4 (Gigabit)	✓	✓	4	-	✓	✓	2	✓	✓	-
DA-683	**RS-232 (2)**	6 (Gigabit)	✓	✓	4	4/4	✓	✓	2	✓	✓	✓
DA-710	**RS-232 (2)**	4 (Gigabit)	✓	✓	4	4/4	✓	✓	4	✓	✓	-

DA-Series Expansion Modules

Model Name	Serial Ports		Isolation	Switch	LAN	Connector			PCI
	RS-232/ 422/485	RS-422/ 485	2KV Digital	10/100 Mbps	10/100 Mbps	DB9	RJ-45	Terminal Block	3.3V 5V
DA-SP08-I-DB	8	-	✓	-	-	✓	-	-	✓
DA-SP08-DB	8	-	-	-	-	✓	-	-	✓
DA-SP08-I-TB	8	-	✓	-	-	-	-	✓	-
DA-SP38-I-TB	-	8	✓	-	-	-	-	✓	-
DA-SW08-RJ	-	-	-	8	-	-	✓	-	-
DA-LN04-RJ	-	-	-	-	4	-	✓	-	-
DA-UPCI-DK	-	-	-	-	-	-	-	-	✓

RICK-based Rackmount Computers

Model Name	Serial Ports	LAN Ports	PCMICA	Storage		OS	
	RS-232/ 422/485	10/100 Mbps		CF	USB	CE	Linux
DA-660	8 or 16	2	-	-	-	✓	✓
DA-661	16	2	✓	✓	✓	✓	✓
DA-662	16	4	✓	✓	✓	✓	✓
DA-662-I	16 (2KV Isolation)	4	✓	✓	✓	✓	✓

Substation Technical Guide Book

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